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Mobile Broadband Internet and Household Participation in Non-Farm Enterprises and Their Performance: Evidence from Nigeria

Hailu Adugna[1] *

Abstract

More than a third of people in Sub-Saharan Africa are believed to earn their living from non-farm businesses. While technological advancements are often associated with favorable business outcomes, it is unclear if this also applies to non-farm household enterprises, the vast majority of which are small-scale informal activities. This paper seeks to address the question: Does mobile broadband internet availability promote household participation in non-farm businesses and their performance? I combine rich datasets from three waves of the Nigerian general household survey panel (2010/11, 2012/13, and 2015/16) with mobile broadband coverage data. Using a difference-in-difference (DiD) strategy with multiple time periods and exploiting quasi-experimental variations in the staggered rollout of mobile broadband, I estimate both group-specific (early vs. late treated) and overall average effects of network coverage. The findings show that the availability of mobile broadband internet significantly increases households' likelihood of owning non-farm enterprises. It also boosts the performance of these businesses, as measured by their employment and sales per worker. The impacts are more evident in early treated groups than in late-treated ones. The event study (dynamic DiD) analysis results suggest that the effects build up with the length of households' exposure to the treatment. The results are robust to alternative model specifications. Overall, the findings imply that mobile broadband internet is essential for promoting household engagement in (or livelihood diversification into) non-farm businesses and improving their success.

JEL Code: D1; E2; O1; O33; L2

Keywords: Mobile Broadband Internet, Household, Non-Farm Enterprises, Nigeria

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[1] Addis Ababa University, Ethiopia; University of Gothenburg, Sweden

* Corresponding Author: Hailu Adugna, Department of Economics, Addis Ababa University, E-mail: hadugna2014@gmail.com , P.O.Box: 1176, Addis Ababa, Ethiopia.

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1. Introduction

Advancements in information and communication technologies (ICTs), such as mobile broadband internet, have gained prominence in recent years. They have been linked with greater business activities (Alderete, 2017; Hasbi, 2020; Houngbonon et al., 2022), increased employment (Hjort and Poulsen, 2019), and better welfare (Masaki et al., 2020; Bahia et al., 2023, 2024; Quinn et al., 2024), among others. Nonetheless, such technologies may have differential impacts on business activities (depending on their type, size, location, and so on) (see Colombo et al., 2013; Kim and Orazem, 2017; Pant and Odame, 2017; DeStefano et al., 2023); therefore, it is uncertain how they may affect household non-farm enterprises (NFEs).

On the one hand, households operating NFEs may benefit from mobile broadband internet-enabled digital platforms to conduct their daily activities, thereby enhancing efficiency and collaboration with various actors in business ventures. Such technologies may also enhance household entrepreneurial activities by easing supply-side constraints, such as access to information and critical inputs (like finance). Further, mobile broadband internet can also encourage such household businesses via the demand channel by creating access to markets for their products. On the other hand, these technologies can make other business establishments more attractive than NFEs by improving their access to information and markets and easing entry and exit barriers. NFEs are mostly seen as less productive and generate fewer jobs (see Nagler and Naud´e, 2014). In other words, mobile broadband technologies may expose household NFEs to stiff competition (in both input and output markets) from established firms that can better leverage digital solutions and broaden their market outreach and influence. As a result, the number of people joining NFEs may drop, while those transitioning away from such businesses may grow. Besides, the fact that most NFEs are small-scale, informal activities operated by unskilled or less-skilled individuals raises questions about how much these people can use broadband technologies in their daily businesses. In this respect, a cross-country study by Paunov and Rollo (2016) suggests that low-productivity firms with limited absorptive capacity may not benefit much from internet-based knowledge access. Despite the uncertainty, evidence linking mobile broadband technologies and NFEs remains scant so far.

This paper examines the impact of 3G[2], on household participation in NFEs and their performance in Nigeria. The country provides a compelling case study due to its staggered rollout of mobile broadband internet and large (informal) NFE sector. The study addresses three related questions: (i) Does the availability of mobile broadband internet improve households' likelihood of participating in

NFEs? (ii) How may the availability of mobile broadband internet impact employment in NFEs? (iii) Does the availability of 3G mobile broadband boost NFEs' sales per worker (a proxy for productivity)? I convert the sales data to real values using the 2010 consumer price index (CPI) for Nigeria to account for inflation effects.

I combine novel data sets from three waves (i.e., 2010/11, 2012/13, and 2015/16) of the Nigerian General Household Survey Panel (GHS-Panel) with mobile broadband coverage[3] data. The GHS-Panel is implemented by the Nigerian National Bureau of Statistics (NBS) in collaboration with the World Bank's Living Standards Measurement Study (LSMS) team. It covers a nationally representative sample of households from both urban and rural geopolitical zones across the country. The survey includes a "Nonfarm Enterprise and Income-Generating Activities" module that contains detailed information about household participation in NFEs and their performance. The mobile coverage data is mainly sourced from Collins Bartholomew (the mapping agent for the Global System for Mobile Communications Association (GSMA)). It is a high-resolution raster data with 1 km by 1 km grid cells (pixels) showing whether a strong or variable network signal[4] is available. I supplement this with data from OpenCelliD (the largest open database of cell tower information).

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[2] The fourth generation (4G) and fifth generation (5G) technologies were not widely available (if at all) in Nigeria at the time of this study. Hence, the scope of this paper is limited to third-generation (3G) network coverage on household NFEs in Nigeria

[3] The 2017 After Access Survey indicates that mobile and internet penetration rates in Nigeria were 64% and 30%, respectively. And 89.8% of the inhabitants live within range of a 2G mobile-cellular signal, while the population coverage for 3G and 4G networks was 62.05% and 11.04%, respectively (Gillwald et al., 2018). In the Nigerian data I use in this paper, about 26% of NFE-owning households are covered by 3G networks.

[4] The Collins Bartholomew's GSMA mobile coverage submission guidelines categorize network signals as either strong or variable. A signal level above -92 decibel-milliwatt (dBm) is defined as strong/indoor in 3G networks, while a signal strength between -92 and -100 dBm is classified as variable/outdoor. A strong indoor signal in 4G networks exceeds -105 dBm, whereas a variable outdoor signal ranges from -105 to -120 dBm. The variable/outdoor signal may be considered as a medium-strength network signal (see Bahia et al., 2024).

In Nigeria, 3G technologies have been gradually rolled out, resulting in plausibly exogenous spatiotemporal variations. Hence, following prior studies (see, e.g., Akerman et al., 2015; Zuo, 2021; Chiplunkar and Goldberg, 2022; Bahia et al., 2023, 2024), I leverage these quasi-experimental variations and estimate the causal impacts of 3G coverage (or availability). This means that the estimates in this paper should be interpreted in an intention-to-treat (ITT) framework. I employ the Difference-in-Difference (DiD) technique with multiple time periods proposed by Callaway and Sant'Anna (2021). This minimizes estimation bias that could arise from overtime changes in group composition and heterogeneity of treatment effects. I specifically use the doubly robust least squares estimator since it is less prone to model misspecification (see Sant'Anna and Zhao, 2020; Callaway and Sant'Anna, 2021). The underlying identifying assumption is that in the absence of 3G coverage, the treatment and control groups' mean outcome trajectories would have been similar. Since this is not testable, I rely on conditional parallel trend tests for verification. I control for 2G coverage as well as other potential confounders such as household characteristics, economic conditions, and geospatial variables.

This study reveals three key findings. First, it shows that households' likelihood of operating non-farm enterprises increases by about 4.2 percentage points in areas covered by 3G networks. This is in line with the findings by Bahia et al. (2023), which show a 3 percentage point increase in non-farm self-employment in Tanzania after mobile broadband coverage. The results imply that broadband technologies enable people to engage in or diversify their livelihoods into NFEs. Second, the findings indicate that 3G coverage boosts household NFE employment by 14.6 percent, suggesting that the availability of broadband infrastructure can help curb the unemployment challenge that many (developing) countries are facing. Third, I find that households with 3G mobile broadband internet have a 56.1 percent increase in NFEs' sales per worker compared to those without network coverage. This suggests that broadband technologies improve labor productivity in such household businesses. The related heterogeneity analyses reveal that female-headed households are more likely to own NFEs than male-headed households. This may imply that women are more likely to engage in NFEs (the bulk of which are small-scale, informal businesses) than in other alternative employment options in developing countries (see Chiplunkar and Goldberg, 2022, 2024). However, the effects on employment and sales per worker (productivity) are only picked up in male-headed households.

In all cases, the impacts are more pronounced in early-treated household groups than in late-treated ones, which means that 3G effects evolve with time. This is also evidenced by the event study (dynamic DiD) analysis, which demonstrates that the positive effects of mobile broadband internet on each of the outcomes grow with the duration of households' exposure to network coverage (or the treatment). Indeed, this is one of the key contributions of the paper, which, to the best of the researcher's knowledge, has not been documented as such in earlier empirical works. The results remain robust under alternative model specifications and estimation approaches.

Our findings build on and complement a handful of earlier works that address (in some way) the effects of mobile broadband internet on household decisions to operate NFEs and their business performance. Houngbonon et al. (2022), for example, demonstrate that access to broadband networks in Africa encourages firm innovations in both processes and products and enhances households' entrepreneurial activities, particularly their likelihood of owning NFEs. However, the TWFE-type DiD approach they employ may generate a biased estimate in the presence of multiple treatment and control groups, as well as treatment effect heterogeneity (see, e.g., De Chaisemartin and d'Haultfoeuille, 2020; Goodman-Bacon, 2021; Sun and Abraham, 2021). Likewise, Bahia et al. (2023) indicate that raising non-farm self-employment is one plausible mechanism, along with boosting labor force participation and wage employment, through which mobile broadband internet coverage improves household welfare and reduces poverty in Tanzania. While they only consider self-employment concerning household NFEs, I use their total employment to better gauge the performance of such businesses.

Closely related to the current study, an earlier work by Caldarola et al. (2023) in Nigeria shows that mobile internet adoption increases sales per worker or labor productivity (mainly in the service sector); however, contrary to the findings in this paper and those of Houngbonon et al. (2022) and Bahia et al. (2023), they report a drop in NFEs' labor requirements after 3G adoption. Their study focuses on mobile broadband adoption, whereas this paper considers its coverage (availability). As such, households have no influence over the deployment of broadband networks to a particular area. Thus, unlike adoption, coverage is not affected by observable and unobservable household characteristics. It also accounts for potential biases that may arise from spillover effects, such as information/device sharing among households (see Beuermann et al., 2012; Bahia et al., 2024). Furthermore, unlike the 2SLS-IV and TWFE techniques used by Caldarola and others, the staggered DiD strategy I employ minimizes biases arising from overtime changes in group composition and treatment effect heterogeneity (see Callaway and Sant'Anna, 2021). Leveraging the different aggregation schemes of this approach, I also estimate the group-specific (early vs. late treated) and overall average treatment effects of 3G coverage on household participation in NFEs and their performance. I also show, using event study (dynamic DiD), that the effects increase with households' length of exposure to 3G coverage (the treatment). I believe these are notable contributions to literature in the field.

The remainder of the paper is organized as follows. Section 2 presents a literature review, whereas Section 3 provides background information on household NFEs in Nigeria. Section 4 deals with the description of data and empirical models. Section 5 presents results and discussions, while Section 6 concludes.

2. Literature Review

A growing body of literature links mobile broadband internet with favorable economic outcomes. Czernich et al. (2011), for example, show that broadband internet penetration increases economic growth by easing information availability and promoting innovation, productivity, and new business start-ups[5]. Alderete (2017) emphasizes the critical role of mobile broadband in fostering entrepreneurial activities and indicates numerous mechanisms—such as simplifying information access and market entry, improving efficiency, and facilitating collaboration among diverse actors in business ventures (see also Hasbi, 2020; Houngbonon et al., 2022). A related strand of literature investigates the link between broadband internet and employment. Hjort and Poulsen (2019), for instance, illuminate that the arrival of submarine internet cables on the coast of Africa and the subsequent availability of fast internet enhanced the employment rate by promoting firm entry, productivity, and export growth. Echoing this, recent studies in developing countries demonstrate that labor force participation and employment are significantly higher in areas covered by mobile broadband networks (see, e.g., Chiplunkar and Goldberg, 2022; Caldarola et al., 2023; Bahia et al., 2023, 2024).

[5] It is also documented in the literature that the spread of mobile phones boosts productivity and economic development (Aker and Mbiti, 2010; Gruber and , 2011), and improves household welfare (Munyegera and Matsumoto, 2016; Danquah and Iddrisu, 2018; Miyajima, 2022).

Nonetheless, evidence also suggests that the effects of broadband technologies may differ based on the type of business activities and one's occupational skills. Kim and Orazem (2017), for example, demonstrate that broadband availability promotes new firm entry, with the impacts being more pronounced in service sector (such as education and health), whereas it is the lowest for the manufacturing sector. They also note that the impacts are more visible in urban or near-urban areas with a greater agglomeration endowment than otherwise. Akerman et al. (2015) indicate that broadband adoption, while augmenting skilled workers in complex tasks, may replace unskilled ones in mundane activities[6]. Several studies also show that the employment-increasing effects of mobile broadband are concentrated in higher-skilled occupations (see, e.g., Atasoy, 2013; Hjort and Poulsen, 2019; Chen et al., 2020; Viollaz and Winkler, 2022; Caldarola et al., 2023). On the other hand, a study by Jin et al. (2023) in China reveals that while broadband internet improves productivity in industries predominated by lower-skilled workers, such as manufacturing, it has no effect on employment for both low- and high-skilled individuals (see also Canzian et al., 2019). And Colombo et al. (2013) indicate that small and medium enterprises (SMEs) can improve productivity with broadband technology only if they adopt its advanced applications that best fit their specific contexts and business processes.

The impact of technological breakthroughs on business start-ups and their performance seems inconclusive so far. This is particularly so for household NFEs[7], the bulk of which are micro and small enterprises run (seasonally) for survival reasons (see Nagler and Naud´e, 2014; McCaig and Pavcnik, 2021). Although NFEs are the most viable source of income or livelihood diversification option for many people in developing countries (more than 40% of households in Sub-Saharan Africa (SSA), for instance, rely on such businesses) (Fox and Sohnesen, 2012, 2016; Nagler and Naud´e, 2014, 2017; Diao et al., 2020), they have been neglected by researchers and policymakers alike (Fox and Sohnesen, 2012, 2016; Diao et al., 2020). Studies

[6] Technological progress has long been linked with greater business dynamism. It could trigger business innovation, which, according to Schumpeter (1976), may result in "creative destruction," meaning that outdated business processes become irrelevant and are supplanted by new ones. Acemoglu and Restrepo (2018) argue that, in a dynamic framework that endogenizes technology, such innovations may lead to rapid automation, rendering some labor-based occupations inefficient in the long run; however, they may also create new tasks where labor might still be productive (see also Autor et al., 2003; Acemoglu and Autor, 2011; Acemoglu and Restrepo, 2022).

[7] Non-Farm Enterprises (NFE) are "unincorporated non-farm enterprises owned by households" (Fox and Sohnesen, 2016).

highlighting the positive impact of broadband internet on new business start-ups (Hasbi, 2020; Deller et al., 2022) and firm productivity and/or employment (Atasoy, 2013; Bai, 2017; Stockinger, 2019; Zuo, 2021; Bhuller et al., 2023; DeStefano et al., 2023) are mostly from advanced economies. Few empirical works address such themes in the context of developing countries (see, e.g., Hjort and Poulsen, 2019; Chiplunkar and Goldberg, 2022; Caldarola et al., 2023; Bahia et al., 2024). However, prior studies have largely focused on formal business establishments rather than NFEs. There is a dearth of systematic evidence linking mobile broadband internet and household NFEs. Hence, this study aims to bridge the existing research gap in the area.

3. Background of Non-farm Household Enterprises (NFEs)

The 2017 survey report by the Small and Medium Enterprises Development Agency of Nigeria (SMEDAN) shows that, there were over 41.5 million medium, small, and micro enterprises (MSMEs) in Nigeria as of the end of 2017. They collectively account for around 76.5% of the workforce and contribute 49.78% to gross domestic product (GDP). However, only 0.2% of them are small and medium-sized, while 99.8% are micro enterprises. In Nigeria, businesses with fewer than 10 workers are categorized as micro, while small and medium enterprises are those with 10 to 49 and 50 to 199 employees, respectively (see SMEDAN, 2017). In this respect, Nagler and Naud´e (2017) indicate that about 95% of rural enterprises in Sub-Saharan Africa (SSA) employ fewer than five workers (see also Diao et al., 2020).

Household non-farm enterprises (NFEs) seem to account for a greater proportion of micro businesses in Nigeria. In the GHS-Panel sample, around 65% of households operate one or more NFEs (68% of which are rural). On average, 55% of NFE-owning sample households run only one business, while the rest operate multiple (2 or more) enterprises. This shows that such businesses are an important source of income (and livelihood diversification option) for many Nigerian households, particularly those in rural areas. Their average employment is 1.8 individuals, indicating that the bulk of NFEs are micro businesses. And over 95% of them are not legally registered, suggesting that informality is the norm rather than the exception in Nigeria.

About 53% of NFEs engage in various trading activities, mostly retail (nearly 50%) and wholesale (3%). Service is the second most prevalent activity, accounting for roughly 23% of NFEs. This includes all types of services, such as health, education, food and beverage, transport, creative arts and entertainment, professional, scientific and technical services, repair and maintenance, other personal service activities, and so on. Manufacturing follows with 18% of the NFEs engaging in the production and processing of one or more products—such as food and beverage, textiles, leather and apparel goods, pharmaceuticals, other chemicals, wood, plastic, and metal products, construction materials, and the like. And approximately 4% of the NFEs are involved in construction and other engineering works. Crop and animal production, forestry and logging, fishing, and aquaculture are the least pursued, next to mining and related activities (see Figure 1).

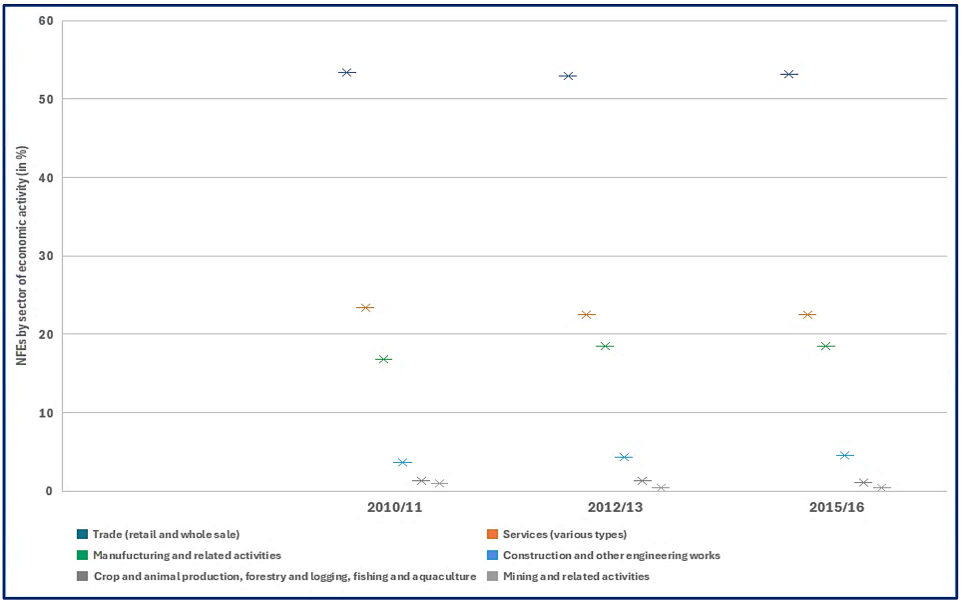


Figure 1: Non-farm Household Enterprises by Sector, Nigeria.
Note: I constructed this figure based on the Nigerian GHS-Panel

4. Data and Empirical Strategy

4.1. Data

This study combines data from three sources: three waves of the Nigerian General Household GSMA mobile explorer data, and cell tower location information from the OpenCelliD. The GHS-Panel provides comprehensive information on a wide range of topics, including agriculture, socioeconomic conditions, and non-farm income-generating activities. It covers a nationally representative sample of households from all 36 states and the Federal Capital Territory (FCT) of Nigeria.

The households were drawn using a multi-stage stratified sampling technique. During the first wave, 4916 households from 500 enumeration areas (EAs) were interviewed; in the second and third waves, 4716 and 4581 households from 495 and 486 EAs, respectively, completed the survey. The attrition rate increased from 5.7% to 8.4% between waves 2 and 3. This was mostly due to deteriorating security conditions in some states, particularly in the Northeast Zone, making accessing houses in those areas very difficult.

Collins Bartholomew's mobile coverage data is a high-resolution raster file with 1 km by 1 km grid cells, containing information that indicates whether 3G network signals are available. It is based on the information provided by mobile network operators, which may not be complete. To fill in any gaps, I use OpenCelliD data as a supplement, which includes GPS coordinates and the first time radio signals were detected for cell towers. I consider an enumeration area (EA) as covered if a strong or variable network signal is available. Since the GPS coordinates of the households' exact locations are not provided in the GHS-Panel, and the EA centroids shifted up to 2 km (5 km) in urban (rural) areas, I match the GHS-Panel with mobile broadband coverage by creating buffer areas of 2 km (in urban) and 5 km (in rural) around the EA centroid (see Figure 2). This helps to correct the artificial distortions in EA centroid locations and hence minimize prediction errors (see Weidmann and Schutte, 2017). Table 1 and Table 2 present descriptions of variables and summary statistics, respectively.

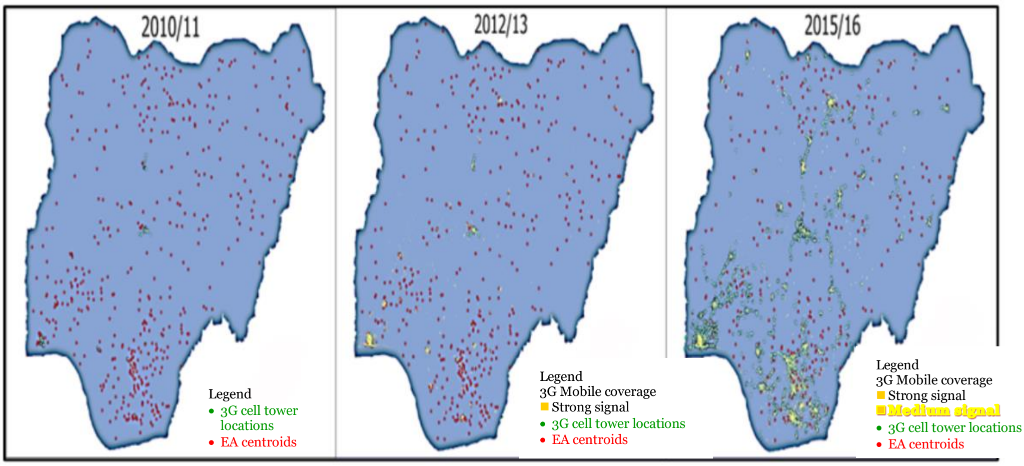


Figure 2: 3G Mobile Broadband Internet Coverage vs EA Centroids, Nigeria

Table 1: Data Description and Sources

Variable	Description	Source
3G coverage	A dummy variable = 1 if a household lives in an area covered by 3G networks; 0 otherwise	GSMA/ OpenCelliD
2G coverage	A dummy variable = 1 if a household lives in an area covered by 2G networks; 0 otherwise.	„
NFE dummy	NFE ownership dummy, which takes a value of 1 if a household operate at least one NFE; 0 otherwise.	Nigerian GHS-Panel
Sales PW	Household NFEs' real sales per workers	„
Employment-NFEs	The total number of NFEs' employees - paid or unpaid, household or non-household member.	„
Age hhead	Age of household head.	„
Age2 hhead	Age of household head squared	„
Gender hhead	Sex of household head	„
Marital status hhead	A multiple dummy variable equals 1 if married (monogamous/polygamous) or in an informal/loose union; 2 if divorced, separated, or widowed; and 3 if never married.	„
Educ hh-head	A dummy variable which takes a value of 1 if household head completed some primary level education or more; 0 otherwise.	„
Household size	Number of people in a household	„
lnaverage consumption	Natural log of average household consumption per-capita.	„
lnhh asset value	Natural log of current selling value of all household assets (own estimation).	„
Home electricity	A dummy variable =1 if a household's dwelling has electricity in a working condition; 0 otherwise.	„
Housing-dummy	A dummy variable =1 if a household own a house; 0 otherwise.	„
Urban Rural	A dummy variable = 1 if household's place of residence is urban area; 0 otherwise.	„
Dist road	Distance of household's place of residence from the nearest major road (in km).	„
Dist popcenter	Distance of household's place of residence from the nearest population center (in km).	„
Dist admctr	Distance of household's place of residence from the nearest administration center (in km).	„
Dist market	Distance of household's place of residence from the nearest market centers (in km).	„
Elevation	Enumeration area elevation (in meters).	„
Slope	Enumeration area slope (in percent).	„
Population density	Number of people per km2 area.	„
Ave. annual rainfall	Average of 12-month total rainfall (in mm).	„

Notes: The 3G and 2G coverage data at the end of 2010, 2012, and 2015 are linked with household information from the first, second, and third survey rounds, respectively.

Table 2: Descriptive Statistics

Variables	Household participation in NFEs			NFEs' employment or sales per worker		
	N. of obs.	Mean	Std. dev.	N. of obs.	Mean	Std. dev.
NFE-dummy (= 1 if a household owns NFE)	14364	0.65	0.48	9399	1.00	0.00
lnSales-per worker	—	—	—	8082	9.64	2.92
Employment NEEs	—	—	—	9399	1.81	2.15
3G strong or medium network signal (=1 if covered)	12992	0.22	0.42	8352	0.26	0.44
2G mobile network (=1 if covered)	12992	0.88	0.33	8352	0.90	0.30
Age (household head)	12314	51.79	15.11	7945	51.01	14.44
Educ (=1 if household head completed some primary level or more)	12688	0.83	0.37	8167	0.82	0.39
Sex (= 1 if female-headed)	12922	0.14	0.35	8333	0.13	0.33
Marital-status1 (= 1 if married or in informal/loose union)	12320	0.81	0.39	7942	0.84	0.37
Marital-status2 (= 1 if divorced or separated or widowed)	12320	0.16	0.37	7942	0.14	0.35
Marital-status3 (= 1 if never married)	12320	0.03	0.16	7942	0.02	0.14
Ln.average-consumption	12948	11.40	0.73	8347	11.44	0.69
Ln.asset value	12842	10.44	1.51	8295	10.64	1.41
Home electricity (= 1 if connected)	12873	0.48	0.50	8337	0.55	0.50
Housing dummy (=1 if owned)	12883	0.76	0.43	8341	0.74	0.44
Urban-Rural (=1 if urban)	12992	0.27	0.45	8352	0.32	0.47
Distance to the nearest road (in km)	12977	9.26	13.25	8352	8.19	11.81
Distance to the nearest admin. center(in km)	12977	67.50	54.81	8352	63.25	52.25
Distance to the nearest popn. center (in km)	12977	21.40	18.92	8352	20.41	18.71
Distance to the nearest market (in km)	12977	68.20	42.52	8352	66.84	42.96
Population density (per km2)	12498	2483.35	4592.03	8103	2905.09	4935.55
Slope (in percent)	12977	2.87	2.63	8352	2.79	2.59
Elevation (in meters)	12977	281.00	212.47	8352	290.45	219.75
Ave. annual rainfall (in mm)	12,977	1280.66	446.61	8,352	1250.64	428.07

Note: The statistical summary under columns (1) — (3) is for the full sample observation, whereas the summary under columns (4) — (6) is only for NFE-owning households. In both cases, the summary is the average value of the three survey rounds, i.e., 2010/11, 2012/13, and 2015/16.

4.2. Empirical Strategy

In Nigeria, 3G technologies have been rolled out gradually, resulting in plausibly exogenous spatial-temporal variations. Following prior studies (see, e.g., Akerman et al., 2015; Chiplunkar and Goldberg, 2022; Bahia et al., 2023, 2024), I leverage these quasi-experimental variations and estimate the causal impacts of 3G coverage. I employ the staggered difference-in-differences (DiD) approach with multiple periods proposed by Callaway and Sant'Anna (2021). I specifically employ the doubly robust (DR) DiD estimator based on inverse probability weighted (IPW) least squares since it is more robust to possible model misspecifications. Unlike alternative models like the Two-Way Fixed Effects (TWFE), the technique I use minimizes estimation biases by accounting for over-time changes in group compositions and heterogeneity of treatment effects (see Sant'Anna and Zhao, 2020; Callaway and Sant'Anna, 2021).

I consider three related outcome variables, i.e., (1) the household NFE participation dummy (which takes a value of 1 if a household owns/operates at least one NFE and 0 otherwise); (2) the total number of NFE employees (this includes self-employment in NFEs and household members working for family-owned nonfarm enterprises with or without compensation, as well as non-household member employment); and (3) NFEs' sales per worker (measured as the ratio of NFEs' to real sales revenue to their total employment). To account for their skewed distributions, I transform the last two outcome variables to natural log form. The key regressor is 3G network coverage, a dummy variable that equals 1 if a household lives in an area with 3G networks (strong or variable signal) and 0 otherwise. I control for 2G coverage and other potential confounders such as household characteristics, economic conditions, geographic and weather-related factors. I also include household and year-fixed effects. To minimize possible bias from a "bad comparison," I drop households with 3G coverage at the baseline (or the always-treated households), as their pre-treatment outcomes are unobservable. Also, I exclude households that have moved between survey rounds to ensure treatment irreversibility. The underlying identifying assumption is that in the absence of 3G coverage, both treatment and control groups' mean outcomes would have followed similar trajectories. Since this is not testable, I rely on conditional parallel trend tests for verification. Based on these assumptions, I relate the outcomes and regressor variables using the empirical model in Equation (1).

$$Y_{i,t} = \beta_1 Coverage_{i,t}' + X_{i,t}\,\Gamma + \alpha_i + \delta_t + \epsilon_{i,t} \qquad \textbf{(1)}$$

where $Y_{i,t}$ denotes either of the outcomes (i.e., participation, employment, or sales per worker) for a household *i* at time *t*, $Coverage_{i,t}$ is the corresponding 3G treatment dummy, β_1 captures treatment effects, and $X_{i,t}$ is a vector of potential confounders, including 2G coverage and ranges of other factors, such as household characteristics (like age, gender, marital status, education level of household head, and family size); economic variables (such as household consumption and asset measures, and dwelling characteristics, like access to electricity and house ownership); and geo-spatial and weather-related variables (like rural-urban dummy, distance from the near-est main road, distance to the nearest population/administration and market centers, elevation, population density, and rainfall). The αi and δt are household and year fixed-effects, whereas $\epsilon_{i,t}$ is an unobserved error term. Adopting Callaway and Sant'Anna (2021)'s DiD framework, I express the group-time average treatment effects for households in a given group or ATT(g, t), as shown in Equation (2).

$$ATT(\mathrm{g}, t) = \mathrm{E}\left[Y_{i\tau,t} - Y_{i\tau,\mathrm{g}-1} | G_i = \mathrm{g}\right] - \mathrm{E}\left[Y_{ic,t} - Y_{ic,\mathrm{g}-1} | G_i = \mathrm{c}\right],\ for\ t\ \geq\ \mathrm{g} \quad \textbf{(2)}$$

where Gi represents the various household groups; each group *g* is designated by its first treatment time. The c represents control groups, and *t* denotes a specific calendar time, and is defined as $t = 1, 2, \ldots T$, where *T* is the entire period over which a given household is observed. $Y_{i\tau,t}$ represents the potential outcome for household group *i* at time *t* with treatment, whereas $Y_{i\tau,g-1}$ denotes the outcome for the period before their first treatment time. Similarly, $Y_{ic,t}$ stands for the post-treatment outcomes for control groups, whereas $Y_{ic,g-1}$ indicates their pre-treatment outcomes. Aggregating all the weighted group-time average treatment effects yields the overall average treatment effect on the treated (ATT), which can be summarized as in Equation (3).

$$ATT = \frac{\sum(\omega_{i,t} * ATT\ (\mathrm{g},t))}{\sum(\omega_{i,t})}\ P(G = \mathrm{g} | G \leq T) \quad \textbf{(3)}$$

where $\omega g,t$ is the weight used in aggregating the group-level average treatment effects.

5. Results and Discussion

5.1. Main results

Table 3 presents the full sample, as well as a disaggregated analysis of the effects of 3G coverage on household participation in NFEs. In the full-sample estimations, the availability of 3G networks increases households' likelihood of participating in NFEs by 4.2 percentage points. I also perform heterogeneity analysis using female- and male-headed, as well as urban-rural household groups. While the effects are about 6.8 percentage points for female-headed households, they are 4.8 percentage points for male-headed households, which is relatively smaller. However, no significant effects are picked up in the urban-rural-based disaggregated analysis (see also Figure A1a). The findings align with earlier works by Conroy and Low (2022) in rural America, which indicate that broadband deployment boosts new business start-ups, particularly those run by women. A study by Rajkhowa and Qaim (2022) in India also reveals that mobile phone ownership is associated with increased participation of households in off-farm employment (such as casual wage, salaried employment, and non-agricultural self-employment), with the effects being more pronounced among female-headed households. They are also consistent with prior evidence showing the vital role of mobile broadband internet in boosting entrepreneurial activities (see, e.g., Alderete, 2017; Falk and Hagsten, 2021; Deller et al., 2022; Stephens et al., 2022; Chen et al., 2024) and household engagement in NFEs and their performance (Houngbonon et al., 2022; Bahia et al., 2023).

Table 3: 3G impact on household participation in NFEs.

	Full sample	Female headed	Male headed	Urban	Rural
ATT	0.042**	0.068**	0.048**	0.044	0.011
	(0.020)	(0.033)	(0.024)	(0.028)	(0.026)
ATT by treatment group:					
Group − average	0.031**	0.052*	0.035**	0.040*	0.002
	(0.015)	(0.029)	(0.017)	(0.023)	(0.023)
Early treated (wave 2)	0.065**	0.108**	0.075**	0.052	0.039
	(0.030)	(0.053)	(0.033)	(0.035)	(0.050)
Late treated (wave 3)	0.002	0.016	-0.002	0.017	-0.015
	(0.013)	(0.033)	(0.012)	(0.014)	(0.021)
ATT by calendar period:					
Calander − average	0.039	0.083**	0.044	0.042	0.024
	(0.025)	(0.037)	(0.027)	(0.029)	(0.039)
t=2012/13	0.030	0.122**	0.031	0.027	0.051
	(0.048)	(0.055)	(0.044)	(0.038)	(0.070)
t=2015/16	0.048***	0.044	0.057***	0.057**	-0.002
	(0.016)	(0.032)	(0.020)	(0.024)	(0.022)
Event study (or dynamic) effects by length of exposure to treatment					
Post-avg	0.060***	0.075*	0.070***	0.052*	0.016
	(0.020)	(0.040)	(0.023)	(0.030)	(0.033)
e=0	0.015	0.059**	0.014	0.024	0.007
	(0.023)	(0.029)	(0.025)	(0.026)	(0.029)
e=1	0.104***	0.091	0.125***	0.080**	0.026
	(0.030)	(0.062)	(0.038)	(0.040)	(0.048)
Pre-avg	0.009	-0.009	0.016	-0.005	0.002
	(0.021)	(0.045)	(0.025)	(0.035)	(0.026)
e =-1	0.009	-0.009	0.016	-0.005	0.002
	(0.021)	(0.045)	(0.025)	(0.035)	(0.026)
All controls (including 2G coverage)	yes	yes	yes	yes	yes
Individual-fixed effects	yes	yes	yes	yes	yes
Year-fixed effects	yes	yes	yes	yes	yes
P-value for test of conditional parallel trends	0.6627	0.8357	0.5341	0.8854	0.9339
N. of observations	11,166	1,605	9,557	3,007	8,133

Note: The ATT means average treatment effect on the treated; early treated refers to the household group covered by 3G networks between waves 1 and 2, while later treated refers to those covered between waves 2 and 3. Under event study dynamic effects, Post-avg denotes the average treatment effect for the post-treatment periods; Pre-avg is the pre-treatment average effect; e stands for event time (i.e., e=0 is the time of first treatment, e=1 is two periods after first treatment; e =-1 is two periods before the event). The comparison groups are never-treated observations. *** p<0.01, ** p<0.05, * p<0.1. Bootstrapped standard errors are in parentheses.

Table 4 shows the effect of mobile broadband internet on NFEs' employment. On average, 3G coverage increases employment by about 14.6 percent. However, a further disaggregated analysis by female- and male-headed households reveals that the effects are only significant in the latter (see also Figure A1b). While this is consistent with several studies demonstrating the employment-boosting effect of (mobile) internet in such businesses (see, e.g., Stockinger, 2019; Zhao, 2020; Denzer et al., 2021; Gu¨rtzgen et al., 2021; Li and He, 2025); it, however, contradicts Caldarola et al. (2023)'s claim that 3G adoption leads to a drop in NFE employment in Nigeria. Broadband internet may enhance employment through multiple channels, including facilitating new job creation as well as simplifying job searches and labor market matching (see Kuhn and Mansour, 2014; Denzer et al., 2021; Bhuller et al., 2023). It may also enable people to easily network with one another, share experiences, and thereby exploit available labor market opportunities. For instance, a study by Viollaz and Winkler (2022) in Jordan indicates that internet access enhances women's labor force participation by changing gender norms and influencing their marriage and fertility choices.

Table 4: 3G Impact on NFEs' employment

	Average treatment effect on the treated	**Group-specific average treatment effect**			**Cumulative average treatment effect by calendar period**		
Key Var: 3G Coverage	ATT	GA	ET	LT	CA	t=2012/13	t=2015/16
Average treatment effects	.146***	.152***	.132**	.170*	.135***	.101*	.169**
	(0.051)	(0.058)	(0.059)	(0.095)	(0.047)	(0.060)	(0.068)
Treatment effects by length of exposure (event study effects)			e=−1	Pre-avg	e=0	e=1	Post-avg
			0.004	0.004	0.136**	0.167*	0.152**
			(0.061)	(0.061)	(0.056)	(0.087)	(0.061)
2G Coverage	yes	yes	yes	yes	yes	yes	yes
All other controls	yes	yes	yes	yes	yes	yes	yes
Individual-fixed effects	yes	yes	yes	yes	yes	yes	yes
Year-fixed effects	yes	yes	yes	yes	yes	yes	yes
P-value for test of conditional parallel trends	0.9492	0.9492	0.9492	0.9492	0.9492	0.9492	0.9492
N. of observations	7,042	7,042	7,042	7,042	7,042	7,042	7,042

Note: The outcome variable, i.e., employment in HH NFEs, is in natural log scale.

The ATT means average treatment effect on the treated; GA = group average treatment effects; CA = average treatment effects; ET = early treated groups; LT = late treated groups; and t denotes time period. Under event study dynamic effects, Post-avg denotes the average treatment effect for the post-treatment periods; Pre-avg is the pre-treatment average effect; e stands for event time (i.e., e=0 is the time of first treatment, e=1 is two periods after first treatment; e =-1 is two periods before the event). The comparison groups are never treated as observations. *** p<0.01, ** p<0.05, * p<0.1. Bootstrapped standard errors are in parentheses.

Empirical evidence suggests that infrastructural bottlenecks, such as insufficient and poor-quality road networks and electrical grids, can greatly impair NFE start-ups and their sustainability in developing countries (Gibson and Olivia, 2010; Nagler and Naud´e, 2017; Tagliapietra et al., 2020; Pelz et al., 2023; Nwaka and Emeagwali, 2024). The availability of ICT technologies, such as 3G networks, may provide cost-effective access to information while also allowing online communication and transaction execution among various actors. That means it can ease some of the barriers that households face, particularly those related to distance or geographic location (see Kim and Orazem, 2017). Besides, such technologies can complement crucial infrastructure like electricity networks and thereby support economic activities. They can boost competition, eliminate entry and exit barriers, and alleviate financial and other constraints on start-ups. This might encourage households to engage in business activities.

Table 5 presents the impacts of 3G coverage on household NFEs' sales per worker (a proxy for labor productivity). In households covered by 3G networks, sales per worker increase by about 56 percent, which is quite substantial. Results from heterogeneity analysis, however, suggest that the impacts are mostly driven by the performance of NFEs operated by male-headed households (see also Figure A1c). The findings align with those of Caldarola et al. (2023), albeit their effect magnitudes are much larger. It is also consistent with those of Gbandi et al. (2025) in Togo, which indicate that micro enterprises that utilize the internet outperform non-users in productivity (see also Colombo et al., 2013; Paunov and Rollo, 2015; Canzian et al., 2019; Koutroumpis and Sarri, 2024). Household NFEs in areas with mobile broadband internet are likely to have better access to information and markets for both inputs and outputs (Demir et al., 2024). They can also leverage these technologies to streamline their business operations and lower transaction costs. Furthermore, with broadband internet, NFE operating households can readily acquire the necessary skills and exploit other available opportunities that may help them boost their business performance.

Table 5: 3G impact on NFEs' sales per worker

	Average treatment effect on the treated	Group-specific average treatment effect			Cumulative average treatment effect by calendar period		
Key Var: 3G Coverage	ATT	GA	ET	LT	CA	t=2012/13	t=2015/16
Average treatment effects	0.561**	0.560*	0.562*	0.557	0.497*	0.273	0.721**
	(0.282)	(0.287)	(0.323)	(0.399)	(0.275)	(0.388)	(0.362)
Treatment effects by length of exposure (event study effects)			e=−1	Pre-avg	e=0	e=1	Post-avg
			0.154	0.154	0.411	0.900*	0.655**
			(0.269)	(0.269)	(0.260)	(0.476)	(0.333)
2G Coverage	yes	yes	yes	yes	yes	yes	yes
All other controls	yes	yes	yes	yes	yes	yes	yes
Individual-fixed effects	yes	yes	yes	yes	yes	yes	yes
Year-fixed effects	yes	yes	yes	yes	yes	yes	yes
P-value for test of conditional parallel trends	0.5710	0.5710	0.5710	0.5710	0.5710	0.5710	0.5710
N. of observations	5,441	5,441	5,441	5,441	5,441	5,441	5,441

Note: The outcome variable, i.e., sales per worker, is in natural log scale. The ATT means average treatment effect on the treated; GA = group average treatment effects; CA = calendar average treatment effects; ET = early treated groups; LT = late treated groups; and t denotes time period. Under event study dynamic effects, Post-avg denotes the average treatment effect for the post-treatment periods; Pre-avg is the pre-treatment average effect; e stands for event time (i.e., e=0 is the time of first treatment, e=1 is two periods after first treatment; e =-1 is two periods before the event). The comparison groups are never treated observations. *** p<0.01, ** p<0.05, * p<0.1. Bootstrapped standard errors are in parentheses.

Overall, across all outcomes, the findings point to greater impacts in early-treated groups than in late-treated ones. The former refers to the group of households that received 3G coverage for the first time between waves 1 and 2, while the latter are those that gained coverage for the first time between waves 2 and 3. The event study (or dynamic DiD) analysis picked up no significant pre-treatment effects, suggesting that there is no systematic difference between the treatment and control groups before treatment (see also Figure A3). This may serve as a placebo test, supporting the conditional parallel trend tests reported in the results tables (see Miller, 2023). I also find evidence that treatment effects grow as households' length of exposure to 3G coverage increases. This implies that it may take some time to fully reap the benefits of (mobile) broadband internet technologies after initial rollout. However, it is worth noting that, with three rounds of data, I only have one lag available (from 2012/13 to 2015/16), which spans three years. This restricts a comprehensive event study dynamic analysis. In other words, analysis based on such a limited number of lags may not fully reveal whether the positive impacts of 3G coverage on household NFE ownership and their business performance are long-term or transient.

Robustness tests

To check for robustness, I re-estimate the main results with not yet treated observations as control group in Table 6 (see also Figure A2a) and balanced sub-sample in Table 7 (see also Figure A2b). I also perform additional estimations using the outcome regression (OR) and inverse probability weighted (IPW) estimators separately and confirm that the results remain the same (the output table for this is omitted for brevity). Regardless of changes in the control group and sample households, the findings remain stable. Most importantly, the consistency of results based on not yet treated controls minimizes any possible concerns regarding the pre-treatment comparability of the treated and never-treated groups in the main estimations.

Table 6: Re-estimation of Tables 3, 4, and 5 using not yet treated control groups.

	Participation in NFEs (Table 3)	**(ln) NFEs' employment (Table 4)**	**(ln) NFEs' sales per worker (Table 5)**
ATT	0.039*** (0.013)	0.127** (0.053)	0.521* (0.276)
ATT by treatment group:			
Early treated (wave 2)	0.061*** (0.019)	0.104* (0.053)	0.503* (0.273)
Late treated (wave 3)	0.002 (0.013)	0.170* (0.095)	0.557 (0.399)
All controls (including 2G coverage) Individual-fixed effects Year-fixed effects	yes yes yes	yes yes yes	yes yes yes
P-value for test of conditional parallel trends	0.6627	0.9492	0.5710
N. of observations	11,166	7,042	5,441

Note: The comparison groups are never treated observations. *** p<0.01, ** p<0.05, * p<0.1. Boot-strapped standard errors are in parentheses.

Table 6: Re-estimation of Tables 3, 4, and 5 using not yet treated control groups.

	Participation in NFEs (Table 3)	(ln) NFEs' employment (Table 4)	(ln) NFEs' sales per worker (Table 5)
ATT	0.039*** (0.013)	0.127** (0.053)	0.521* (0.276)
ATT by treatment group:			
Early treated (wave 2)	0.061*** (0.019)	0.104* (0.053)	0.503* (0.273)
Late treated (wave 3)	0.002 (0.013)	0.170* (0.095)	0.557 (0.399)
All controls (including 2G coverage) Individual-fixed effects Year-fixed effects	yes yes yes	yes yes yes	yes yes yes
P-value for test of conditional parallel trends	0.6627	0.9492	0.5710
N. of observations	11,166	7,042	5,441

Note: The comparison groups are never treated observations. *** p<0.01, ** p<0.05, * p<0.1. Boot-strapped standard errors are in parentheses.

Table 7: Re-estimation of Tables 3, 4, and 5 using balanced sub-sample.

	Participation in NFEs (Table 3)	(ln) NFEs' employment (Table 4)	(ln) NFEs' sales per worker (Table 5)
ATT	0.043** (0.022)	0.133** (0.060)	0.663** (0.260)
ATT by treatment group:			
Early treated (wave 2)	0.067** (0.033)	0.112* (0.067)	0.717** (0.309)
Late treated (wave 3)	0.002 (0.013)	0.170* (0.093)	0.557 (0.384)
All controls (including 2G coverage) Individual-fixed effects Year-fixed effects	yes yes yes	yes yes yes	yes yes yes
P-value for test of conditional parallel trends	0.4828	0.7299	0.2407
N. of observations	10,892	6,774	5,341

Note: The comparison groups are never treated observations. *** p<0.01, ** p<0.05, * p<0.1. Boot-strapped standard errors are in parentheses.

Mechanisms

It is evident from Table A1 and Figure A4 that greater access (adoption) of mobile internet can be achieved by deploying mobile broadband networks. There are multiple mechanisms by which the availability and subsequent adoption of ICTs might impact business outcomes. While I do not present empirical evidence to support this (due to a dearth of data), I draw on the available literature to discuss the different channels through which 3G mobile broadband internet may affect business activities.

One plausible mechanism by which (mobile) broadband internet may impact household NFEs is by causing changes to their internal business organization and operation. The availability of 3G internet may allow firms to innovate in their products and processes. As a result, NFEs can handle traditionally tedious tasks (e.g., routine manual transaction processing) easily with digital means, thereby achieving greater efficiency (productivity) in their operations (Paunov and Rollo, 2015; Bertschek and Niebel, 2016). Such innovations may also result in the birth of new (NFE) start-ups, as well as the growth and sustainability of existing ones (Canzian et al., 2019; Hasbi, 2020; Conroy and Low, 2022; Deller et al., 2022; Houngbonon et al., 2022; Yang et al., 2022; Briglauer et al., 2024).

Improving access to critical inputs, such as information and financing, is another likely channel via which broadband internet might affect household non-farm enterprises (NFEs). In this respect, Pellegrina et al. (2017) indicates that broadband internet simplify market entry and exit, increase competition, and hence facilitate NFEs' access to critical inputs such as funding at competitive prices. Likewise, Alderete (2017) shows that broadband technology allows households to easily connect with each other, share information and experiences (skills), and coordinate and collaborate in their business.

Another way broadband internet may promote household NFEs is by simplifying their access to output markets. Many small businesses, especially those in small towns and rural areas, struggle to market their products. 3G mobile broadband internet may enable firms, including NFEs, to easily access markets both nearby and distant, potentially eliminating the need for brokers. Consequently, they might be able to sell their products at better prices, resulting in increased revenue and profit (Goldmanis et al., 2010; DeStefano et al., 2018; Caldarola et al., 2023; Cariolle and Le Goff, 2023; Koutroumpis and Sarri, 2024). Broadband internet may allow business owners to explore and access prospective markets for their products all around the world. In this respect, Hjort and Poulsen (2019), for example, find evidence of increased firm exports after the arrival of broadband internet in Africa (see also Akerman et al., 2022).

6. Conclusions

Using quasi-experimental variations created by the uneven rollout of mobile broadband internet in Nigeria, this study highlights the vital role of 3G network coverage in improving household participation in NFEs, as well as its employment- and productivity-enhancing effects. The impacts are more pronounced in early-treated households than in late-treated ones. The results from the event study dynamic analysis indicate that the full benefits of 3G networks build up over time as households' length of exposure to these technologies increases. While the impacts on household engagement in NFEs are more evident in female-headed households, their effects on NFEs' employment and sales per worker (labor productivity) are only significant in male-headed ones. There may be numerous policy-relevant factors underlying such differential impacts; however, diving into such explanations is beyond the scope of this paper. Overall, the findings suggest that expanding mobile broadband internet networks can help improve household income-generating (livelihood diversification) activities and their business growth.

Although this paper makes substantial contributions to bridging the research gap in the area, it has some limitations. First, it would have been more enlightening to include a disaggregated analysis by business sectors, but the lack of unique enterprise codes prevented this. Second, due to the absence of precise household geolocations, I match the GHS-Panel with 3G coverage data using EA centroid geo-coordinates; hence, all households within a given EA receive the same treatment status. Using households' actual geo-coordinates would have been more helpful in fully exploiting variations in 3G coverage.

Appendix

Table A1: Impact of 3G coverage on mobile-internet access (proxy for mobile broadband adoption).

Dependent var: mobile-internet dummy	Pooled OLS	Two-way Fixed Effects (TWFE)
	(1)	(2)
3G coverage using a buffer size of 2km (in urban) and 5km (in rural)	0.058***	0.047***
	(0.015)	0.015
All controls (including		
2G coverage) Local Gov't Area-fixed effects Year-fixed effects	yes yes yes	yes - -
Observations	11,043	11,043
R-squared	0.295	-

Note: The mobile-internet dummy is a proxy for mobile broadband internet adoption. It takes a value of 1 if at least one household member has access to both a mobile phone and the internet, and 0 otherwise. The comparison groups are never treated observations. *** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the enumeration area level.

Table A2: Correlation between mobile-internet access (adoption) and household participation in NFEs and their performance.

Panel A: Mobile internet access (adoption) vs. household NFEs

	Participation in NFEs	**(ln) NFEs' employment**	**(ln) NFEs' sales per worker**
	1	**2**	**3**
Internet-internet adoption	0.054**	0.057*	0.522***
	(0.022)	(0.030)	(0.108)
Observations	12,422	8,092	6,977
R-squared	0.001	0.001	0.004

Panel B: Internet access (adoption) vs. household NFEs

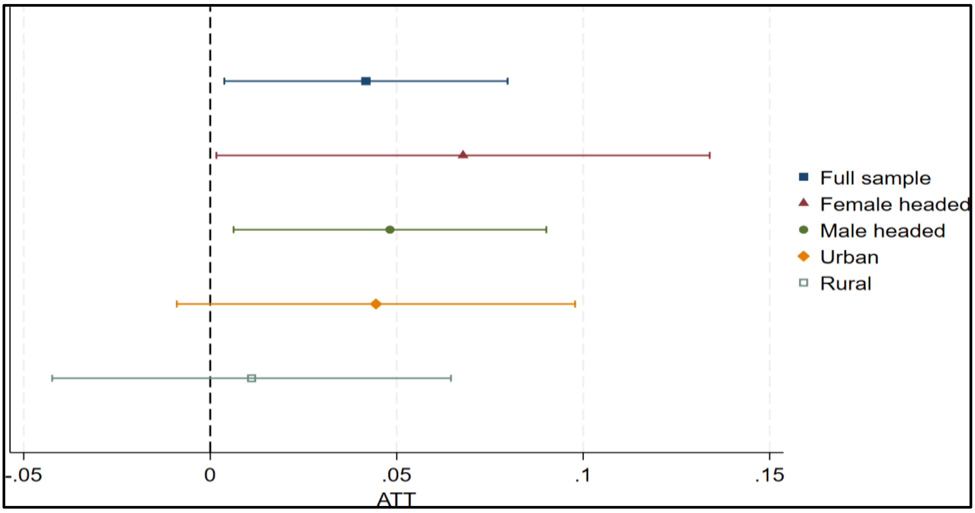
	Participation in NFEs	**(ln) NFEs' employment**	**(ln) NFEs' sales per worker**
	4	**5**	**6**
Internet access (adoption)	0.051**	0.054*	0.512***
	(0.022)	(0.030)	(0.108)
Observations	12,187	7,976	6,892
R-squared	0.001	0.001	0.004

Panel C: Mobile access (adoption) vs. household NFEs

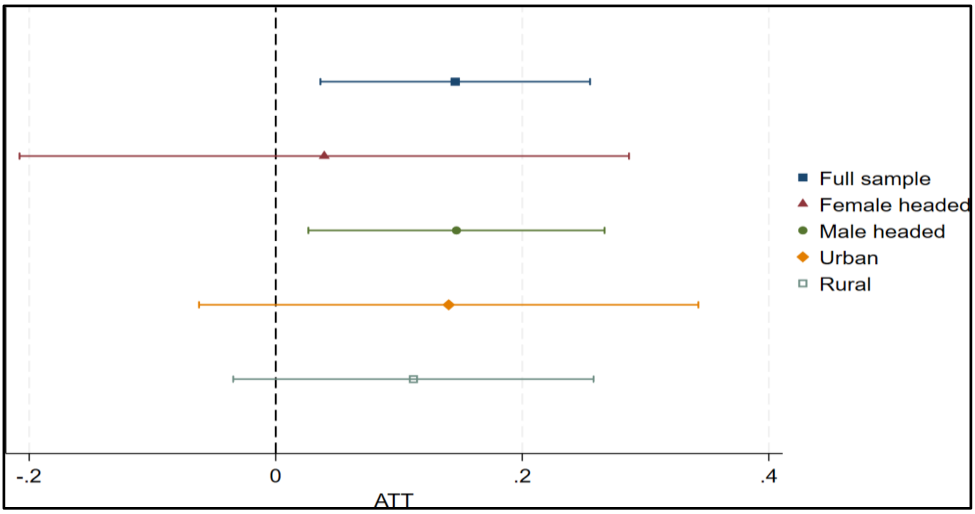
	Participation in NFEs	**(ln) NFEs' employment**	**(ln) NFEs' sales per worker**
	7	**8**	**9**
Mobile access (adoption)	0.223***	0.093***	0.795***
	(0.020)	(0.031)	(0.130)
Observations	12,427	8,095	6,980
R-squared	0.024	0.0015	0.006

Note: The mobile-internet dummy is a proxy for mobile broadband internet adoption. It takes a value of 1 if at least one household member has access to both a mobile phone and the internet, and 0 otherwise. The correlation coefficients are estimated using pooled OLS regression. *** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the enumeration area level.

Household Participation in NFEs



NFE Employment



NFE Sales Per Worker

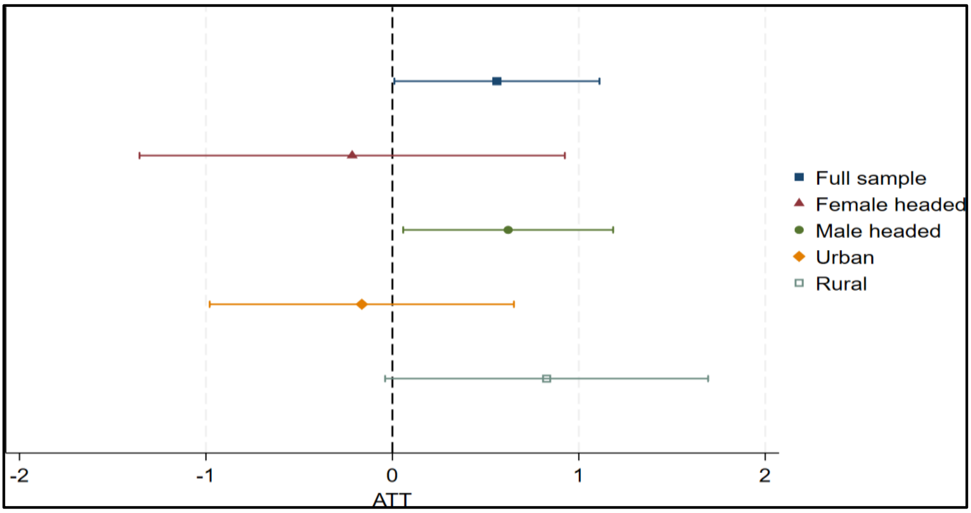
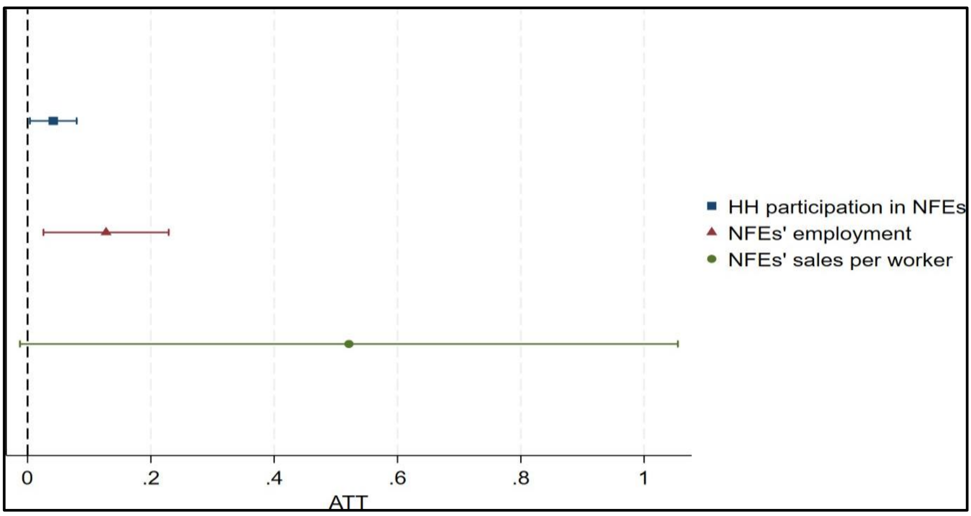


Figure A1: Average Treatment Effect on the Treated (ATT): Full and sub-sample estimates.

Not yet treated control



Balanced sub-sample

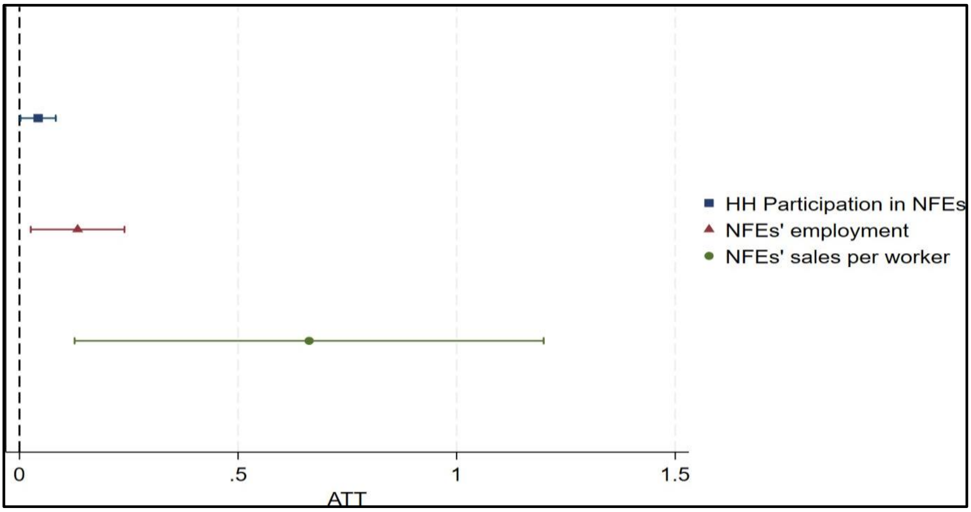


Figure A2: Average Treatment Effect on the Treated (ATT): Household participation in NFEs and their employment and sales per worker.

(a) Household Participation in NFEs (b) NFE Employment (c) NFEs' Sales Per Worker

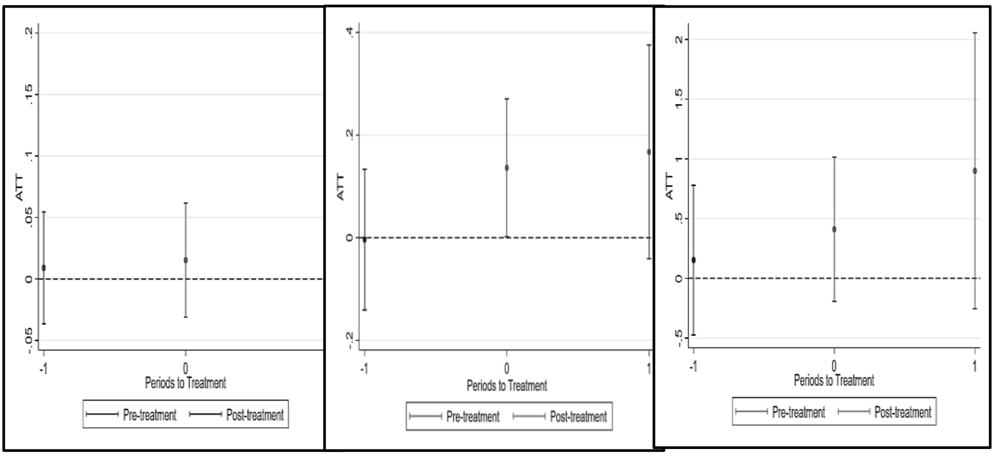


Figure A3: Average treatment effects by length of exposure to the treatment (event study dynamic effects).

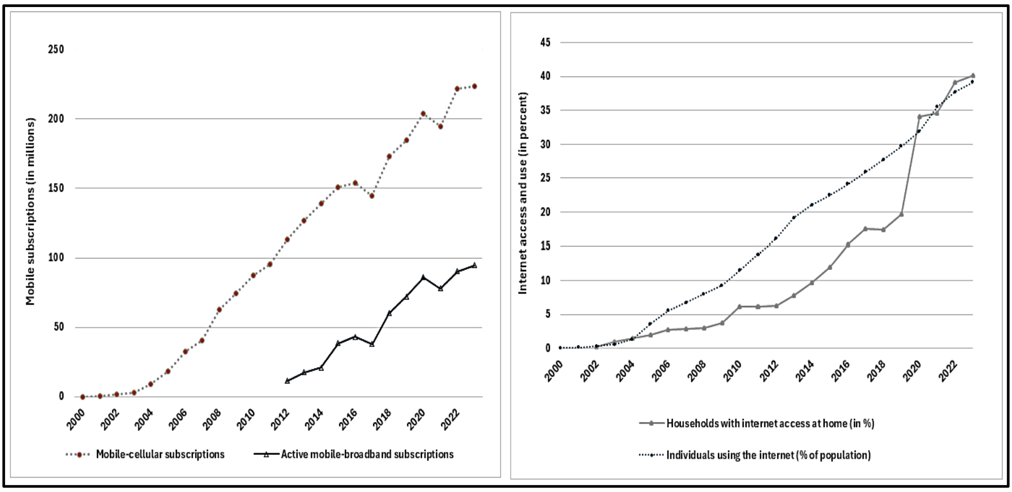


Figure A4: Mobile subscriptions and internet access and use, Nigeria. Note: I create this picture using data from the International Telecommunication Union (ITU) and the World Bank's World Development Indicator (WDI) databases.

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Impacts of Mechanisation on Rural Multidimensional Poverty in Arsi Zone, Oromia Region, Ethiopia

Gizachew Mengesha Abebe[1],* Wondaferahu Mulugeta Demissie[2], Markose Chekol Zewdie [1 3 4]

Abstract

Farm mechanization is widely regarded as a key pathway to improving productivity and alleviating rural poverty among smallholder farmers, yet empirical evidence on its multidimensional poverty impacts remains limited. This study analyzes data from 413 households in Ethiopia's Arsi Zone to examine the determinants of mechanization adoption and its effects on rural multidimensional poverty using the Multinomial Endogenous Switching Regression (MESR) model and the Alkire and Foster Rural Multidimensional Poverty Index (R-MPI). Results indicate that access to extension services, credit, and cooperative membership significantly increase the likelihood of adopting both tractors and combine harvesters, while factors such as crop diversification and distance from cooperatives reduce adoption rates. The conditional treatment effects reveal that mechanization adoption substantially lowers poverty levels: combine harvester use alone reduces R-MPI by 6.75%; likewise, tractor adoption alone yields a significant 4.6% reduction; and joint adoption of both machines produces the largest and most significant poverty decrease of 20.51%, equivalent to a 0.09-point decline in R-MPI. These findings highlight the critical role of integrated mechanization strategies and cooperative support in rural development, suggesting that policies enhancing access to machinery and rural services can effectively reduce multidimensional poverty in Ethiopia and comparable settings.

Keywords: Mechanisation, Smallholder Farmers, Poverty Reduction, multinomial endogenous switching regression, Ethiopia

[1] Bahir Dar University, Department of Economics, Bahir Dar, Ethiopia
*Corresponding Author: Gizachew Mengesha Abebe: Email: gmengesha06@gmail.com.
[2] Ethiopian Civil Service University (ECSU), Department of Economics, Addis Ababa, Ethiopia.
[3] WorldFish, Department of Aquatic Food; C/o International Livestock Research Institute (ILRI), Nairobi, Kenya
[4] University of Antwerp, Department of Engineering Management, Antwerp, Belgium

1. Introduction

The topic of mechanization has recently gained renewed attention on the research agenda, particularly following the Green Revolution in Asia and due to the increasing accessibility and acceptance of machinery among smallholder farmers in Asia and other developing countries (Daum, 2023; De Groote et al., 2018). Despite numerous studies that look in detail at the degree of mechanization and its correlation with productivity, there is a notable lack of in-depth, rigorous analyses that allow us to capture the observed and unobserved factors that explain the role of mechanization in reducing poverty and improving the livelihoods of poor farmers in different countries and regions. Therefore, conducting a rigorous analysis is essential to determine the impact of mechanization on welfare indicators (Berhane et al., 2017; Daum & Birner, 2020).

Agriculture is one of the key drivers of economic growth, job creation, poverty reduction and food security in sub-Saharan Africa (SSA) (Dimnwobi et al., 2023; Mekonnen et al., 2024; OECD-FAO, 2016). However, the sector faces persistent challenges, mainly due to low technology diffusion and insufficient mechanization and technological advancement. These mechanization challenges are exacerbated by factors such as inadequate skills of farmers, limited accessibility and high costs associated with machinery, credit and financial resource decisions, availability of spare parts and access to maintenance services (Pingali, 2023). In addition, the lack of sound financing mechanisms and infrastructure hinders the widespread adoption of machinery, especially in SSA regions characterized by smallholder farming methods (Mrema et al., 2018).

Research emphasizes the central role of technological progress in promoting the growth of the agricultural sector and reducing poverty in rural areas. Traditional methods and subsistence farming alone are not sufficient to meet the increasing demand for agricultural products (Habtewold, 2020). Therefore, improving technological capabilities through research in the agricultural sector is essential. This approach, coupled with optimal conditions of use and investment in human capital, is crucial for sustaining food production and effectively combating poverty (Emami et al., 2018). Studies indicate that machinery such as tractors and combine harvesters positively impact agricultural productivity, income levels, and poverty reduction (Abass et al., 2017; Jena & Tanti, 2023; Mdoda et al., 2022; Olasehinde-Williams et al., 2020). Mechanization allows farmers to increase production capacity, save time and labor, and potentially achieve higher crop yields, all of which lead to higher incomes and improved livelihoods for rural households (Ahmed et al., 2020; Peng et al., 2022). This is particularly crucial for breaking the cycle of poverty in developing regions like SSA. Mechanization offers a multifaceted approach to reducing rural multidimensional poverty by enhancing productivity, reducing farming time, and enabling diversification into non-agricultural sectors (Cossar, 2019; Ma et al., 2024).

Despite the clear benefits of mechanization, its adoption remains low in many parts of sub-Saharan Africa (SSA). Poverty reduction remains an ongoing and urgent challenge in the region. Multidimensional poverty, in particular, is widespread across the region, with nearly five out of every six individuals living in poverty in SSA (UNDP, 2023). Ethiopia, one of the fastest-growing economies in the region, faces particularly high levels of both uni- and multidimensional poverty. The World Bank classifies Ethiopia as one of the poorest countries in the world, with a per capita gross national income of $1,020 (WorldBank, 2024). With 126.5 million inhabitants, it is the second most populous country in Africa. The World Bank classifies Ethiopia as one of the poorest countries in the world, with a per capita gross national income of $1,020 (WorldBank, 2024). The UNDP (2023) report highlights the alarming rise in multidimensional poverty in Ethiopia and shows that 68.7% of the population is affected by multidimensional poverty, reflecting deprivation in areas such as education, health and living standards. In addition, 18.4% of the population is at risk of multidimensional poverty, highlighting their vulnerability to slipping into poverty.

In our world, rural areas, despite being places of food production, harbor a disproportionate number of poor and malnourished people. For these individuals, agriculture represents not only a means of sustenance but also a critical pathway to improving their welfare. Shockingly, 84% of the global impoverished population resides in rural settings (UNDP, 2023). In Ethiopia, according to FAO and OPHI (2022) assessing rural multidimensional poverty using livelihood resources and risk exposure indicators, alongside other metrics, it is revealed that approximately 81% of the rural population faces multidimensional poverty. These findings are based on a comprehensive household survey conducted in Ethiopia in 2016. Hence, there exists a clear link between poverty reduction and the transformation of the agricultural sector.

To effectively combat poverty in developing countries like Ethiopia, prioritizing initiatives that enhance productivity, profitability, and sustainability in smallholder farming is paramount. This necessitates the implementation of robust agricultural policies and targeted research focused on integrating technology into rural development (Pray et al., 2017; Rosegrant et al., 2017). Additionally, giving due consideration and support to the rural economy is vital to address the challenges associated with the rapid growth of urban areas (Fang, 2022). Therefore, investigation on the impact of mechanization on multidimensional rural poverty is an urgent and timely issue.

The aim of this study is to analyze the impacts of mechanization on rural multidimensional poverty in the Arsi Zone, Ethiopia. The analysis focuses on measuring poverty across four dimensions in the rural sector, with the livelihood sector included as an additional dimension.

The present study contributes to the existing literature by examining the relationship between mechanization and rural poverty from four aspects. First, to the best of my knowledge, this study is the first to address the impact of mechanization on multidimensional rural poverty in Ethiopia or elsewhere by considering the rural economy setup. Previous research has mainly concentrated on examining how mechanization impacts income poverty, with a primary emphasis on the productivity enhancements linked to mechanization (Adu-Baffour et al., 2019; Berhane et al., 2017; Jena & Tanti, 2023; Paudel et al., 2023). Although there have been studies investigating the effects of technology adoption on rural multidimensional poverty, the main focus of these studies has been on the adoption of climate-smart, high-yield seeds (HYS) and fertilizer technology (Ali et al., 2022; Gebrekidan et al., 2021; Habtewold, 2020, 2021; Zegeye, 2021). The specific impact of mechanization within this particular context has not been extensively investigated. Despite the recognized benefits of mechanization, such as increased productivity, time savings, task simplification, and its contribution to economic transition and balanced growth, its specific effects on multidimensional poverty have not received sufficient attention.

Secondly, we measure and quantify rural multidimensional poverty by incorporating livelihood resources as an additional dimension. Relying solely on the global multidimensional poverty index is inadequate for understanding rural poverty due to the diverse nature of rural areas and their marginalization in infrastructure development. Rural livelihoods rely on natural resources and face various risks, such as crop failures and social service exclusion due to remote locations (De La O Campos et al., 2018). To address this, FAO and OPHI (2022) introduced new dimensions in their poverty measure to reflect the unique challenges of rural communities globally, which include livelihood and resource indicators. Therefore, this study adds livelihood and resource indicators and estimates the Rural Multidimensional Poverty Index (R-MPI) using the Alkire-Foster method, which is crucial for understanding rural poverty and assessing the impact of mechanization on it.

Third, this study contributes significantly by examining the impact of mechanization on rural poverty using Multinomial Endogenous Switching Regression (MESR) and Multinomial Endogenous Treatment Effects (METE[5]) methodology. While existing studies often rely on propensity score matching (PSM) and instrumental variables (IV), which may not adequately address unobserved factors and self-selection issues, MESR and METE provide robust frameworks. These methodologies account for both observed and unobservable factors influencing technology adoption and outcomes, ensuring a more precise estimation of mechanization's impact on rural poverty.

Fourth, this study examines the nuanced effects of the combined and individual adoption of tractors and combine harvesters on multidimensional poverty in rural areas. This approach allows for a detailed examination of the specific impacts of each type of agricultural machinery as well as the synergistic effects that arise when they are used together.

The rest of the paper is structured as follows: Section 2 provides a literature review, while Section 3 discusses the methodology. In Section 4, we discuss the results of descriptive statistics, multidimensional poverty measurement, and present the Multinomial Endogenous Switching Regression (MESR), and Multinomial Endogenous Treatment Effect (METE) models, which serve as the estimation strategies in this study. Finally, in Section 5, we conclude by summarizing the main findings and highlighting their policy implications.

2. Literature Review

2.1. Theoretical Literature

In reviewing poverty theories, several influential perspectives emerge. The individualist theory emphasizes the role of individual capacity and innovation in income generation and resource utilization (Rainwater, 1967). It views poverty through the lens of individual initiative and diligence. Cultural theories, in contrast, highlight how societal norms, beliefs, and values shape economic outcomes and vulnerability to poverty (Lewis, 1954; Valentine, 1968), emphasizing the socio-cultural context of poverty manifestation.

[5] METE follows the same method as MESR; the primary distinction is that METE is intended for binary outcome variables, whereas MESR is intended for continuous outcome variables. In the following, we concentrate on the MESR derivation, which can be extended to the METE.

Geographic theories shift focus to natural resource abundance, institutional accessibility, and public service availability as critical factors influencing poverty levels across regions (Weber, 2001). These theories underscore geographical determinants contributing to disparities in poverty outcomes. Structuralist theories broaden the perspective by examining societal structures and systemic factors perpetuating poverty (Bradshaw, 2007; Jencks, 1996). Delving into deeper economic frameworks that sustain poverty over time.

In our study, while we acknowledge the relevance of these theories and approximate their influence using various proxies, our primary focus remains on examining the impact of mechanization on rural multidimensional poverty. Mechanization, known for enhancing productivity, streamlining tasks, and contributing to economic transformation, is pivotal in our investigation. Figure 1 illustrates how mechanization interacts with rural multidimensional poverty, aiming to uncover nuanced insights into its specific effects within this context.

Mechanization's primary benefit lies in reducing labor requirements in agriculture (Baudron et al., 2019; Berhane et al., 2017), enabling farmers to engage in non-farm activities (Zheng et al., 2022), and boost their income, thereby improving their living standards (Adu-Baffour et al., 2019; Berhane et al., 2017; Daum, 2023; FAO & AUC, 2018). Additionally, mechanization contributes to reducing child labor and increasing child and adult enrollment rates in education (Goulart et al., 2024; Takeshima & Vos, 2022), crucial for sustainable rural development.

Mechanization facilitates the expansion of cultivated land, particularly where traditional methods like the ox plough are inefficient. This expansion enhances agricultural productivity (Daum et al., 2020), ensuring food security and contributing to economic growth (Fuglie et al., 2019). It also minimizes post-harvest losses, improves timeliness, and enhances overall productivity (Animaw et al., 2016; Berhane et al., 2017; Diao et al., 2016; Emami et al., 2018; Mottaleb et al., 2017; Van Eerdewijk & Danielsen, 2015; Wang et al., 2022), translating into asset ownership, improved housing, and better sanitation, critical for reducing rural poverty (Amejo et al., 2018).

As discussed earlier, mechanization significantly affects various indicators of poverty. Poverty, particularly in rural areas, is a multifaceted issue that extends beyond simple measures of income and consumption (Abeje et al., 2020; Alkire et al., 2015; Atkinson, 2003; Thorbecke, 2013; Wang, 2022). Livelihoods in rural settings depend on diverse economic activities such as agriculture, livestock rearing, and traditional craftsmanship (Madzivhandila & Niyimbanira, 2020). The Alkire and Foster (2011) methodology provides a robust and policy-relevant approach to measuring poverty across education, health, living standards, and Livelihoods, reinforcing the appropriateness of this method in our analysis.

Mechanization's role in alleviating rural poverty can be effectively understood through the Sustainable Livelihood Framework (SLF), which outlines five key capitals—human, natural, physical, financial, and social (Scoones, 1998). Each of these capitals supports farmers' capacity to adopt mechanized technologies: education and health (human capital) enhance skillful use; land and livestock (natural capital) determine the scope of mechanization; infrastructure and extension services (physical capital) enable operational use; access to income and credit (financial capital) facilitates equipment acquisition; and cooperative networks (social capital) foster information flow and shared access. Moreover, recent global development studies underline the importance of integrated systems and infrastructure in driving economic transformation. For instance, aggregation of economic models with GIS tools in the India–Caspian corridor highlights how spatial integration and trade linkages can inform efficient resource use and connectivity (Khan et al., 2023). Similarly, the integration of gravity models and network analysis in the India–Middle East–Europe Economic Corridor (IMEC) shows how strategic logistics planning fosters economic inclusion and reduces regional disparities (Khan et al., 2025). Drawing parallels, rural mechanization, when embedded in a broader infrastructural and networked framework, can similarly serve as a localized engine of poverty reduction by strengthening livelihood capitals, improving access to markets, and enhancing overall economic resilience. Therefore, our approach emphasizes the assessment of multidimensional poverty as crucial for gaining a comprehensive understanding of household well-being in rural areas, where mechanization not only enhances economic opportunities but also improves education, living standards, and sanitation.

2.2. Empirical Evidence

Mechanization plays a pivotal role in poverty reduction across various countries, exemplified by significant findings in recent studies. Fuglie et al. (2019) highlight its substantial contributions to poverty alleviation in China and East Asia. For instance, Peng et al. (2023) demonstrate that a 1% increase in agricultural machinery in China correlates with a 3.3% rise in income and a 0.523% reduction in poverty. Similarly, in India, Jena and Tanti (2023) reports positive impacts on net agricultural income, household income, and consumption following machinery adoption. In Nepal, Paudel et al. (2023) underscore the benefits of scale-appropriate mechanization, enhancing maize productivity, household food self-sufficiency, and poverty reduction among smallholder farmers. Additionally, Abass et al. (2017) findings indicate that mechanized cassava processing lifts rural Zambian villages out of poverty.

Evidence on the determinants of poverty in Ethiopia, especially rural poverty, has been growing in recent times, as evidenced by studies such as those by Eshetu et al. (2022), Motuna et al. (2020), Gebrekidan et al. (2021), Mare et al. (2022), and Shitaye (2024). However, there is a notable gap in research regarding the impact of mechanization on rural poverty, either in unidimensional or multidimensional aspects, in Ethiopia. The identified research gap highlights the critical need for a rigorous investigation to validate the role of mechanization in reducing poverty in rural areas of Ethiopia. Such a study would not only provide essential insights but also make valuable contributions to both academic knowledge and practical applications. It would shed much-needed light on the actual impact of mechanization on addressing rural poverty, an aspect that has been largely overlooked in existing literature.

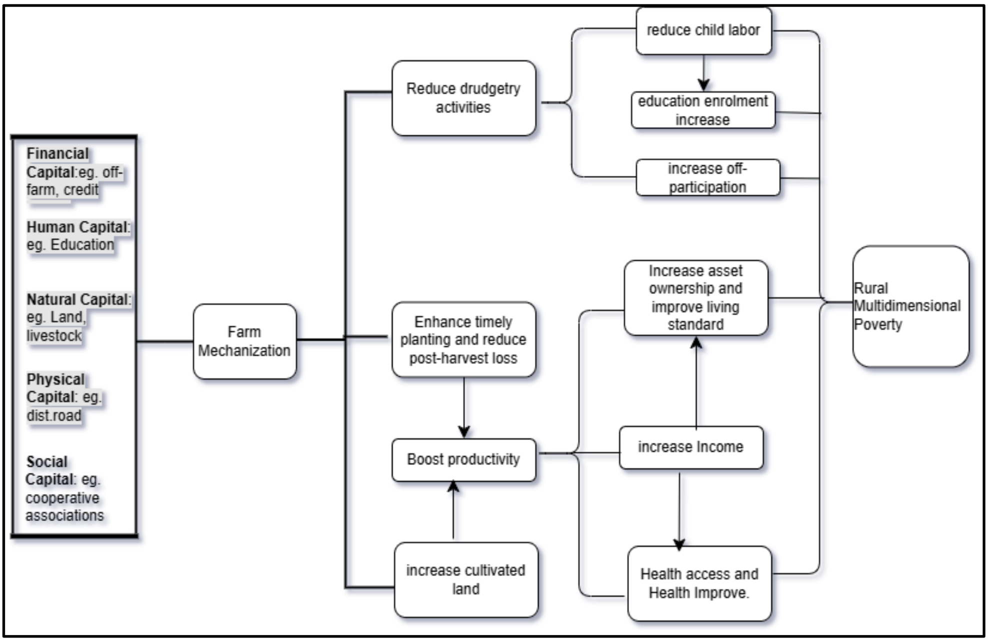

Figure 1: Relationships between Farm mechanization and rural multidimensional poverty

3. Methodology

3.1. Description of the Study Area

The Arsi Zone is situated in the Oromia National Regional State of Ethiopia, covering an area of 21,008 km2. It shares borders with the Bale zone to the south, the West Arsi zone to the southwest, the East Shewa zone to the northwest, the Afar Region to the north, and the West Hararghe zone to the east. Assela town, located 75 kilometers south of Adama town and 175 kilometers from Addis Ababa, serves as the capital of the zone. The study concentrated on four selected districts within the zone: Hitosa, Lude Hitosa, Dodota-Dera, and Sire (see Figure 2 below).

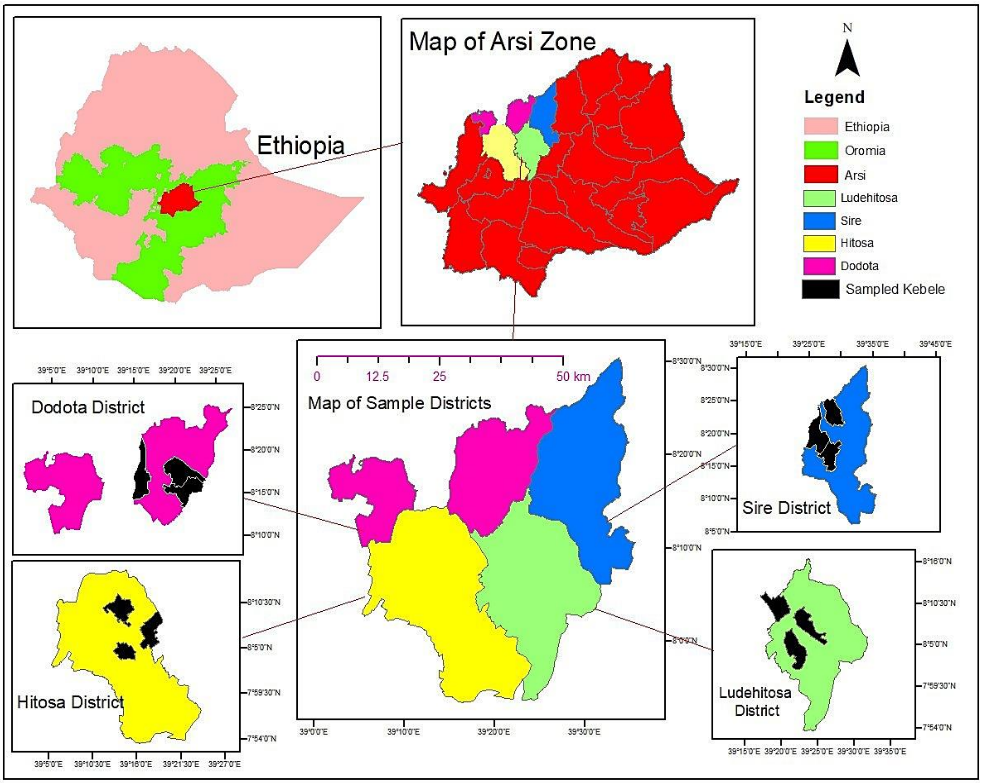

Figure 2: Map of the Study Area

Sire is one of the woredas (districts) in the Arsi Zone, positioned at an altitude range of 1200-2700 meters. The mean temperature in this district fluctuates between 15 and 30 degrees Celsius, with an average annual rainfall of 500mm. Similarly, Dodota Woreda encompasses an altitude range of 1400-2500 meters, with a mean temperature ranging from 20 to 25 degrees Celsius and a relatively higher average annual rainfall of 1000mm. Hetosa Woreda, located at an altitude range of 1500-4170 meters, experiences a mean temperature varying between 5 and 28 degrees Celsius, with an average annual rainfall of 1000mm. Lude Hetosa Woreda, with an altitude range of 1800-2500 meters, maintains a mean temperature between 10 and 27 degrees Celsius and receives an average annual rainfall of 800-1000mm. The primary crops cultivated in these woredas include wheat, barley, teff, beans, and onions see (Mekonnen, 2010; Semahegn et al., 2021)

3.2. Data Sources, Types, and Collection

The study incorporated both primary and secondary data. Efforts were made to enhance the quality of the questionnaire based on feedback received during the pre-testing phase. Trained enumerators collected primary data through a semi-structured questionnaire that was developed after conducting an initial survey. The primary data collection involved sampling 413 rural households from four selected districts. Additionally, secondary data was gathered from various sources, including the Arsi zone and district offices of agriculture and rural development.

Published and unpublished documents were also utilized to provide a comprehensive overview and validate the primary data.

3.3. Sampling Technique and Sample Size

The study used a carefully planned sampling technique and sample size calculation to ensure representation and reliability. The study population consisted of rural farm households in the four woredas of the Arsi Zone, and the sample households were selected from specific kebeles within these woredas. To achieve a representative sample, a multi-stage sampling technique was employed, combining purposive and simple random methods.

The Arsi Zone was purposively selected in the first stage due to its importance in wheat production and its relatively high level of agricultural machinery adoption. In the second stage, four woredas—Sire, Dodota, Lode Hitosa, and Hitosa—were selected based on their wheat production potential, level of machinery adoption, vulnerability to drought, and the presence of a stable peace situation conducive to reliable data collection. In the third stage, kebeles that were not suitable for four-wheel tractor ploughing and combine harvester operation were excluded, after which

12 kebeles were randomly selected from those with suitable terrain. Finally, the unit of analysis—sample farm households—was randomly drawn from the selected 12 rural kebeles.

The sample size was determined using the Krejcie and Morgan (1970) formula, taking into account a 95% confidence interval, population size, population proportion, and degree of accuracy. The resulting sample size of 374 households was adjusted with a 10% contingency to account for sampling error, resulting in a total of 413 households for the survey. After the survey, we identified adopters and non-adopters for each machinery, and then we undertook a rigorous analysis of the impacts of adoption on rural multidimensional poverty.

3.4. Measuring Rural Poverty

To measure rural multidimensional poverty, researchers employ a diverse range of indicators and methodologies. While changes in household income or consumption levels post adoption are crucial metrics for estimating poverty reduction effects, they are not enough to capture the broader impacts of mechanization or other technologies aimed at reducing rural poverty, which encompass diverse scenarios. This is because, according to Sen, mere possession cannot automatically translate into well-being (Sen, 1985). Therefore, adopting a multidimensional approach is now very common and undisputed in the academic world (Alkire & Santos, 2013).

The measurement of poverty has evolved from a unidimensional analysis to a multidimensional approach, taking into account various dimensions of well-being. This shift has led to the development of different measurement methods to capture the complex nature of poverty, as recognized by both development practitioners and academics (Alkire & Fang, 2019). In the 1990s, the UNDP introduced human development indicators with three dimensions and four indicators. Subsequently, in 2010, the Global Multidimensional Poverty Index (Global MPI) was developed by OPHI and UNDP, encompassing education, health, and living standards dimensions, serving as the basis for the Rural Multidimensional Poverty Index (R-MPI). The R-MPI, developed as an adaptation to the Global MPI, includes five dimensions: Food Security and Nutrition, Education, Standard of Living, Livelihood, and Risk Exposure, tailored to capture rural poverty (FAO & OPHI, 2022).

The study focused on four dimensions of poverty. The first dimension, food and nutrition security, is measured by household dietary diversity, which has a positive association with the Household Dietary Diversity Score (HDDS) (FAO, 2010). A cutoff of five and below types of food consumed per day by the household within the 24 hours prior to the survey is used to classify households as food insecure and secure, following the categorization by Setsoafia (2021). Health access is another important indicator within the first dimension of the study, measured by household members' participation in health insurance, which is determined by their payment of a fixed annual premium. The inclusion of this indicator takes into account the availability of health insurance in the study area, a method previously utilized Eshetu et al. (2022) in southern Ethiopia. The third indicator is child mortality, derived from the household's response regarding child loss in the past five years.

The second dimension, education, is indicated by household members' attendance and enrollment. The third dimension, living standards, encompasses indicators such as cooking fuel, sanitation, water access, electricity, housing quality, and asset ownership. The fourth dimension, livelihood and resource use, includes indicators like land ownership, livestock ownership, access to extension services, social protection, child labor, and non-farm income.

The maximum weighted score for deprivation is 100, with equal weights assigned to each poverty dimension, as shown in Table 1, additionally, within each dimension, all indicators are weighted equally, following the approach proposed by Alkire and Foster (2007). The estimation of multidimensional poverty involves two steps. Firstly, the ratio of multidimensionally poor households to the total number of households (incidence, H) is calculated by dividing the number of multidimensionally poor households (q) by the total number of households (n).

$$\mathbf{H} = \frac{\mathbf{q}}{\mathbf{n}} \tag{1}$$

Secondly, the intensity of poverty among the multidimensionally poor households (intensity, A) is estimated as the average deprivation intensity across dimensions for poor households. It is obtained by summing the weighted deprivation indicators (ci) for each dimension and dividing by the number of multidimensionally poor households (q).

$$\boldsymbol{A} = \sum_{i=1}^{n} \boldsymbol{c_i}\,(\boldsymbol{k})/\boldsymbol{q} \tag{2}$$

Finally, the adjusted headcount or multidimensional poverty (R_MPI) is derived by multiplying the intensity and incidence.

$$\boldsymbol{R_{MPI}} = \boldsymbol{M0} = \frac{1}{n}\sum_{i=1}^{n} c_i\,(k) = H \times A \qquad \textbf{(3)}$$

In this study, households are classified as non-poor or poor based on their multidimensional deprivation scores, with a score below 0.33 indicating non-poor status and a score above 0.33 indicating multidimensional poverty. This classification methodology is based on the approach proposed by Alkire and Foster (2007). Further, the approach offers three merits: simplicity, monotonicity, and decomposability by dimensions and sub-population groups. To assess the specific influence of each dimension on overall multidimensional poverty, the contribution of the j-th dimension can be determined using the following expression:

$$\text{Contribution of j dimension} = \frac{\frac{\sum_{n=1}^{q} c_j}{n}}{R_{MPI}} \qquad \textbf{(4)}$$

where n is the total number of households, q is the number of poor households, Cj is the deprivation in jth dimension and $\boldsymbol{R_{MPI}}$ is the rural multidimensional poverty index, respectively. This measure helps in identifying which dimensions contribute most to poverty, thereby informing policy priorities.

Moreover, multidimensional poverty can be further decomposed by different population subgroups, such as by gender, specific dimensions, and sample districts, using a population-weighted decomposition approach.

$$\text{Contribution of population subgroup } (ns) = \frac{\frac{\sum_{n_s=1}^{q_s} c_j}{n_s}}{R_{MPI}} \qquad \textbf{(5)}$$

Where ns is the total number of households in a given group, Ci is the deprivation of the ith household and qs is the total number of poor households in that group, respectively.

Table 1: Dimensions, Indicators, and Cutoff of Rural Multidimensional Poverty.

Dimension	Indicator	Deprived if:	Weighted in percentage
Food security and nutrition	Food security	The household's consume Five and below food types prior to 24 hours	$\frac{1}{12}$
	Health access	No one in the household is a user of the local insurance system for health care.	$\frac{1}{12}$
	Child mortality	One or more child died in the past five years	$\frac{1}{12}$
Education	Year of schooling	Fourteen years or older family members not complete grade 8	$\frac{1}{8}$
	School attendance	At least one household member of schooling age does not attend school.	$\frac{1}{8}$
Living standard	Cooking fuel	If the household uses dung, charcoal and firewood as cooking fuel	$\frac{1}{24}$
	Improved sanitation	a household's does not have improved sanitation facility	$\frac{1}{24}$
	Drinking water	The household does not have access to safe drinking water, or safe drinking water is at least a 30-minute walk (round trip) from home	$\frac{1}{24}$
	Electricity	The household has no electricity/solar energy	$\frac{1}{24}$
	Housing	The household has inadequate housing: either the floor, roof or walls are made of rudimentary or natural, inadequate materials	$\frac{1}{24}$
	Assets	The household does not own more than one of radio, television, cellphone, bike, motorbike or refrigerator and does not own a car or truck	$\frac{1}{24}$
Rural livelihood and resources	Land ownership	The land size is lower than the mean value in the area	$\frac{1}{24}$
	Livestock ownership	The value of TLU is lower than the mean value in the area	$\frac{1}{24}$
	Extension service	The frequency of visits by development agents per year is lower than the mean visit in the area	$\frac{1}{24}$
	Social protection	No member of the household has enrolled in any pension, insurance, or other social programme (in our case, it was captured by Idir participation).	$\frac{1}{24}$
	Child labour	At least one family member aged less than 14 years old participates in agricultural activity	$\frac{1}{24}$
	Non-farm income	No family members participate in any non-farm activities	$\frac{1}{24}$

Source: FAO & OPHI, 2022

3.5. Description of the Main Variable

Data for the study were collected through a household survey conducted in the Arsi Zone, Oromia, Ethiopia. The study estimates the proportion of households experiencing deprivation in each poverty dimension, the headcount ratio, and the adjusted incidence of multidimensional poverty. To investigate the impact of machinery adoption on farm fields to reduce poverty rural multidimensional poverty, the study employs Multinomial Endogenous Switching Regression (ESR) and Multinomial Endogenous Treatment Effects (METE) models to control for endogeneity resulting from both observed and unobserved variables. For robustness, Propensity Score Matching (PSM) and Instrumental Variables (IV) are used, particularly for the continuous version of R-MPI.

The dependent variable in this study is the rural multidimensional poverty index (R-MPI), measured using the methodology developed by Alkire and Foster (2007). We employ the continuous version of the R-MPI following the approach by Habtewold (2020), Ogutu and Qaim (2019), and Yang et al. (2021) for nuanced analysis. Additionally, we utilize the binary version, applying a cutoff of 0.33 for robust estimation.

Central to our investigation are mechanization variables, specifically the adoption of tractors and combine harvesters, both individually and in combination. This categorization presents four distinct choices: (1) non-adoption, (2) adoption of tractors alone, (3) adoption of combine harvesters alone, and (4) adoption of both tractors and combine harvesters.

Apart from mechanization, this research incorporates several control variables based on existing literature (Ambaye et al., 2021; Djahini-Afawoubo et al., 2023; Eshetu et al., 2022; Haile et al., 2021; Mare et al., 2022; Motuna et al., 2020; Thapa et al., 2018). These studies consider various factors that contribute to multidimensional poverty, such as age, household size, sex of the household head, land size plotted, tropical livestock units (TLU), distance from the main road, crop diversification index (CDI), off-farm participation, extension contacts, credit access, and mobile ownership. All of these factors play significant roles in affecting poverty in different literature. For instance, education level and land size plotted are identified as reducing factors in multidimensional poverty in Jimma Geneti Woreda (Ambaye et al., 2021); similarly, tropical livestock units and schooling have reducing effects in the southern part of Ethiopia (Eshetu et al., 2022). Conversely, household size and age are found to aggravate multidimensional poverty in rural Ethiopia, although the square of household size has a reducing effect (Habtewold, 2020). Distance to the main road is also shown to increase multidimensional poverty (Mare et al., 2022; Motuna et al., 2020). Access to mobile technology plays a crucial role in reducing rural multidimensional poverty in China (Yang et al., 2021). The study also controls for the resilience mechanisms of crop failure, such as crop diversification, which has been found to be important in reducing poverty in Nepal (Thapa et al., 2018).

3.6. Method of Analysis

3.6.1. Multinomial Endogenous Switching Regression

In this study, we are investigating the impact of mechanization on rural multidimensional poverty. Since our data is non-randomized and households are not randomly assigned to specific treatments, they could self-select themselves into any treatment category based on their observed and unobserved characteristics, leading to selection bias. Using ordinary least squares (OLS) regression methods would result in inconsistent and biased results due to this self-selection bias. To mitigate this issue, we employ the Multinomial Endogenous Switching Regression (MESR) model, as proposed by (Bourguignon et al., 2007). The MESR model consists of three key equations: the selection equation, the outcome equation, and the treatment effect equation. These equations are estimated simultaneously to tackle issues related to self-selection and endogeneity. By doing so, MESR allows us to analyze how mechanization impacts poverty reduction among households that adopt mechanization (adopters) compared to those that do not (non-adopters). This approach has been extensively used in recent empirical studies, demonstrating its effectiveness in addressing similar analytical challenges (Amankwah & Gwatidzo, 2024; Sisay, 2023).

Households make decisions about adopting agricultural machinery such as tractors, combines, or both within the framework of random utility theory. This theory posits that households assess the utility they derive from using these technologies based on their specific needs and circumstances. In this study, it is assumed that the errors in this assessment process follow a Gumbel distribution independently and with identical characteristics (Bourguignon et al., 2007).

To model the likelihood that a farmer with particular characteristics (represented as farmer i) will choose a specific machinery package (represented as package j), the study employs a multinomial logit model. This statistical approach allows researchers to analyze how different factors influence the probability of adopting specific agricultural machinery configurations, considering variables such as farm size, cropping patterns, and socioeconomic conditions. This MNL is specified as follows:

$$\boldsymbol{P_{ij}} = \boldsymbol{\eta_{ij}} < 0 | \boldsymbol{X_i} = \frac{\boldsymbol{expX_i\beta_j}}{\sum_{n=1}^{J} \boldsymbol{expX_i\beta_n}} \qquad \textbf{(6)}$$

Were P_{ij} represents the probability that a farmer i chooses to adopt agricultural machineries. X_i is vector of exogenous variable, and β_j is a vector of parameters to be estimated, respectively.

In the second stage of the MESR framework, the study employs an Ordinary Least Squares regression with selectivity correction to analyze the relationship between the outcome variable and a set of explanatory variables $\boldsymbol{Z_i}$, estimated for each agricultural machinery regime)1=non-adoption,2= tractor only, 3=combine only and 4=joint adoption). The outcome equation for each potential regime j is given as:

$$\begin{cases} \boldsymbol{regime1\ Yi1 = Z_i\beta_1 + u_{i1}\ if\ T = 1} \\ \vdots \\ \boldsymbol{regimeJ\ YiJ = Z_i\beta_j + u_{ij} if\ T = j = 2, 3, 4} \end{cases} \qquad \textbf{(7)}$$

Where T is an index that denotes farmer i's choice of adopting a type of Agricultural machineries technology; Yi is the outcome variables for the i-th farmer; Zi is a vector of exogenous variables; β_1 and β_j are parameters to be estimated; $ui1$ and uiJ are the error terms. Equation (7) addresses selection bias using observed covariates (Zi). However, unobserved factors that affect both the adoption of agricultural machinery and the outcome variables lead to unobserved selection bias, as the error terms of Equations (7) would be correlated. This bias results in inaccurate and biased estimates. Thus, we use the MESR (Multinomial Endogenous Switching Regression) framework to determine the selectivity correction terms from the estimation of Equation (6) and those terms are included in Equations (7) to solve the unobserved selection bias. Following Amankwah and Gwatidzo (2024),and Setsoafia et al. (2022) the second stage of the MESR is estimated as follows, including the correction.

$$\begin{cases} \boldsymbol{regime1\ Yi1 = Z_i\beta_1 + \delta_1\lambda_1 + \varepsilon_{i1}\ if\ I = 1} \\ \quad\quad\quad\quad\quad\quad\quad\quad . \\ \quad\quad\quad\quad\quad\quad\quad\quad . \\ \boldsymbol{regimeJ\ YiJ = Z_i\beta_j + \delta_j\lambda_j + \varepsilon_{ij} if\ I = j} \end{cases} \quad (8)$$

where δ_1 and δ_j are covariance between error terms in Equations (8), $\lambda 1$ and λJ are selectivity correction terms used to address unobserved selection bias issues, which is the estimated IMR computed using the predicted probabilities from the multinomial logit model in Equation (6). The IMR is provided as:

$$\boldsymbol{\lambda_j} = \sum_{k \neq J}^{J} \Upsilon_j \left(\frac{\boldsymbol{P_{ik}} \ln(\boldsymbol{P_{ik}})}{\boldsymbol{1 - P_{ik}}} + \ln(\boldsymbol{P_{ij}}) \right) \quad (9)$$

Where Ƴ is the correlation between eij and εij, In the multinomial choice setting, there are J − 1 selectivity-correction term for each alternative agricultural machinery option being considered. The standard errors in Eq. (8) are bootstrapped to account for the heteroskedasticity arising from the generated regressor (λj) in the second stage.

Following Di Falco et al. (2011), and Shiferaw et al. (2014) we incorporated selection instruments to address for unobserved heterogeneity in estimating the poverty reduction effects of the agricultural machineries and conducted a falsification test to ensure the integrity of the model (see Table 1A: Falsification **tests** in the appendix). The instrument variable used is membership in an agricultural co-operative and distance to the co-operative, which have been used as selection instruments in previous studies in the impact literature, such as Ahmed et al. (2017) Aung et al. (2023). The selected instrument should generally fulfill two criteria: It should be correlated with the endogenous variable(s) but not correlated with the outcome variable(s). The joint test results of these variables in the MNLR indicate that they are jointly significant and thus decisive for households' decisions to adopt the technologies. These tests generally show that these variables have no effect on rural poverty at the household level in the study area. Therefore, we do not expect these variables to directly affect multidimensional rural poverty except through their influence on technology adoption decisions.

We estimate the expected actual and counterfactual R-MPI and compare them pairwise. Specifically, we first derive the expected outcomes of the treated households, which in our study means *j*=2, 3 and 4 (*j*=1 is the reference, i.e. non-adoption). From equation (7), the conditional expectations for each outcome variable based on practice can be derived as follows:

For adopters with actual adoption, the expected value of the outcome variable is

$$\mathbf{E}\ (\mathbf{YiJ}|\mathbf{T}=\mathbf{J})=\mathbf{Z_i}\boldsymbol{\beta}_\mathbf{j}+\boldsymbol{\delta}_\mathbf{j}\boldsymbol{\lambda}_\mathbf{1} \text{ if T=J} \quad \textbf{(10)}$$

and for adopters had they not adopted (counterfactual)

$$\boldsymbol{E}\ (\boldsymbol{Yi1}|\boldsymbol{T}=\boldsymbol{J})=\boldsymbol{Z_i\beta_1}+\boldsymbol{\delta_1\lambda_j} \text{ if T=J} \quad \textbf{(11)}$$

The impact of adopting agricultural machineries j is denoted as the average treatment effect on the treated (ATT), which is calculated by subtracting equation 120 from 131.

$$\text{ATT}=\boldsymbol{E}\ (\boldsymbol{YiJ}|\boldsymbol{T}=\boldsymbol{J})-\boldsymbol{E}\ (\boldsymbol{Yi1}|\boldsymbol{T}=\boldsymbol{J})=\boldsymbol{Z_i}(\boldsymbol{\beta_j}-\boldsymbol{\beta_1})+\boldsymbol{\lambda_j}(\boldsymbol{\delta_j}-\boldsymbol{\delta_1}) \quad \textbf{(12)}$$

4. Result and Discussion

In this section, we present the extent, depth, and severity of rural multidimensional poverty, computed using the Alkire–Foster method. Unlike the Global Multidimensional Poverty Index (G-MPI), which focuses on three deprivation dimensions, the R-MPI adds rural livelihood as an extra dimension alongside education, health, and living standards. Furthermore, this section presents descriptive statistics, independent samples t-tests, and the extent of R-MPI. Lastly, we analyze the impact of mechanization or machinery adoption on R-MPI using the MESR and METE using Stata 18 software.

4.1. Descriptive Statistics

Table 2 presents the definitions and summary statistics of variables for the sampled households in the study area. The data indicates a moderate adoption rate of tractors, with approximately 51.8% of households using them for plowing. However, only 10% of households use tractors alone. Additionally, about 59.1% of households use combines for harvesting, but only 18% use combine harvesters alone. Notably, around 40.9% of households use both tractors and combines in their farming practices.

Table 2 shows that the Arsi zone has an average multidimensional poverty rate of 78.7% based on a cut-off value of 0.33, which is lower than the national average of 83.5% reported in 2016, but higher than the rates observed in some other areas of Ethiopia. In a study by Eshetu et al. (2022) from southern Ethiopia, a lower incidence of multidimensional poverty of 72.3% was found, and Gebrekidan et al. (2021) show an even lower rate of 60% for northern Ethiopia. In the Amhara region, however, according to Mulusew et al. (2023) 81.5 % of rural households were classified as multidimensionally poor, which is higher than in the study areas. Similarly, the results

Ambaye et al. (2021) show that 80.1 of households in western Ethiopia are multidimensionally poor.

Table 2: Definition and summary statistics of the variables used in the econometric estimation

Variable|		Mean	Std. dev.
R_MPI	Rural multidimensional poverty continuous	.4158594	.1203953
R-MPI_binary	1 If the household RMPI index greater than 0.33,0 otherwise	.7869249	.4099769
Tractor adoption	1 if the household use tractor for ploughing, 0 otherwise	.5181598	.5002761
Combines adoption	1 if the household use combiner for harvester, 0 otherwise	.590799	.4922828
Joint adoption	1 if the household use both tractor and harvester, 0 otherwise	.409201	.4922828
Tractor only	1 if the household use tractor for ploughing only, 0 otherwise	.1089588	.3119655
Combine only	1 if the household use combiner for harvester only, 0 otherwise	.1815981	.3859805
Age	Household head age in year	46.48668	9.785959
Household size	family in the household in number	5.532688	2.274174
HHS square	Square of the family in household in number	35.76998	33.74761
Sex	Gender of the household 1 if male, and 0 if female	.8474576	.3599819
Years of Education	Household head year in formal education	5.445521	3.55403
Distance from MR	Distance from main roads/all-weather road in kms	1.636017	2.040322
Crop diversification	Simpson index of crop diversification continuous	.4242456	.2562928
TLU	Tropical livestock unit (continuous)	3.96937	2.84633
Off farm part.	1 if any Household members participate in off-farm, 0 otherwise	.6101695	.4883032
Land size cultivated	Land cultivated in hectare in survey time	2.277966	1.164515
Access to mobile	1 if the house hold owned mobile, 0 otherwise	.7288136	.4451113
Credit access	1 if household get access of credit, 0 otherwise	.5496368	.4981335
Extension contact	Frequency of extension experts visit per year	24.89346	25.93772
Farm cooperative	If the house hold is member of cooperative, 0 otherwise	.7263923	.4463507
Distance from cooperative.	the household house Distance from the cooperative office	2.20908	1.393243

The average age of household heads is approximately 46.5 years, with an average household size of about 5.53 members. The average squared family size is around 35.77. Male-headed households constitute the majority at 84.7%, while female-headed households make up the remaining 15.3%.

A significant portion of households, approximately 61.3%, have one or more members of households participating in off-farm activities. On average, households are located about 2.2 kilometers from agricultural cooperatives and 1.6 kilometers from the main road. In the study area the average land size farmed by households is approximately 2.27 hectares.

In terms of technology and communication, around 72.9% of households own a mobile phone, whereas access to credit is lower, at about 23.2%. The frequency of visits from extension experts averages around 24.89 times per year.

Table 3 compares mean household characteristics between adopters and non-adopters of combine harvesters, tractors, and both types of machinery, highlighting significant differences that contribute to their self-selection into an adoption category and the resulting poverty reductions. Tractor-only adopters are more likely to participate in off-farm activities, have larger cultivated land sizes, have more access to mobile phones, have higher credit access, have more extension contacts, more of farm cooperatives, and are near to farm cooperatives. Combine-only adopters tend to be older, have shorter distances to main roads, less crop diversification, fewer livestock units, more access to mobile phones, lower extension contact, higher participation in farm cooperatives, and shorter distances to cooperatives. Joint adopters (both tractor and combine) are characterized by older age, larger household sizes, shorter distances to main roads, less crop diversification, more access to mobile phones, higher credit access, more extension contacts, greater participation in farm cooperatives, and shorter distances to cooperatives. The analysis controls for these observed factors and other unobserved heterogeneity to determine the actual welfare effects of the technologies.

Table 3: Mean differences in characteristics between non-adopter and adopter of machinery

	Non-adoption	Tractor only	Combine only	Joint adoption
R_MPI	.4415323	-0.047**	0.027	-0.062***
R-MPI binary	.8145161	-0.103	0.119**	-0.093*
Age	44.22581	-0.159	3.068**	4.206***
Household size	5.266129	0.178	-0.106	0.651**
HHS square	34.00806	-0.875	-4.715	6.631
Sex	.8629032	0.026	0.044	-0.064
Years of Education	5.217742	0.960	-0.711	0.617
Distance from MR	1.879435	0.725	-0.803***	-0.432*
Crop diversification	.5239786	0.021	-0.183***	-0.165***
TLU	4.235968	-0.201	-1.187***	-0.151
Off farm part.	.5967742	0.181**	0.003	-0.017
Land size cultivated	1.774194	0.787***	0.206	0.930***
Access to mobile	.5725806	0.227***	0.281***	0.197***
Credit_access	.1693548	0.031	-0.063	0.174***
Extension contact	19.29032	6.021*	-4.957*	14.290***
Farm cooperative	.1854839	0.792***	0.788***	0.761***
Distance to cooperative	2.762097	-0.823***	-0.499**	-0.911***
Nom. Observation	124	45	75	169

Notes: The test is used to compare the means of variables between adopters of each technology and non-adopters (those who did not adopt any technology). ***, ** and * represent significance levels at 1%, 5%, and 10% respectively.

4.2. Results of Rural Multidimensional Poverty (R-MPI) Measurement

The method of Alkire and Foster (2007) Alkire and Foster (2007) was used to measure the incidence, depth and adjusted headcount of rural multidimensional poverty in Arsi Zone. The analysis was conducted using Stata 18 software and the results are presented in Table 4.

Accordingly, dimension 1, which contributes 20.7% for the overall R-MPI, includes indicators such as food and nutrition insecurity, access to health care and infant mortality were considered.

Table 4: Mean deprivation and Contribution of Indicators to Multidimensional Poverty

Indicator	Type	Weight	Deprived	M0	
Domain 1: Food security and nutrition					*0.207*
The household's consume four and below food types prior to 24 hours	Binary	.08	50.121%	0.105	
No one in the household is a user of the local insurance system for health care.	Binary	.08	36.562%	0.072	
One or more child died in the past five years	Binary	.08	14.770%	0.030	
Domain 2: Education					*0.287*
Fourteen years or older family members not complete grade 8	Binary	.13	73.366%	0.235	
At least one household member of schooling age does not attend school.	Binary	.13	15.254%	0.053	
Domain 3: Living standard					*0.272*
If the household uses dung, charcoal and firewood as cooking fuel	Binary	.04	98.78 %	0.091	
a household's does not have improved sanitation facility	Binary	.04	23.48 %	0.025	
The household does not have access to safe drinking water, or safe drinking water is at least a 30-minute walk (round trip) from home	Binary	.04	41.40 %	0.042	
The household has no electricity/solar energy	Binary	.04	5.327 %	0.005	
The household has inadequate housing: either the floor, roof or walls are made of rudimentary or natural, inadequate materials	Binary	.04	97.33 %	0.089	
The household does not own more than one of radio, television, cellphone, bike, motorbike or refrigerator and does not own a car or truck	Binary	.04	19.855%	0.021	
Domain 4 :Rural livelihood and resources					*0.233*
The land size is lower than the mean value in the area	Binary	.04	41.40 %	0.040	
The value of TLU is lower than the mean value in the area	Binary	.04	58.11 %	0.057	
The frequency of visits by development agents per year is lower than the mean visit in the area	Binary	.04	69.01 %	0.064	
No member of the household has enrolled in any pension, insurance, or other social programme (in our case, it was captured by Idir participation).	Binary	.04	9.201 %	0.009	
At least one family member aged less than 14 years old participates in agricultural activity	Binary	.04	26.392%	0.027	
No family members participate in any non-farm activities	Binary	.04	38.983%	0.036	

Table 4 shows that 50.121% of the population is deprived in the food and nutrition insecurity category, which accounts for 10.5% of the total poverty measure. In dimension 2, with a contribution of 28.7.% for overall R-MPI, 73.366% of the population are deprived in terms of years of schooling, which makes a significant contribution of 23% to the overall R-MPI. Similarly, dimension 3, which contributes 27.2% of overall R-MPI, includes indicators of living conditions, including cooking fuel, sanitation, access to water, energy sources, housing and asset ownership. Sampled households are mainly deprived in cooking fuels, 98.789 % of households are deprived. Besides, livelihood dimensions, which carriers 23.3% of overall R-MPI contribution and extension contacts indicate that 69.007% of the population is deprived in terms of extension contacts, making a contribution of 6.4% to the overall poverty measure.

The results from Table 5 provide insights into the multidimensional poverty indices (MPI) across different districts and gender groups. Among the districts, the poverty headcount ratio (H) is most pronounced in Sire, with 84.1% of its population experiencing headcount poverty, while the Loode Hetosa district has the lowest poverty headcount ratio at 73%. Similarly, considering the adjusted R-MPI (M0), the Sire district stands out with the highest value at 39.6%. On the other hand, the Hetosa district exhibits a lower adjusted R-MPI (M0) at 31%. In terms of intensity, Loode Hetosa has the highest value at 49.2%, while Hetosa is the lowest with 42.8%.

The overall multidimensional poverty of the sampled households is 78.7%, mainly contributed by Sire districts, while the poverty intensity is 46%, mainly contributed by Loode Hitosa. The adjusted R-MPI for the sampled households is 36.2%, with Sire Woredas contributing more. This is lower than the national values for head count, intensity and R-MPI(Mo) of 80.2 %, 53.2 % and 42.6 % respectively (FAO & OPHI, 2022).

Gender disparities in poverty are also evident from Table 5 below. Female-headed households show a higher poverty headcount ratio (85.7%) compared to male-headed households (77.4%). Additionally, the adjusted MPI incidence for females is higher at 39.8% compared to 35.6% for males, indicating a higher intensity of poverty among females experiencing multidimensional poverty. These findings underscore the need for targeted interventions addressing poverty across different districts and taking into account the specific challenges faced by gender groups. Addressing both the prevalence and intensity of poverty is crucial for effective poverty reduction strategies.

Table 5: R-MPI dimension and indicators (by woredas and sex)

		(H)	(A)	(M0)	Dimension 1	Dimension 2	Dimension 3	Dimension.4
Districts	Sire	0.841	0.471	0.397	0.234	0.256	0.258	0.252
	Dera	0.809	0.443	0.358	0.235	0.270	0.281	0.214
	Hetosa	0.724	0.428	0.310	0.187	0.265	0.267	0.281
	Loode Hetosa	0.730	0.492	0.359	0.141	0.379	0.291	0.189
Sex	Male	0.774	0.469	0.356	0.209	0.283	0.274	0.234
	Female	0.857	0.464	0.398	0.199	0.309	0.264	0.228
	Total	0.787	0.460	0.362				

The data from Table 6 indicates that non-adopters of tractors have a poverty headcount ratio of 81.5%, whereas adopters have a lower ratio of 71.1%. However, this trend is not seen among combine adopters, with non-adopters having a lower poverty headcount ratio of 81.5% compared to adopters at 93.3%. Adopting both types of machinery shows improved poverty levels, with both adopter groups having a poverty headcount ratio of 72.2% and adjusted multidimensional poverty scores of 30.9% for adopters compared to 39.3% for non-adopters.

Table 6: R-MPI dimension and indicators (by adoptions status)

Multidimensional poverty index	**Tractor**		**Combiner**		**Combined**	
	Non-adopter	**Adopter**	**Non-adopter**	**Adopter**	**Non-Adopter**	**adopter**
Multidimensional poverty headcount ratio (H)	0.815	0.711	0.815	0.933	0.815	0.722
Adjusted multidimensional poverty incidence (M0)	0.393	0.326	0.393	0.454	0.393	0.309
Population share	0.734	0.266	0.623	0.377	0.423	0.577
Contribution of each dimension in percent						
Dimension 1	0.183	0.216	0.183	0.235	0.183	0.209
Dimension 2	0.293	0.273	0.293	0.294	0.293	0.283
Dimension 3	0.297	0.281	0.297	0.236	0.297	0.271
Dimension 4	0.228	0.230	0.228	0.235	0.228	0.238

4.3. Determinants of Adoption of Agricultural Machineries

The Multinomial Logit (MNL) model results presented in Table 7 demonstrate a good fit with the data, supported by the Wald test (Wald chi2(51) = 226.65), $p>\chi 2=0.000$. The instruments utilized in identifying the Multivariate Endogenous Switching Regression (MESR), namely: membership in a farm cooperative and distance from the cooperative, showed significant joint significance. Furthermore, a falsification test indicated that these instruments influenced adoption across all levels but did not impact the R-MPI of non-adopters.

The findings highlight various factors influencing machinery adoption levels, including household head characteristics, household size, proximity to main road, land size, and other attributes. Notably, being female has a positive influence on the joint adoption of machinery; This finding aligns with previous research, indicating that women, facing challenges with traditional farming methods, are more likely to adopt agricultural machinery (Kirui, 2019; Saliou et al., 2020).

Household size contributes positively to combine adoption but demonstrates a negative impact when squared. Age exhibits a negative association with tractor adoption, suggesting a higher likelihood of tractor adoption among younger household heads. Distance to the main road negatively affects combine adoption but positively influences tractor adoption. Crop diversification has a negative impact on the adoption of combines and joint machinery. This can be attributed to various factors, including the machinery's crop-specific nature, operational challenges associated with diverse crops, and economic considerations. This aligns with the research conducted by Berhane et al. (2017).

Tropical Livestock Units (TLU) negatively affects the adoption of combines and joint machinery, as TLU serves as a direct substitute for agricultural machinery. This is likely because households with significant livestock resources rely on animal labor instead of mechanization. Conversely, the size of cultivated land positively influences the adoption of combines, tractors alone, and in combination. As the total land area cultivated increases, the probability of adopting agricultural machinery also increases. This is possibly due to the economies of scale and the need for more efficient farming methods on larger plots, making machinery a more attractive and practical investment. This result is consistent with previous studies in Ethiopia (Gebiso et al., 2023).

Access to mobile phones and credit significantly enhances the likelihood of adopting agricultural machineries. Mobile phones play a vital role by improving access to timely market information, enabling better coordination for machinery rental or sharing, and fostering communication among farmers an insight supported by Daum et al. (2021). Similarly, access to credit provides farmers with the financial capacity needed to afford the costs associated with hiring or purchasing mechanized services, aligning with the findings of Mohammed et al. (2023), who emphasize the importance of credit in overcoming financial constraints in mechanization in Ghana. Moreover, contact with extension services positively influences tractor adoption, both alone and in combination with combines, possibly because extension services offer valuable information and training on the benefits and use of agricultural machinery, enhancing the farmers' ability to effectively utilize and maintain these technologies, the result is consistent with previous technology adoption literature (Bilal & Jaghdani, 2024; Mumah et al., 2024).

Table 7: Parameter estimates of adoption of Agricultural machinery: Multinomial logit selection model

Variable	Tractor Only	Combine Only	Joint Adopter
Age	-0.065 *(0.037)	-0.029 (0.030)	-0.042 (0.029)
Household size (HHS)	0.139 (0.453)	0.976 *(0.511)	0.039 (0.273)
HHS squared	-0.026 (0.036)	-0.097 **(0.048)	-0.001 (0.013)
Sex (1=Male)	-0.856 (0.833)	0.105 (0.690)	-1.276 **(0.607)
Years of Education	0.020 (0.091)	-0.138 (0.084)	0.010 (0.085)
Distance to main road	0.306 ***(0.113)	-0.346 ***(0.123)	0.005 (0.094)
Crop diversification	0.613 (1.140)	-3.223 ***(0.891)	-3.751 ***(0.828)
Tropical Livestock Unit	-0.112 (0.115)	-0.207 **(0.088)	-0.096 (0.095)
Livelihood diversification	1.555 **(0.603)	0.111 (0.482)	0.688 (0.468)
Total crop area	1.253 ***(0.312)	0.453 *(0.248)	1.326 ***(0.225)
Access to mobile phone	0.043 (0.657)	0.897 (0.577)	-0.062 (0.524)
Credit access	0.505 (0.695)	-0.391 (0.739)	1.149 **(0.555)
Extension service contact	0.040 ***(0.013)	0.004 (0.014)	0.055 ***(0.011)
Member of cooperative	6.075 ***(1.313)	5.184 ***(1.007)	5.033 ***(0.682)
Distance to cooperative	-0.635 ***(0.190)	-0.448 **(0.187)	-0.661 ***(0.167)
Constant (_cons)	-5.073 **(2.368)	-2.025 (2.041)	-1.235 (1.922)
Joint significant of instrument	23.25***	40.12***	90.61***
Number of obs = 413	Wald chi2(51) = 212.39		Prob > chi2 = 0.0000
	Log LR= -273.94639		Pseudo R2 = 0.4811

Notes: ***, ** and * represent significance levels at 1%, 5%, and 10% respectively

The study indicates a substantial and positive correlation between belonging to cooperatives and the inclination to adopt tractors, combines, and both. This outcome underscores the pivotal role of farmers' association membership as a key source of information concerning inputs and innovations. Membership in cooperatives likely facilitates access to shared resources, collective bargaining power, and pooled knowledge, making it easier for farmers to adopt new technologies. This finding is consistent with previous technology adoption literature, which also highlights the importance of cooperative membership in enhancing technology uptake (Manda et al., 2020; Zhang et al., 2020; Zhou et al., 2024)

Conversely, the coefficient for proximity to cooperatives denotes a negative effect on machinery adoption, implying that greater distances are linked to reduced rates of agricultural machinery adoption. This negative effect could be due to several reasons. Farmers located farther from cooperatives may find it less convenient to access the services, information, and support provided by these organizations, thus reducing their likelihood of adopting new machinery. Additionally, the farther a farmer is from a cooperative, the higher the transportation and opportunity costs associated with accessing cooperative services, which may deter machinery adoption. Distance can also lead to delays or gaps in communication, resulting in farmers being less informed about the benefits and availability of agricultural machinery. Furthermore, proximity to cooperatives often means better access to support services, such as machinery maintenance and repair, which are crucial for sustained adoption. Farmers further away might face difficulties in getting timely support, leading to reluctance in adopting new machinery. This pattern is also consistent with previous research, which found that greater distances from cooperatives hinder technology adoption due to increased costs and reduced access to essential services (Khonje et al., 2018; Wu et al., 2023).

4.4. Determinant of Rural Multidimensional Poverty

We investigate the factors influencing R_MPI based on the selection of agricultural machinery. To address selectivity effects arising from unobserved factors, we introduce selectivity correction terms denoted as m0, m1, m2, and m3. These terms are estimated using bootstrapping with 100 replications to handle heteroscedasticity, following the approach recommended by Bourguignon et al. (2007). The result in Table 8 reveals the significance of selectivity correction terms in the R_MPI equations related to combined only and joint adoption options. This suggests the presence of sample selectivity effects, emphasizing that using OLS would have resulted in biased and inconsistent estimates. Therefore, accounting for selectivity effects is crucial for obtaining reliable and consistent estimates in the Multinomial Endogenous Switching Regression (MESR) model.

Table 8: Impact of agricultural machinery adoption on R-MPI: Second stage MESR estimation

Variable	Non-adopter	Tractor adopter	Combine adopter	Joint adopter
Age	-0.0001 (0.0017)	0.0040 (0.0061)	-0.0034 (0.0023)	-0.0010 (0.0011)
Household size	0.0000 (0.0230)	0.076 (0.102)	-0.009 (0.103)	-0.005 (0.014)
HH size²	0.0005 (0.0021)	-0.0069 (0.0101)	0.0020 (0.0102)	0.0003 (0.0010)
Sex	-0.030 (0.051)	-0.060 (0.195)	-0.061 (0.135)	-0.019 (0.0278)
Education	-0.010** 0.0048)	-0.020 (0.0170)	-0.004 (0.0108)	-0.007** (0.0031)
Distance to MR	-0.004 (0.0049)	-0.044 (0.0334)	0.020 (0.0296)	0.023*** (0.0090)
CDI	-0.080 (0.0677)	-0.706 (0.688)	-0.073 (0.186)	0.011 (0.0668)
TLU	-0.013** (0.0056)	-0.012 (0.024)	-0.023* (0.0131)	-0.006** (0.0031)
Off-farm participation	-0.070** (0.0281)	-0.124 (0.120)	0.009 (0.0605)	-0.010 (0.0235)
Land size cultivated	-0.025 (0.0167)	-0.003 (0.0682)	0.043 (0.0470)	-0.014 (0.0097)
Access to mobile	-0.024 (0.0232)	0.064 (0.159)	-0.128** (0.0651	-0.016 (0.0190)
Credit access	0.014 (0.0271)	0.003 (0.161)	0.063 (0.0946)	-0.011 (0.0212)
Extension contacts	-0.001 (0.0007)	0.002 (0.0043)	0.004 (0.0029)	-0.0003 (0.0004)
_m0		-0.442 (0.356)	-0.211** (0.100)	-0.059 (0.0455)
_m1	0.054 (0.194)		0.181 (0.217)	0.158* (0.094)
_m2	0.004 (0.119)	0.260 (0.338)		-0.063 (0.0635)
_m3	-0.065 (0.110)	0.303 (0.455)	0.095 (0.197)	
_cons	0.721*** (0.101)	1.019 (1.303)	0.803*** (0.314)	0.589*** (0.078)
Sigma²	0.012 (0.019)	0.202 (0.429)	0.053 (0.088)	0.024** (0.012)
rho0		-1.263* (0.639)	1.170*** (0.364)	-0.495 (0.475)
rho1	0.625 (1.404)		1.008 (0.812)	1.315 (0.810)
rho2	0.044 (0.927)	0.742 (0.673)		-0.521 (0.592)
rho3	-0.756 (0.830)	0.866 (0.918)	0.528 (0.722)	

Notes: ***, ** and * represent significance levels at 1%, 5%, and 10% respectively

Table 8 also shows that factors such as education, TLU (Tropical Livestock Units), non-agricultural employment, and access to mobile phones play an important role in poverty reduction, consistent with previous studies (Agza et al., 2023; Eshetu et al., 2022; Mare et al., 2022; Mulusew et al., 2023). More years of education generally lead to better employment opportunities and higher incomes, lifting individuals and families out of poverty. Livestock ownership provides additional sources of income and food security, especially for rural households. Participation in off-farm activities diversifies income streams and reduces dependence on agriculture, which can be vulnerable to environmental and market fluctuations. Access to mobile phones improves communication, access to information, and financial services, opening up new economic opportunities. Conversely, living far from main roads can exacerbate poverty. Greater distances from transportation networks limit access to markets, healthcare, education, and employment opportunities. This isolation can hinder economic activities and access to essential services, perpetuating poverty.

4.5. Impact of the Adoption of Agricultural Machineries on R-MPI

The results of the unconditional treatment effect analysis indicate that the adoption of agricultural mechanization technologies is associated with a reduction in rural multidimensional poverty. Specifically, households that adopted tractors, combine harvesters, and both technologies experienced reductions in their R_MPI by approximately 9.7%, 7.75%, and 18.39%, respectively. While these findings suggest a promising link between mechanization and poverty alleviation, they must be interpreted with caution. The estimates are unconditional, meaning they do not adjust for potential self-selection bias. In practice, households that adopt such technologies may differ systematically from non-adopters in both observable characteristics, such as education level, landholding size, and access to credit, and unobservable traits like entrepreneurial ability or motivation. These differences can independently influence poverty outcomes, irrespective of mechanization. Consequently, attributing the entire reduction in poverty to the adoption of agricultural technologies may lead to overestimation of their true impact. Without accounting for these underlying differences, policy recommendations based on unconditional results risk being misleading or ineffective. A more robust estimation strategy is therefore required to isolate the causal effect of mechanization from confounding factors (Amankwah & Gwatidzo, 2024)

In contrast, the conditional treatment effect analysis, which controls for both observed and unobserved self-selection biases, provides a more reliable picture of the true impact of agricultural mechanization on poverty reduction. Focusing on the

Arsi Zone in Ethiopia, the analysis reveals that the adoption of agricultural machinery, particularly combine harvesters, either alone or together with tractors, has a strong and statistically significant effect on reducing multidimensional poverty among rural households. Specifically, adopting combine harvesters alone is associated with a 6.75% reduction in the Rural Multidimensional Poverty Index (R-MPI) compared to non-adopters. Tractor adoption alone leads to a 4.6% decrease in R-MPI, and this effect is also statistically significant. The most notable impact arises from the joint adoption of tractors and combine harvesters, which leads to a 20.51% reduction in R-MPI, the most substantial and significant effect observed among the adoption groups.

Table 9: Average treatment effects of the adoption of individual and combined Agricultural machinery on R-MPI

	Technology	Adopter	Non-Adopter	Treatment Effect	T-stat.	Change (%)
Unconditional	Tractor user only	.4153854	.4648321	-.0494468***	-4.6682	9.41%
	Combine harvester user only	.4342754	.4648321	-.0305568***	-4.8305	6.5%
	Joint user	.3771415	.4648321	-.0876906***	-28.613	18.8%
	Tractor user only	.3944445	413469	-.0190245*	-1.3233	4.6%
Conditional[1]	Combine harvester user only	.4688889	.5028008	-.0339119 ***	-4.6343	6.75%
	Joint user	.3791913	.4787545	-.0995631 ***	24.8573	20.7%

Notes: ***, ** and * represent significance levels at 1%, 5%, and 10% respectively

[1] In addition to classification based solely on adoption status, this study also categorizes households by their level of adoption. A farm household can adopt mechanization at different levels: low, medium, or high—based on the Mechanization Index (MI), which is calculated using the household's per-hectare expenditure on farm mechanization. This approach is consistent with previous studies (Gebiso et al., 2024; Singh, 2006). In this study, sampled households were classified into three groups according to their level of mechanization: low (MI < 20%), medium (20% ≤ MI < 45%), and high (MI ≥ 45%). Furthermore, the treatment effects estimated using counterfactual analysis reveal that the Rural Multidimensional Poverty Index (RMPI) decreases for both medium- and high-level adopters compared to low-level adopters, indicating that mechanization has a poverty-reducing effect (see Appendix, Table 3A)

These results are in line with findings from other developing regions. For instance Peng et al. (2023), studying rural areas in China found that a 1% increase in the level of agricultural mechanisation led to a 3.3% rise in farmer income and a 0.523% decline in poverty levels. Likewise, Abass et al. (2017) reported that in northeastern Zambia, the mechanisation of cassava processing contributed meaningfully to poverty reduction. Villages equipped with mechanized post-harvest processing facilities had a lower incidence of poverty (49%) compared to those without. These international examples provide strong empirical backing for the current study's findings, reinforcing the argument that mechanisation, especially when technologies are adopted in combination, can serve as a vital tool for improving rural livelihoods and reducing multidimensional poverty.

4.6. Robustness Result PSM and IV

As a robustness test, we used Propensity Score Matching (PSM) and Instrumental Variables (IV), and the results are generally consistent with the Multivariate Endogenous Switching Regression (MESR) results, particularly in the case of joint adoption. The robustness tests confirm the initial findings from the MESR, specifically the significant reduction in household multidimensional poverty (R-MPI) from the joint adoption of tractors and combine harvesters. PSM addresses selection bias by matching households based on observable characteristics, while IV tackles endogeneity by using instruments correlated with technology adoption but not directly with R-MPI. Both methods reinforce the conclusion that the adoption of combine harvesters, especially in combination with tractors, substantially reduces poverty, validating the effectiveness of these agricultural technologies and supporting targeted policy recommendations to promote their adoption.

Table 10: Robustness result PSM and IV

	Machinery type	Treatment effect	Se	p-values
PSM	Tractor adopter only	.0157407	.0222716	.4797147
	Combines adopter only	.0205556	.0198475	.3003539
	Joint adopter	-.0655819***	.0210651	.0018501
IV	Tractor adopter only	.0222222	.1056497	.8334033
	Combines adopter only	.08	.0497262	.107658
	Joint adopter	-.147929***	.0474366	.001818

Notes: ***, ** and * represent significance levels at 1%, 5%, and 10% respectively

4.7. Binary Version of R-MPI: Treatment Effects on Technology Adoption

We used the METE[2] model for the binary version of R-MPI, and the results are generally consistent with the continuous version, particularly in the case of combines-only adoption, as the table below indicates. The findings show that adopting combines only significantly reduces the probability of being classified as poor, suggesting that this technology may enhance productivity or income sufficiently to lift households out of poverty.

Table 11: Average treatment effect of machinery on Binary version of R-MPI

Outcome variable	Technology type	Exogenous		Endogenous	
		Treatment effect	Se	Treatment effect	se
R-MPI binary	Tractor only	.0297024	.075	.018592	.077
	Combines only	-.1567855***	.061	-.1898**	.062
	Joint adoption	.0667771	.053	.0454	0.59

Notes: ***, ** and * represent significance levels at 1%, 5%, and 10% respectively

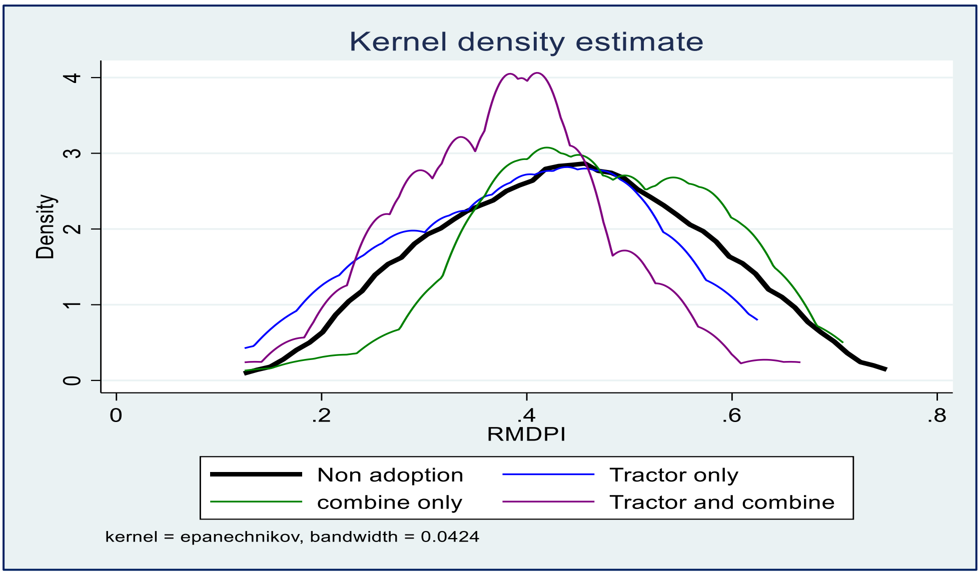

Figure 2: Kernel density distribution of R-MPI by adoption status

[2] Full result of METE is not reported to save space

5. Conclusion and Policy Implications

The study comprehensively explores the impact of mechanization on rural multidimensional poverty, employing robust empirical methods and revealing significant insights. It begins by identifying the importance of mechanization in enhancing rural living standards through increased productivity and reduced agricultural labor. The analysis, supported by methodologies such as Multinomial Endogenous Switching Regression (MESR) and Multinomial Endogenous Treatment Effects (METE), along with the Alkire and Foster counting approach for measuring the Rural Multidimensional Poverty Index (R-MPI), highlights substantial adoption rates of tractors and combine harvesters among rural households.

Empirical results show that mechanization, focusing on the Arsi Zone in Ethiopia, the analysis reveals that the adoption of agricultural machinery, particularly combine harvesters, either on their own or together with tractors, has a strong and statistically significant effect on reducing multidimensional poverty among rural households. Specifically, adopting combine harvesters alone is associated with a 6.75% reduction in the Rural Multidimensional Poverty Index (R-MPI) compared to non-adopters. Although tractor adoption alone leads to a 4.3% decrease in R-MPI, this effect is not statistically significant, suggesting a more limited poverty-reducing role when used in isolation. The most notable impact arises from the joint adoption of tractors and combine harvesters, which leads to a 20.51% reduction in R-MPI, the most substantial and significant effect observed among the adoption groups.

Findings further indicate varied poverty levels across districts, with gender disparities showing higher poverty rates among female-headed households. The study emphasizes a strong association between mechanization and poverty reduction, particularly in areas where the combined adoption of machinery is practiced. Policy implications highlight the need to enhance access to appropriate mechanization technologies, strengthen extension services, and facilitate cooperative membership tailored to rural farmers' constraints and opportunities.

To effectively combat rural multidimensional poverty, integrated approaches are essential—spanning social, educational, health, livelihood, and infrastructure-related dimensions. Reassessing national poverty reduction strategies to comprehensively address deprivations is also crucial. Furthermore, incorporating additional poverty dimensions enhanced the study's measurement accuracy, while a larger sample size improved statistical power and generalizability. The use of panel analysis techniques provided valuable insights into the long-term impact of mechanization adoption, reinforcing its role as a sustainable pathway to poverty alleviation.

Appendix

Table 1A: Falsification tests

Variables	RMDPI (non-adopter)	R_MPI binary (non_adopter)
Farm cooperatives	.039344 (.0289698)	.4675117 (.6738273)
Distance from cooperatives	-.0059141 (.0092537)	.0631844(.1986904)
Constants	.45057***(.0275425)	1.2318** (.5774226)
F-tests on instruments	1.01(0.3680)	0.71(0.7019)

Standard errors in parentheses. The values in the square bracket indicate the p-values of the F-test indicating the validity of the instruments used to identify the MESR model.

Table 2A: A Variance inflation factor

Variable	VIF	1/VIF
Age	2.21	0.452711
totalareac~p	1.97	0.506895
HHS	1.87	0.534470
Education_~s	1.76	0.567005
livelihood~n	1.66	0.602137
TLU	1.61	0.620938
extesion_s~e	1.57	0.635197
CDIl	1.24	0.806188
credit_acc~s	1.22	0.820356
Assets_mob~e	1.22	0.820758
d_mainroadKM	1.18	0.850128
Sex	1.11	0.903476
Mean VIF	1.55	

Table 3A: Estimated Treatment Effects of Mechanization Level on Rural Multidimensional Poverty Index (RMPI) Using Counterfactual Analysis

	Level of adoption	Actual	Low level	Treatment effect	t-value	% change
Conditional	Middle level of adoption	.4125296	.440635	-.0281054***	-6.3238	6.38%
	High level of adoption	.3882576	.4296856	-.041428 ***	-9.3538	9.5%

Note: The percentage change is calculated relative to the counterfactual (low-level adoption).
*** indicates statistical significance at the 1% level.

Please the Author to provide references

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Digital and Financial Literacy as Policy Drivers of Mobile Banking-based Financial Inclusion: Empirical Evidence from Ethiopia's Evolving Socioeconomic Disparities

Abdella Hussen Mudessir[1], Abbi M. Kedir[2], Abebaw Kassie[3]

Abstract

Digitalization and financial inclusion are at the lead of Ethiopia's policy agenda and central to the global development discourse. This study empirically investigated the influences of digital and financial literacy (DFL/FL) on digital financial inclusion via mobile banking, employing nationally representative socioeconomic survey data. Employing the bivariate and hybrid mixed-effect modeling, the analysis robustly addresses hierarchical selection bias and reveals practical, effective interpretations of the insights. Results show that adults with high digital literacy are 68.1 percentage points more likely to use digital financial services than those who are digitally illiterate. Dual literacy (DFL/FL) is identified as the most significant predictor of digital financial inclusion, even when accounting for 61.8% of intra-household dependency. Specifically, DFL demonstrates greater robustness when applying the Heckman correction ($\beta = 1.794$, $p < 0.001$).However, persistent disparities remain: women and rural residents are less likely to own and use mobile devices for financial transactions, and regional gaps are evident, with Gambella, Benishangul-Gumuz, and Afar behind. Youth are the main drivers of both mobile ownership and usage, while digital finance access is further stratified by income. These findings highlight the urgent need for comprehensive digital upskilling and Re-skilling initiatives that target women, youth, low-income and rural residents, and underserved regions. Such innovative intervention not only increases account ownership and ICT expansion but also advances empowerment, dignity, and social inclusion. Furthermore, innovative, adaptive regulatory frameworks designed to be income inclusive and risk sensitive are critical for bridging the digital divide and advancing Ethiopia's transition progress from exclusion to inclusion. Aligning digital ecosystem policies with the country's socioeconomic diversity is essential to achieving inclusive growth and ensuring no one is left behind in the digital financial revolution.

Keywords: digital financial literacy, financial literacy, digital financial inclusion, socioeconomic disparities, mixed-effect maximum likelihood, selection bias.

[1] PhD Candidate of Finance at Addis Ababa University, Addis Ababa, Ethiopia; email: abdella.hussen@aau.edu.et, Mobile +251909787855
[2] Associate Professor and Director of Research at the African Economic Research Consortium (AERC) abbi.kedir@aercafrica.org https://aercafrica.org/leadership/prof-abbi-m-kedir//
[3] Assistance professor at Addis Ababa University, Addis Ababa, Ethiopia; abebaw.kassie@aau.edu.et

1. Introduction

Financial inclusion, a cornerstone of the United Nations Sustainable Development Goals (SDGs), remains inaccessible for millions in developing economies, where structural barriers perpetuate socioeconomic disparities (Elmassah and Mohieldin, 2020; Demiurge-Kunt et al., 2022; Demirguc-Kunt, Pedraza, and Ruiz-Ortega, 2020). Ethiopia, like many developing nations, is undergoing a significant digital transformation, with digital financial services (DFS) emerging as a critical component of its ecosystem inclusivity strategy, according to studies by Achew et al. (2021) and Menza, Jerene, and Oumer (2024). Studies revealed that digitalized finances, by significantly reducing the transaction cost of financial service provisions, contribute a lot to reaching a large portion of the unbanked segment of society. In this case, broadening DFS has the potential to transform financial development by increasing financial inclusion, promoting transparency and fairness, providing convenience for the delivery of goods and services, opening jobs and business opportunities, reducing poverty, and driving innovation in line with the promise of the African Union Agenda 2063 and the Sustainable Development Goals as asserted (Africa Union, n.d., and UNSGSA, 2018).

According to Ozili (2018), Mu et al. (2022), and Kedir and Kouame (2022), digital finance refers to financial services delivered via digital platforms, including mobile money, online banking, and agent banking, which enable transactions such as payments, savings, and credit without physical bank infrastructure.

Ethiopia's 2020 digital transformation strategy (2021-2030) focuses on national digital ID, digital payments, e-governance, and e-commerce, and aligns with specific goals like the National Financial Inclusion Strategy and National Digital Payments Strategy, which aim to transform the digital ecosystem, building a cashless and holistic inclusive economy (Africa Union, n.d., 2020). Those initiatives aim to broaden access to financial services, particularly for the unbanked and underbanked population, fostering economic empowerment and robust, inclusive growth (Elmassah and Mohieldin, 2020, and Shaikh et al., 2023). However, this country continues to confront contextual obstacles in accomplishing these national/regional objectives (GSMA, 2022, 2023a, and Yang et al., 2020).

Accessing and utilizing financial services is severely affected by gender and rural-urban divides, with particularly vulnerable groups such as women, young people without jobs, those in poverty, and small business owners being disproportionately excluded. The low level of financial literacy (FL) and a lack of required skills to use banking technology further hinder digitalized financial inclusion, as claimed by Agar et al. (2020), Setiawan et al. (2022), and Wang et al. (2022).

In Ethiopia, DFS encompasses platforms like Telebirr, HelloCash, Chapa, Safari M-Pesa, Kacha, and Kifiya, among the major players setting milestones on DFSs. These platforms aim to expand financial access in underserved rural and pastoralist regions. Despite efforts, DFS usage remains low owing to infrastructural deficiencies, necessitating digital literacy re-skilling initiatives to let adults take advantage of digital Ethiopia projects (NBE, 2021; Ahmed Ali, n.d.; Hordofa, 2024).

Compounding the accessibility and availability challenges of financial services. The effectiveness of DFS adoptions depends on how the users are willing to take up and use the provided services. In this regard, financial and digital literacy significantly impacts bridging digital divides. (Hasan et al., 2021; Lyons & Kass-Hanna, 2021)

The concepts of FL underlined the understanding and use of financial concepts: interest rates, inflation, and budgeting to make informed decisions (Klapper and Lusardi 2019; Ozili 2021). DFL's new advanced skills represent the application of financial knowledge to securely and effectively use digital tools (e.g., mobile apps, debit and credit cards, and ATMs) to access financial services. They require technical proficiency to navigate digital interfaces, mitigate fraud and data breaches, and adults require adaptive skills to analyze digital financial products (OECD/INFE, 2023). By fusing financial decision-making with digital capability, DFL goes beyond FL. An example of this would be someone with a high FL who is aware of compound interest but likely lacks the digital literacy necessary to use mobile banking to its full potential (Lyons & Kass-Hanna, 2021, and Morgan and Trinh, 2019).

In economies where contextual socioeconomic problems exist, financial literacy (FL) is impeded by deficiencies in general education. Only 18% of citizens comprehend interest rates, and 30% harbor distrust toward formal financial institutions (CSA 2018, 2020, 2023). On top of that, Ke, D. (2017) argued cultural norms further limit women's FL due to financial decision-making being dominated by males. Digital exclusions are further extended by substantial internet connection disparities (22% rural versus 65% urban), a lack of digital skills among rural majority adults, and the fact that just a lower number of women utilize mobile money compared to males (Tindi, 2025, and Hernandez et al., 2024).

Prior studies synthesized from literature argued Ethiopia's financial inclusion ecosystem is marked by a paradox: while mobile banking and digital financial technology drivers promise to leave no one behind for economic liberation, their designed practices often entrench top-down hierarchies structured as asserted in (Crenshaw, 2013; Scholz, n.d.; Suri and Jack, 2016), excluding rural residents, women, pastoralists, and diverse minorities. Only 3% use mobile banking, and 14% use digital financial services (UNCDF, August 08, 2024), while financial exclusion is high at 64%, lagging behind many countries (GSMA, 2023b, and the PSI, 2024).

Advancing adults' digital financial literacy skills (DFL and FL) enhances adoption and usage of digital financial services across diverse socioeconomic groups (Choung et al., 2023; Golden and Cordie, 2022; Klapper and Lusardi, 2019; Lusardi and Messy, 2023; Prasad et al., 2018; Yang, Wu, and Huang, 2020). In regional economies, tech-driven digital/financial literacy enhances practical adoption drivers and overall financial well-being. However, low levels of digital and financial literacy can exacerbate financial exclusion, as evidenced by various studies. Therefore, enhancing adult digital literacy is crucial for promoting financial inclusion (Gafoor and Amilan (2024), Seiawan et al. (2021), Hasan et al. (2024), Jünger and Mietzner (2020), and Shubbangi Singh et al. (2020)).

Conversely, there remains a critical gap in understanding how these literacies influence DFS in the specific, localized, challenging context of Ethiopia. Particularly, there is a lack of studies on how FL and DFL affect the adoption and effective use of digital financial services via mobile banking, accounting for socioeconomic disparities that characterize the Ethiopian localized contexts. Additionally, minimizing the gender gap in digital financial inclusion necessitates a better comprehension of the unique challenges women encounter when striving to access and use the emergent DFS, which are connected to their lower financial and digital literacy status, as well as a special awareness of how to lessen current socioeconomic inequalities (Ahmed Ali, 2025; GSMA 2023b; PSI newsletter

2024). This study is unique in that it examines the nexus of DFL/FL for DFS in Ethiopia's contextual challenges, accounting for socioeconomic correlation, where rural-urban divides, gender disparities, and regional inequalities persist.

Consequently, the general objectives of this study is: To empirically examine the role of digital and financial literacy as policy tools in advancing mobile banking-driven financial inclusion, while accounting for the broader context of socioeconomic disparity in Ethiopia. Specifically, this study addresses the knowledge gap by 1) analyzing the influences of DFL/FL on advancing DFS usage in Ethiopia and 2) examining how adult contextual demographic, socioeconomic, and geographic factors exacerbate the usage of DFS. To achieve these objectives, the researchers have employed mixed-effect Logit/Probit Heckman selection modeling by utilizing nationally representative data from the 2018-19 Ethiopia socio-economic survey with a financial inclusion module.

In doing so, the study contributes valuable insights for policymakers, practitioners, and stakeholders in designing targeted interventions and policies that bridge the gaps in digital financial inclusion through a robust, tailored approach to digital and financial literacy in Ethiopia.

The next sections of the paper are structured as follows: First, the theoretical hypothesis was developed, followed by the data and the methodological underpinnings of FL/DFL PCA scores and the mixed-effect Logit/Probit modeling strategy. Then, a discussion follows the presentation of the results with robustness testing in Section four. The conclusion, recommendations, and future research directions are included in the last section.

2. Theoretical hypothesis developing

2.1. The Effect of Digital and Financial Literacy on Digital Financial Services.

Ozili's (2020; 2021) Theory of Financial Literacy (TFL) suggests that financially literate individuals are more likely to participate in the formal economic sector, offering three main advantages: increased awareness of basic financial services, self-sufficiency, and stability in private finances. Governments with limited public funds may use financial literacy as a national financial inclusion strategy. Empiric reveals that higher financial literacy is strongly associated with increased DFS usage.

However, financial literacy differs from digital literacy and focuses on an individual's knowledge, skills, attitude, and behaviors to use financial products effectively.

Morgan, A., et al. (2022) defined digital literacy as a tridimensional framework consisting of technical, cognitive, and etiquette skills, with higher proficiency in social literacy skills like communicating appropriately online. This digital skill to search online information and make online transactions (e.g., mobile money) is strongly predicted by literacy, they clarified. While user attitude was found to be the most important element towards the adoption of digital services, user innovativeness was found to be a major predictor, both directly and indirectly, supporting the theory of the FLT empirical result by Asad, H., Shaheen, M., & Aftab, M. (2021).

Concurrently, adult intention to accept technology posits that perceived ease of use and usefulness drive technology adoption (Venkatesh et al., 2003; Golden & Cordie, 2022). In line with this theory, digital financial literacy (DFL) makes things seem easier to use by teaching people how to use mobile money apps, and financial literacy (FL) makes things seem more useful by building trust in formal financial systems (World Bank, 2020).

By employing a combination of the acceptance model (behavioral and technological) and financial literacy theory, research by Howard et al. (2020) and Setiawan et al. (2021) revealed that DFL has a positive effect on behavioral intention to use financial services.

Therefore, according to what is currently known, individuals who possess the requisite DFL and FL abilities are very likely to be digitally financially inclusive. For instance, in India (Sarma & Pais, 2011) and Kenya (Suri, 2020), higher DFL was associated with DFS adoption. However, those without DFL could find it challenging to access these services, potentially leading to financial exclusion (Zins & Weill, 2016). Based on the above priors, the authors tested the following two key hypotheses:

Hypothesis 1 (H1): *Adult DFL has a significant positive influence on the usage of DFS. H1: $\beta \neq 0$. (Campbell-Verduyn & Giumelli, 2022) and Al-Khowaiter, W. (2020).*

Hypothesis 2 (H2): *Financial literacy (FL) has a strong, significant, positive influence on the usage of DFS. H2: $\beta \neq 0$. (Lusardi & Mitchell, 2014)*

2.2. Demographic, socioeconomic, and regional heterogeneity effects on digital financial services.

Ethiopia is socially and culturally diverse, with language, geographical places of residency, ethnicity, and religiously identifiable groups or communities.

The theoretical roots of this study are aligned with the early works of Mignolo (2011), which critique how the global financial system, now called the fintech system, perpetuates colonial power dynamics by erasing Indigenous financial practices, for example, in Ethiopia, ROSCA, Iddir, and mutual aid networks. Mignolo argued that Western platforms often prioritize urban elites, sidelining rural communities and stifling grassroots innovations. In this case, by centering marginalized voices and critiques of Western-centric fintech paradigms, this research tests DFS outcomes as a tool for inclusivity.

Similarly, platform cooperativism theory argues against the conventional model of digital financial services. By advocating for user-owned platforms, it prioritizes equity over profit (Scholz, 2016), which can create a more equitable and inclusive digital financial ecosystem by empowering users and promoting democratic practices.

For example, Kenya’s M-Pesa partnership with Chamas boosted rural women’s adoption by 28% (Suri, 2020). A similar test revealed that in Ethiopia, Kerala’s cooperative fintech reduced poverty by 18%, as indicated by studies (Etefa, D. 2021, Beyene, E. (2020), and Manyazewal, T., et al. (2021)), while they face digital disruption and are challenged to realize these potential benefits fully.

In the context of the current study, this theory suggests that cooperatives, owned and controlled by their members, can offer more equitable access to financial services, leverage transparency, and ensure the benefits are shared among local individuals. Platform cooperativism could revive Digital 'Iddir' and Digital Equb decentralized networks as DFS hubs.

Further, gender disparities persist globally, but Ethiopian women face compounding barriers due to sociocultural limitations on mobile ownership and financial autonomy (UNDP, 2022).

Regional inequality, particularly in pastoralist areas like Afar, mirrors trends in Niger (Aker et al., 2016), though Ethiopia’s federal governance structure exacerbates infrastructural and policy fragmentation (NBE, 2021). Supportive studies show PayPal's extractive fees perpetuate colonial reliance in Latin

America (Gomez, 2022). Such biases mirror exclusionary practices in India, where caste and language barriers limit UPI adoption (Gupta, 2021).

Addressing behavioral, socioeconomic, and contextual factors is crucial to fostering effective and inclusive DFS adoption, but, despite these insights, the nature and strength of these relationships remain to be empirically tested within the Ethiopian context. This study fills critical gaps by integrating household-level clustering and regional heterogeneity into an analysis of DFS, offering novel insights for policymakers.

After synthesis with the above theoretical underpinning, this study's hypothesis is to investigate the demographic, socioeconomic, and regional heterogeneity effects on digital financial services.

Hypothesis 3 (H3): Demographic factors (gender, age, education) and socioeconomic factors (income, employment status, and own mobile) have a significant influence on the adoption of digital financial services (DFS) in Ethiopia. H3: $\beta \neq 0$.

Hypothesis 4 (H4): *Rural vs. Urban Residence: Individuals residing in urban areas are more likely to adopt Digital Financial Services (DFS) compared to those in rural areas in Ethiopia.*

Hypothesis 5 (H5): Geographical Region: Geographical region significantly affects DFS adoption, with individuals in more developed regions (e.g., Addis Ababa, Dire Dawa) more likely to adopt DFS compared to those in less developed regions (e.g., Somali, Afar).

H5: $\beta \neq 0$. Mustafa, J., Marie, A., Al-Amarneh, A., & Al-Abbadi, A. (2023)

3. Data and Estimation strategy

3.1. The data and variable measurements

This study employed the 2018/19 Ethiopia Socioeconomic Survey (ESS4)[4]. This data is a nationally representative, consistent survey conducted by the central statistical agency in collaboration with the World Bank. The survey interviewed 6,700 households across the country, including an observation of 14,862, of which the authors used mainly a sample of 5,125 adults aged 18 and above, all of

[4] The original data are available from the World Bank Microdata Library: https://microdata.worldbank.org/index.php/catalog/3823 .The refined modeling dataset is available from the corresponding author on reasonable request.

whom reported on their use of digital financial services and have access to a mobile phone.

The ESS4 provides extensive socioeconomic and demographic information: age, gender, education (years of schooling), employment status, expenditure, and geographic location (rural/urban, regional state). Crucially, the module includes financial literacy and financial inclusion status measuring questions.

These variables allow for a reliable analysis of variation in financial exclusion and inclusion across regions and the effect of socioeconomic factors on digital financial inclusion.

The variable measurement of digital financial service adoption and usage (DFS) is based on respondents' answers to the question: Have you used any of the following services in the last 12 months: ATM/debit/credit card, mobile banking, internet banking, agent banking, or interest-free banking? particularly to measure the outcome-dependent variable. Adoption and usage of digital financial services, as well as ownership of a mobile money account and actual use of mobile money by the user, are defined by a binary answer variable with a value of 1 or 0, respectively.

Financial literacy is a key variable, measured through sub-dimension indicators: financial knowledge (knowledge of inflation, interest, and budgeting); financial behavior (credit gap financing, emergency savings, and saving to start a business); and financial attitude (trust in formal financial institutions, financing preferences, and home cash saving). The level of digital financial literacy (DFL) is measured by how well Ethiopian adults can (skillfully) use available financial services. This includes online and mobile banking, using debit and credit cards at ATMs, agent banking, and the Internet banking service (IFB).

Age, gender, employment status, mobile phone ownership, income as a proxy for frequency of saving, education, respondents' geographic location, urban-rural divide, and distance from FFI were the additional variables chosen to assess the heterogeneity of demographic, socioeconomic, and geographic characteristics as independent variables. Appendix Table 16: Presents details of the definitions of variables, symbols, and hypotheses of the study.

3.2. Data Estimation Strategy

3.2.1. PCA methods

3.2.1.1. Constructing Financial Literacy (FL) and Digital Financial Literacy (DFL)

In this study, we constructed a reliable measure of financial literacy (FL) and digital financial literacy (DFL) via principal components analysis (PCA) methods. The use of PCA allowed for the decrease of dimensionality while keeping important information and properly measuring latent variables. The PCA, in a two-stage approach, was guided by procedures used in previous publications by Camara and Tuesta (2014), Mukherjee and Sood (2020), and Nguyen.

To begin this PCA estimate technique, we used STATA software to create distinct PCAs for each FL multidimensional indicator, such as knowledge, attitude, and behavior, for FL and DFL subdimensions. In the second stage, dimension scores are aggregated into composite scores, which are weighted by explained variance.

This study recognizes that the FL multidimensional variable encompasses not only general financial knowledge but also adult financial attitudes and behaviors aligned with prior studies (Rai, et al.; Kadoya & Khan, 2017; Chu, et al., Lusardi & Mitchell, 2014).

In the first stage of PCA FL score estimation, unobserved endogenous sub-dimensional (knowledge, behavior, and attitude) indicators were assessed, and then the resulting dimension indices were combined into an aggregate FL score using weighted scores. This method acknowledges that each dimension contributes differently to overall financial literacy, aiming to capture a more comprehensive measure of FL.

Similarly, the DFL score was constructed using the PCA score approach, emphasizing the practical application of digital financial services. Given the data from ESS2018/19 availability, indicators such as the use of online banking, mobile banking, ATMs, and agent banking were used as measures of aggregate digital financial literacy skills (Prykaziuk & Khodakivska (2023), Lo (2021), and Golden & Cordie (2022)). This latent variable DFL score was derived through a weighted linear combination of these indicators.

3.2.1.2. Assessment of Measurement Validity and Reliability

To ensure the measurement reliability and validity of the FL and DFL scores, first, the PCA estimation result, which indicated that FL and DFL score components cumulatively explained 68% and 72% of the variance, respectively, exceeding the 60% threshold for robustness (Sharma et al., 2023), and corresponds with the claims of Hair et al. (2019). Secondly, PCA out of FL/DFL estimates is theoretically aligned with the aforementioned prior studies that reflect the methods, linking literacy to individual decision-making capability measurement analysis. The result corresponds with the technology acceptance models (Venkatesh et al., 2003). Thus, an individual is deemed literate if their PCA score on the correct answers to financial and digital literacy questions is above average or mean (DFL/FL score). In line with previous research by OECD (2020), Hasan et al. (2021), and Setiawan et al. (2021). Conversely, a person with a DFL/FL score of less than 0.5 is deemed illiterate in financial and digital literacy. These estimated PC score outcomes were then used in bivariate descriptive and econometric models for further analysis. A detailed description of the PCA procedure is available in previously published and preprinted chapters of the authors' work (SSRN Working Paper; EJBE Article).

3.2.1.3. Mixed effects modeling estimation strategy

The choice of mixed-effect logit and Probit models aligns with the hierarchical structure of the EES4 datasets, where individual units of analysis are nested within households and regions.

In this context, the OLS main assumption of adult independence (i.e., independent identically distributed (IID) $N = (0, \delta^2)$) does not hold in situations where there is financial behavior interdependence among adults in the same region, city, and household, making OLS an unreliable estimator (Burn and Harrison, 2019; and Embaye et al., 2021).

To overcome the limitation of OLS, Gomes et al. (2020) and Chu et al. (2010) suggest that household finance studies employing mixed-effect models that take hierarchical dependency into survey datasets increase modeling performance by controlling for heterogeneity between observed and unobserved correlations. The same suggestion was made by Robson and Peetz (2020) that by offering simultaneous estimates, supporting complex experimental designs, and accounting for nonsystematic response sets and variables, mixed-effects modeling improves behavioral economic demand analysis. Those priors revealed that household finance studies data are complex and interdependent, with social factors, peer effects, and financial literacy playing a role in their decision-making process, as asserted by Al-Khowaiter (2020), Aziz and Naima (2021), and Gabor and Brooks (2017).

The author's justification for the use of mixed-effect logit/probit models in this Ethiopia-region-focused study using EES4 microdata is aimed at accounting for disparities between observable and unobserved differences (Kaplan et al., 2021).

Contextually, the adoption of digital financial services and the use of digital payment systems by adults within the same household, region, and place of residence are likely to be positively correlated based on their individual demographic and socioeconomic features. On the other hand, this dependence control is considered by mixed effect modeling (MEM) using the assumption of adult financial behavior dependency modeling maximum likelihood (ML) estimator. Thus, Equation 1**Error! Reference source not found.** and, Equation 2 present mixed-effect Logit/Probit modeling specifications.

Model 1: Mixed effect logit

This logistic mixed effect modeling (**Error! Reference source not found.**) s pecification applied clustered survey data models guidance mainly from McNeish and Kelly (2019).

$$\boldsymbol{Pr}(\boldsymbol{DFSU_{ij}} = \mathbf{1}) = logit^{-\mathbf{1}}\Big(\boldsymbol{\beta_0} + \boldsymbol{\beta_1} DFL_{\boldsymbol{ij}} + \boldsymbol{\beta_2} FL_{\boldsymbol{ij}} + \boldsymbol{\beta_3}\boldsymbol{PLACE_{ij}} + \boldsymbol{\beta_4} SEX_{\boldsymbol{ij}} + \boldsymbol{\beta_5} AGE_{\boldsymbol{ij}} + \boldsymbol{\beta_6} AGE2_{\boldsymbol{ij}} + \boldsymbol{\beta_7} EMP_{\boldsymbol{ij}} + \boldsymbol{\beta_8}\boldsymbol{Mobile_{ij}} + \boldsymbol{\beta_9} Weekly_{\boldsymbol{ij}} + \boldsymbol{\beta_{10}} Monthly_{\boldsymbol{ij}} + \boldsymbol{\beta_{11}} Quarterly_{\boldsymbol{ij}} + \boldsymbol{\beta_{12}} Semiannual_{\boldsymbol{ij}} + \boldsymbol{\beta_{13}} Annual_{\boldsymbol{ij}} + \boldsymbol{\beta_{14}} Region_{\boldsymbol{ij}} + \boldsymbol{\beta_{15}} EDUC_{\boldsymbol{ij}} + \boldsymbol{u_j}\Big) \qquad \textbf{Equation\_1}$$

Where: $Pr\big(DFSU_{ij} = 1\big)$ is the probability for adult $i$in household j chooses to use DFS adoption and usage.

$\boldsymbol{Logit}^{-\mathbf{1}}$, refer to the inverse logit function and it measures the natural log of the odds of choosing to use DFSU (1) relative to not choosing to the i individual(0), which transforms the linear predictors into a probability between 0 and 1.

Where **Hierarchy** adult ij observations (i) are nested within households j Mixed-effects model subscripts estimate algorithms that use both fixed and random effects.

Fixed effect estimate is the $DFSU_i$ binary outcome (1=DFSU; 0=not use).

$\boldsymbol{\beta_0}$: is the intercept or constant coefficient of predictors (β1, β2, β3….β15) included like DFL, FL, and other measures. Socioeconomic disparity (rural, gender, age, income) for DFSU.

In a random or restricted mixed-effects (REME) estimate, a hierarchy of adult observations nested within households accounts for variation(correlation or dependency) and Coefficients (β1, β2, β3….β15) are predictors, and for explanatory and control variables DFL and FL regarding unobserved characteristics captured by the random effect predictors to measure socioeconomic disparity (rural, gender, age, and income) for DFSU.

$\boldsymbol{u_j}$:is the household-specific intercept. Predictor control variables are assumed to be correlated within household clusters, as per a mixed effect modeling specification requirement, assumed to be normally distributed with mean 0 and variance.

Random effect: *The assumption that the adult dependency:* null hypothesis Ho β=0 and alternative hypothesis H1 β≠0 are assumed to be true, which serves as an inference about dependencies within and between cluster effects.

Model 2: Mixed-effect Probit

$$\boldsymbol{Pr(DFSU_{ij}=1)} = \Phi\Big(\boldsymbol{\beta_0} + \boldsymbol{\beta_1}DFL_{ij} + \boldsymbol{\beta_2}FL_{ij} + \boldsymbol{\beta_3 PLACE_{ij}} + \boldsymbol{\beta_4}SEX_{ij} + \boldsymbol{\beta_5}AGE_{ij} + \boldsymbol{\beta_6}AGE2_{ij} + \boldsymbol{\beta_7}EMP_{ij} + \boldsymbol{\beta_8 Mobile_{ij}} + \boldsymbol{\beta_9}Weekly_{ij} + \boldsymbol{\beta_{10}}Monthly_{ij} + \boldsymbol{\beta_{11}}Quarterly_{ij} + \boldsymbol{\beta_{12}}Semiannual_{ij} + \boldsymbol{\beta_{13}}Annual_{ij} + \boldsymbol{\beta_{14}}Region_{ij} + \boldsymbol{\beta_{15}}EDUC_{ij}) + \boldsymbol{u_j}\Big) \qquad \textbf{Equation\_2}$$

From Equation 2, for Mixed probit model, where Hierarchy, Same as Mixed logit; Link function ,Φ (.) denotes the cumulative distribution function ($\boldsymbol{CDF}$), other terms are defined similarly to the logit model.

In this study, the maximum likelihood (ML) estimation(via STATA software) is employed , which enables investigators to account for a complex of clustered survey designs and imputed variables and is similar to that employed by Clark and Moore (2011) and Kim (2025). Mixed-effect MLE estimation separates household-specific variability (random dependency) from population-level fixed deviation (i.e., HHs level in this case). Furthermore, after the estimation of Logit/Probit by maximum likelihood, the authors computed the marginal effects for Probit models for each covariate by using the margins at means to determine the marginal effects of each explanatory variable on the dependent variable to interpret the change in probabilities on average marginal effect (AME) and model robustness testing.

Model 3 and 4: Heckman Selection Probit (heckprob)

In order to further reduce biasness of this study's results' robustness, the authors used a Heckman two-stage selection model (1979) with mobile ownership (adoption) modeled (Equation 3) as the selection equation to correct for potential bias in the outcome models (Equation 4).

Model 3: Selection Equation (Own_Mobile)

$$OWN\_mobile_i^* = \boldsymbol{\theta_0} + \boldsymbol{\theta_1} EDUC_i + \boldsymbol{\theta_2} \boldsymbol{PLACE_i} + \boldsymbol{\theta_3} AGE_i + \boldsymbol{\theta_4} AGE2_i + \boldsymbol{\theta_5} SEX_i + \boldsymbol{\omega_i} \qquad \textbf{Equation\_3}$$

Where: $OWN\_mobile_i = \begin{cases} 1 & \text{if Own\_mobile}_i^* > 0, \\ 0 & \text{otherwise.} \end{cases}$

Model 4 :Outcome Equation (proxy by Used_Mobile_Banking):

$$\boldsymbol{DFSU_i^*} = \boldsymbol{\mu_0} + \boldsymbol{\mu_1} DFL_i + \boldsymbol{\mu_2} FL_i + \boldsymbol{\mu_3} \boldsymbol{Place_i} + \boldsymbol{\mu_4} AGE_i + \boldsymbol{\mu_5} AGE2_i + \boldsymbol{\mu_6} EMPLOYED_i + \boldsymbol{\mu_7} Weekly_i + \boldsymbol{\mu_8} Monthly_i + \boldsymbol{\mu_9} Quarterly_i + \boldsymbol{\mu_{10}} Semiannual_i + \boldsymbol{\mu_{11}} Annual_i + \boldsymbol{\mu_{12}} Region_i + \boldsymbol{\xi_i} \qquad \textbf{Equation\_4}$$

$$DFSU_i = \begin{cases} 1 & if\ DFSU_i^* > 0\ and\ OWN\_Mobile_i = 1, \\ Unobserved & otherwise. \end{cases}$$

Where, Error Structure: Standard errors ω_i and ξ_i follow a bivariate normal distribution: $\begin{pmatrix} \omega_i \\ \xi_i \end{pmatrix} \sim \mathcal{N}\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix} \right)$

And Rho ($\rho\rho$): the correlation between the selection and outcome equations.

μ_0 And θ_0 are intercepts under models 4 and 3. And are coefficients for the predictors under these models.

Accordingly, the Heckman selection model corrects for selection bias by utilizing a Probit model with correlated errors, denoted as rho (ρ). It is assumed that the exclusion of education from the outcome equation is necessary to test for validity.

This approach in the Heckman model serves as a robust estimation technique that effectively isolates the causal effects of education on outcomes. Its reliability is based on the validity of the exclusion restriction and the inclusion of relevant variables.

As shown at the bottom of Table 15, the results of the Heckman Probit estimation Model line 4 and selection model in 5 are well-fitted, with joint significance and selection bias confirmed by Wald $\chi^2(1)$=513.91, indicating the need for the mobile ownership Heckman selection correction model.

4. Results

4.1. Bivariate Analysis of Digital Financial service adoption and usage

The bivariate t-test is summarized in Table 12 and 2. Cohen's deffect size and a two-sample bivariate approach are used to estimate it. As described below, the results show notable disparity by gender and between rural and urban dwellers in DFS adoption, DFL, and FL.

4.1.1. Rural deficits in DFS, DFL, and financial literacy

This study's findings reveal rural deficits in DFS, DFL, and FL. In this case, the urban residents are 7.5% more likely to use DFS than rural residents ($p<0.001$), with a small effect size (Cohen's d=0.226). Similarly, the financial literacy gap is strong (34.8% difference) with a large effect size (d = 0.646). Additionally, urban residents marginally outperform on digital literacy, though this difference is statistically significant ($p<0.05$). This data insight, finding the DFS gap (d=0.226) and FL gap (d=0.646), represents a small to medium practical effect.

4.1.2. Gender disparities in digital financial inclusion

The finding indicates general gender gaps persist across all indicators, with male-headed households and female-headed households facing distinct challenges. For example, adult females' adoption of DFS is statistically significant at 5.3-7.1% lower than that of males, indicating a minimal to small practical relevance (d=0.160-0.218). Financial literacy has a high DFL than for those with low DFL (76.8% vs. 8.7%; $t = -28.55$, $p < 0.001$), and the effect magnitude was an unmatched Cohen's d of -2.33.

4.1.3. Digital Financial Literacy (DFL): a critical driver of DFS adoption

Table 13, shows that DFS adoption was 68.1 percentage points higher for people with This is consistent with findings from throughout the world that digital financial inclusion is fueled by DFL, as indicated by abilities like web-based navigation, financial services, and mobile money applications (CSA, 2021; World Bank, 2021).

Table 12: DFS, DFL, and FL comparison by urban and rural areas and gender.

Rural vs. Urban	[5]Mean 1 Urban	Mean 2 Rural	Diff (M1-M2)	t	Pv	Cohen's d[6]
DFSU	14.1%	6.6%	7.5%	7.85	0.000	0.226
DFL	6.4%	4.6%	1.8%	2.3	0.02	0.075
FL	15.9%	-19%	34.8%	38.65	0.000	0.646
DFS, DFL, and FL By Gender.						
DFS >Female	15.1%	9.8%	5.3%	5.95	0.000	0.16
Head Female	14.1%	7%	7.1%	6.15	0.000	0.218
DFL >Female	7.4%	4.4%	3%	4.75	0.000	0.127
DFS>Female Head	7.1%	3%	4.1%	5.15	0.000	0.175
FL >Female	3%	-2.6%	5.6%	5.85	0.000	0.099
FL >Female Head	3.8%	0.2%	3.6%	2.45	.014	0.065

4.1.4. Employment and Mobile Ownership

The result reveals that employed adults have only 3.6 percentage points higher DFS adoption than unemployed peers (14.3% vs. 10.6%; $t = -4.05$, $p < 0.01$), with a trivial effect size ($d = -0.11$).

[5] NB. 1. DFS Adoption Gap, difference reported as percentage mean 2-mean 1 (M2-M1). And Welch's t-test with Satterthwaite's degree of freedom is used for unequal variances.
[6] Effect Size Test Cohen's d is calculated as $|M_1 - M_2| / \sqrt{[(SD_1^2 + SD_2^2)/2]}$. The interpretation: $|d| < 0.2$: Trivial, $0.2 \leq |d| < 0.5$: Small, $0.5 \leq |d| < 0.8$: Medium, and $|d| \geq 0.8$: Large (Brydges, 2019).

Table 13: DFS Adoption and use by DFL, Employment, and Mobile Ownership.

Variable	Mean1	Mean2	diff(M2-M1)	t value	Pv	Cohen's d 95% CI
DFL	8.7%	76.8%	68.1%	-28.55	0.000	-2.334[-2.542,-2.126]
Employed	10.6%	14.3%(yes)	3.6%	-4.05	0.000	-0.110[-0.165,-0.056]
Mobile	4.4%	14.3%(yes)	10%	-11.3	0.000	-0.300[-0.375,-0.225]

NB: 1. DFS Adoption Gap, difference reported as percentage mean 2-mean 1 (M2-M1).

As shown in Table 13. In the case of mobile ownership, it demonstrated 10 percentage points higher DFS adoption than non-owners (14.3% vs. 4.4%; $t = -11.30$, $p < 0.001$), with a small practical size effect ($d = -0.30$). While mobile access is important, Ethiopia's 35% mobile ownership gender gap (GSMA, 2023b) and low digital literacy reveal that ownership alone cannot drive inclusion without targeted digital upskilling.

4.1.5. Regional place disparity

Table 14 and Table 17, which is annexed , provide a detailed breakdown of regional and inter-regional disparities in DFS adoption, DFL, and FL.

DFS adoption and usage by region: The Somali region demonstrates the largest gain at +29% compared to 12.3% in non-Somali regions ($t = -4.15$, $p < 0.001$). This corresponds to a medium effect size (d=-0.500, 95% CI [-0.683, -0.316]), highlighting significant adoption advantages in the Somali region. Likely, Harar exhibits a 7.1 percent increase ($t=-3.9$, $p<0.001$), with a small practical effect ($d=-0.213$).

Gambella shows a 6.3 percent mean point deficit in DFS usage ($t=4.3$, $P<0.001$, $d=0.187$, 95% CI [0.077, 0.297]), which reflects lower adoption and usage rates compared to other regions. In contrast, the Addis Ababa administration shows minimal disparity ($t=0.95$, $p=0.3320$, with a trivial effect size $d=0.029$). This indicates that urban-centric infrastructure in Addis Ababa may have mitigated some of the barriers seen in other regions as presented below.

Table 14: DFS adoption and usage by region

Variable	Mean 1%	Mean 2%	Dif (M2-M1)	t	*pv	*Cohen's d, 95%CI
AFAR	12.8	11.9	0.9	.4	0.674	0.028
AHMARA	13.3	8.4	0.5	3.7	0.001	0.145
OROMIA	12.6	15.1	-2.6	-1.4	0.169	-0.077
SOMALI	12.3	29	-16.7	-4.15	0.001	-0.500
BG	12.9	11	1.8	.85	0.408	0.055
SNNP	12.9	12	0.9	.5	0.605	0.027
GAMBELLA	13.2	7	6.3	4.3	0.001	.187
HARAR	12.1	19.2	-7.1	-3.9	0.001	-0.213
TIGRAY	13	11.2	1.8	1.25	0.221	0.054
DD	12.6	14	-1.4	-.95	0.339	-0.042
AA	13.1	12	1	.95	0.332	0.029

Digital Financial Literacy (DFL): Table 17, DFL gaps are smaller but still significant in certain regions. Gambella lags with a 4.1 percent on mean deficit ($t=4.65$, $p<0.001$), corresponding to a small effect size ($d=0.169$). Aligned with DFS adoption, Somali region adults exhibited a 5.5% mean percentage of extra digital skills than others ($t=-1.95$, $p=0.052$), but it was insignificant and a small too trivial effect size. ($d=-0.231$). Surprisingly, the Oromia region shows a significant positive 4.3 percent digital skills than others ($t=-2.75$, $P=0.006$), with a small practical policy effect size ($d=-0.178$).

Regions/cities such as Afar and Amhara displayed average differences with small effect sizes ($d=0.145$ and $d=0.087$, respectively), while there was no significant difference in Addis Ababa compared to DFL between Addis and other region adults (urban or rural) ($t=-0.25$, $p<0.799$; $d=-0.008$).

Financial Literacy (FL): Similarly, Table 17, Findings from this bivariate test revealed strong FL disparities, with Somali adults' information results indicating the largest gap of 28.8% ($t=19.65$, $p<0.001$). The result corresponds to a medium to large effect size ($d=0.514$, 95% non-zero CI [0.455, 0.573]), arguably indicating Somalia's largely pastoralist community exclusion from formal financial education despite high DFS adoption rates in the region. Addis

Ababa mirrors this result with a 29% point difference compared to non-Addis Ababa adults ($t=-18.75$, $p<0.001$, $d=-0.5220$), reaffirming the exclusion of the other region adults from formal financial education. Additionally, Dire Dawa shows a significant FL difference at 11% ($t=-7.3$, $p<0.001$, $d=-0.199$), while Gambella reports no significant gap with inter-regional general analysis ($t=-0.6$, $p=0.538$, $d=-0.020$).

The study's bivariate analyses finding confirms policy setbacks exacerbate persistent inequality, including rural-urban divides, gender gaps, income, employment, and mobile and digital divides. Furthermore, regional disparity studies using the two-sample t-test and effect size metrics for adults DFS, DFL, and FL revealed a persisting difference in digital financial inclusion across Ethiopia's regions. In the next section, mixed effects Regression results and discussion follow.

4.2. Mixed effects results robustness testing

Table 15: The output of mixed-effect logistic models estimated in Stata ML by including random intercepts at the household-level individuals grouping shows that unobserved household characteristics account for 61.8% of the variation in DFS adoptions. It is evidenced by the constant coefficient region to the household ($\beta=5.32$, $p<0.001$). In accordance with suggestions for clustered binary outcomes (Huang 2021,Angrist & Picchike, 2009), the mixed logit model (AIC=2734.4) fits marginally, outperforming the Probit specification (AIC=2737.5) by a little margin, (% changing AIC=3.4, % change BIC=3.4).

The Wald chi^2 test reveals mixed logit/probit; both models show a highly significant fit ($P=0.0000$), with the mixed Probit having a higher chi^2 (246.65 vs. 201.46), suggesting stronger predictor significance, but substantive conclusions can align.

Additionally, the LR test ratio (prob ≥ 0.0000) supports retaining the random effects structure over a standard linear mixed effect model, which mirrors the OLS model.

Therefore, the results of both mixed Logit/Probit models are employed side by side for interpretations and discussions. More importantly, the researchers used hybrid/mixed-effect logit output for interpretability, along with Heckman selection.

Table 15: Hybrid Modeling (DFS adoption and usage via mobile banking usage)

DFSU	Mixed effects		Heckman selection[7]	
	Model 1[8]	**Model 2**	**Model 4**	**Model 3**
DFL	5.655***(12.83)	2.997***(14.38)	1.794***(18.99)	
FL	0.382*(2.32)	0.187*(2.18)	0.108*(1.98)	
EDUC	0.0844***(9.58)	0.0446***(9.81)		0.0617***(22.21)
Rural	-0.507(-1.80)	-0.265(-1.81)	0.524***(5.32)	-1.290***(-33.41)
Female	-0.514**(-3.18)	-0.270**(-3.18)	0.0485(0.92)	-0.270**(-3.18)
AGE	0.0131(0.38)	0.00875(0.48)	-0.0509***(-3.68)	0.114***(17.13)
age2	-0.000336(-0.79)	-0.000192(-0.86)	0.000551**(3.12)	-0.00123***(-16.11)
EMPLOYED	0.373*(2.18)	0.186*(2.06)	0.102*(1.96)	
Own_ mobile	0.722*(2.26)	0.369*(2.25)		
≥600 ETB saving frequency				
Weekly	1.424***(4.58)	0.759***(4.56)	0.397***(4.17)	
Monthly	0.763***(3.92)	0.404***(3.93)	0.192**(3.29)	
Quarterly	0.618*(2.22)	0.328*(2.22)	0.173*(2.17)	
Semiannually	0.805*(2.03)	0.447*(2.16)	0.213(1.84)	
Annually	-1.097(-1.56)	-0.556(-1.54)	-0.319(-1.40)	
Region (refer to Addis Ababa)				
AFAR	0.256(0.57)	0.134(0.57)	0.0881(0.62)	
AMHARA	0.0820(0.23)	0.0539(0.29)	0.0832(0.90)	
OROMIA	0.726*(2.08)	0.384*(2.09)	0.191(1.83)	
SOMALI	2.235***(4.57)	1.194***(4.62)	0.777***(4.37)	
BG	0.0406(0.09)	0.0409(0.17)	-0.0785(-0.58)	
SNNP	0.182(0.50)	0.108(0.56)	0.0854(0.77)	
GAMBELLA	-0.493(-1.17)	-0.253(-1.15)	-0.121(-1.04)	
HARAR	1.052***(3.39)	0.555***(3.38)	0.333***(3.51)	
TIGRAY	0.0558(0.16)	0.0351(0.20)	0.118(1.09)	
DIRE DAWA	0.610*(2.06)	0.324*(2.09)	0.170*(1.98)	
_cons α	-7.031***(-8.05)	-3.757***(-8.33)	-0.141(-0.53)	-2.401***(-16.04
Robustness tests(continued)				
var(_cons[REGION >household_id])	5.318***(4.68)	1.413***(4.98)		
N	5125	5125	11751	4336
AIC	2722.7	2726.1	11578.4	11578.4
BIC	2899.3	2902.7	11799.6	11799.6
Log likelihood	-1334.34	-1336	-5759	-5759
Wald chi2	201.46(P=0.0000)	246.65(P=0.0000)	513.91	147
LR test (vs. Linear)	120.13(P=0.0000)	111.49(P=0.000)		
ICC or	0.6178,SE=0.05	0.58.6, SE=0.05	-0.896***(-12.15) Rho -0.71	0.896***(-12.15)

NB: t/z statistics in parentheses * p < 0.05, ** p < 0.01, *** p < 0.001

[7] The Heckman probit model (usage) estimated 11,751 STATA observations, with 4,336 adult data selected (adoption) due to mobile banking and mobile phone usage, while 7,415 were not selected.
[8] Line 2: Output from the mixed logit model estimation; Line 3: Output from the mixed probit estimation; Line 4: Results of the Heckman probit analysis; Line 5: Heckman selection regarding mobile variables

4.3. Heckman selection bias testing

In the context of digital financial inclusion via mobile money derived from mobile ownership, the question is, are mobile phone ownership (adoption) decisions distinct from mobile money usage? The assumption is that adoption starts by owning a mobile; selection bias negatively affects usage while adoption increases usage. To structure the analysis, we hypothesize the test of Heckman selection bias as:

Mobile ownership (adoption) is a necessary condition for mobile money usage, with younger adults (aged 18≥) significantly higher adoption and usage due to greater tech-savviness compared to older (aged2) adults in Ethiopia.

Priors validate the hypotheses (Venkatesh et al., 2003 & Demirgüç-Kunt et al., 2018), but without mobile ownership difference selection bias analysis. Accordingly, this study (i.e., the case of Ethiopia) estimates a Heckman Probit probability two-stage selection model, and the result is shown in nested Table 15.

4.3.1. Heckman Sample Selection Bias correction and instrument validity

The DFS outcome model Table 15 (i.e Heckprobit line 4) joint significance is shown by Wald $\chi^2(1)$=513.91), which also validates that the outcome and selection models are well-fitted (Prob>χ^2=0.0000, Log pseudo likelihood=-5759.22).Similarly, the Wald Test of Independence test ($\chi^2(1) = 147.71$ ($p < 0.001$)) validates the selection bias exists, reinforcing the need for the mobile ownership Heckman selection correction model.

According to the hyperbolic arctangent of rho = -0.896, $p < 0.001$), indicating a strong negative correlation ($\rho = -0.71$) between the residual error terms of the selection and outcome equations. After correction, digital financial literacy and financial literacy remained strong predictors of mobile money usage ($\beta = 1.794$, $p < 0.001$; $\beta = 0.108$, $p = 0.048$) as presented in Table 15's line 4.

Heckman correction: The selection equation includes education, which is excluded from the outcome equation. This satisfies the exclusion restriction, as education likely affects mobile ownership but not usage directly (Arora & Lochab, 2018) after controlling for other covariates. The significance of education in the selection equation (β=0.0617, $p < 0.001$) and non-significance in the outcome model (not included) support instrument validity (Wolfolds & Siegel, 2019).

Due to unobserved household-level characteristics, the better-fitted melogit findings are biased on the coefficient (for example, accurate on the direction (+-), but insignificant for age, age2 and rural effects). But when sample selection bias is taken into account, the Heckman selection shows that gender and rural residence are the main factors influencing mobile ownership (adoption), although age has a nonlinear effect on both ownership and usage. In order to ensure that estimates for key DFL and FL variables are truthful, the Heckman model's correction for selection bias is validated by the substantial rho(ρ= -0.714, $P < 0.001$). For example, the melogit model coefficient (β=5.65, $p<0.001$) for DFL appears exaggerated for practical effect analysis. However, following Heckman selection bias adjustment, the DFL coefficient appears to have a practical effect, supporting DFL's dominance in the mobile banking usage study. Thus, the Heckman selection model highlights the importance of accounting for potential biases in the data estimation (i.e., validating the hypotheses), ensuring a more accurate representation of the factors influencing mobile money usage across different rural, gender, and age groups.

4.3.2. Hybrid modeling approach for enhanced practical implication

The key robustness testing analysis finding is that the Heckprobit model detects selection bias, and the melogit/meprobit models fit marginally as shown by lower AIC/BIC but do not account for selection bias. In particular, mixed-effect ML explicitly models hierarchical/clustered data, which often improves fit (lower AIC/BIC) by controlling for unobserved heterogeneity. Which model should be used for better theoretical and practical interpretations?

The across-model comparisons revealed highly fitted while selection and outcome Meprobit models agree on coefficients mostly. In this case, a hybrid approach or reporting by focusing on cluster-adjusted results leads to rigorous interpretation (Angrist and Pischke, 2009; Ullmann et al., 2021; Absalom et al., 2020), which is also more advantageous for emphasizing those empirical outcomes and behavioral and economic practical implications.

These methodologies collectively enhance understanding of the complexities surrounding digital financial inclusion, particularly in diverse socio-economic contexts of Ethiopia. By integrating these advanced econometric analytical techniques, it provides more profound insights into theoretical and practical interpretations to inform policymakers on effective strategies to promote financial inclusion.

5. Discussion and Interpretations

5.1. The influence of literacy as a catalyst to bridge the digital divide

Digital financial literacy (DFL) emerges as the strongest predictor of DFS adoptions. A one-unit increase in adults' DFL score raises the log-odds of adoption by 5.65-fold ($p<0.001$) in the mixed logit model and 2.99 ($p<0.001$) in probit, underscoring its centrality to overcoming technological barriers. The Heckman correction ($\beta=1.794$, $p<0.001$) reinforces the validity of the findings, suggesting that DFL significantly influences user adoption and engagement in mobile banking platforms.

The analysis reveals FL has a smaller but significant effect: a one-unit increase raises log-odds by 0.38 ($p<0.05$) in mixed logit and 0.187 ($p<0.05$) in mixed probit modeling. This mirrors global findings where FL alone is insufficient without complementary digital skills, aligning Kenya's and India's DFS adoption trends (Tony & Desai, 2020; Lyons, A., et al., 2020; and Amnas, M., et al., 2024). But after selection correction, this finding is against the finding of no gender gap in DFS adoption when literacy is controlled (Siddiq & Scherer, 2019; Borgonovi et al., 2021).

General education significantly predicts DFS usage, with a logit odds ratio of 0.0844 indicating that each extra year of education increases the likelihood of DFS adoption by 23% ($\beta=0.0844$, $P<0.001$). In other words, persons with more years of education can better grasp and use digital money than those with a lesser level of education. Education is a dual role that is ownership in Heckman and usage in Melogit, reflecting its broader influence of education for inclusive finance ($\beta=0.062$, $P<0.001$). This is consistent with the aforementioned and comparable to Oberrauch et al. (2024). Therefore, adult literacy status in general, as well as FL and DFL in particular, has a significant positive influence on digital financial inclusion (i.e., reject null hypothesis of H1 and H2).

5.2. Demographic and Socioeconomic Heterogeneity

Rural and Gender Differential: The result from Table 4, presents heterogeneity in rural and gender finance inclusion.

The negative sign of the coefficient of rural residency implies that rural adults are 50% (β = -0.507) less likely to adopt DFS than their urban counterparts. In this, the melogit result suggests that rurality's effect is caused by unobserved household-level factors captured by the random intercept. Heckman selection agrees; rural residents exhibit a 1.29-unit lower probability of mobile ownership (β=-1.29, $p<0.001$).

Table 15, Line 4 Rural residents are 52.4% more likely to utilize mobile banking ($\beta = 0.524$, $p < 0.001$) when infrastructure limitations in mobile connection and digital access are addressed (ITU, 2023). After correcting for residence clustering, the urban-rural usage disparity narrows, suggesting that household features (social dependency, shared resources, access to mobile technology) mitigate rural disadvantages.

Similarly, this finding presents that women face 51% lower odds of adoption ($\beta = -0.514$, $p < 0.01$), reflecting continued lagging in using DFS (i.e., consistency with low DFL and FL scores presented in the prior bivariate testing), which Melogit revealed a gender disparity that is masked by household-level clustering. The Heckman mobile selection model is the same on this. The result validated existing hypotheses.

However, the outcome model line 4 indicates gender differences in usage are statistically insignificant (β=0.049, p=0.356). This suggests that once females overcome ownership deficits, their usage patterns align with males. The key insight is that gender gaps come primarily from ownership disparity, not behavioral differences in usage. Robust intervention could mitigate this inequality.

Thus, despite assertions of progress, millions of rural citizens and women remain excluded from digital financial services via mobile technology, echoing the traditional financial exclusion of earlier times. This underscores the need for redoubled efforts to transition from exclusion to inclusion.

Mobile ownership as a gateway: The logistics mixed-effect estimation, the finding reveals that mobile ownership is positively associated with the likelihood of using mobile money banking, and the estimate is statistically significant ($\beta = 0.722$, $P < 0.05$). And the Heckman selection equation ($\beta = 0.062$, $p < 0.001$), indicating that as much as education, mobile ownership is a critical gateway to usage. Implying usage of mobile technology not only enhances access to financial services but also empowers individuals to make informed economic decisions. This connection marks the importance of integrating educational initiatives with mobile technology to foster greater financial inclusion. These testing findings suggest that while mobile ownership is a crucial starting point (validating the hypotheses), it is the intersection of factors such as user education and within-household social influences that drives the actual usage of mobile money services.

This result validates the hypothesis that mobile technology facilitates digital finance access depending on digital consumer protection (Bongomin & Ntayi, 2020; Della Peruta, 2018).

Income and employment influence on DFS: Weekly and monthly ≥600 ETB savings had a 3.87 (at ORs) and 0.763 times larger possibility of adopting DFS ($\beta=1.424$, $\beta=0.763$, $p<0.001$), as expected. Quarterly/semiannual frequent savers have also demonstrated statistically significant relationships with DFS use ($\beta=0.618$ and $\beta=0.805$, $p<0.05$). Poorer groups have less access to digital finance, as indicated by a negative 1.1 times lower mobile money adoption probability ($\beta=-1.097$). Income stratification's negative effect on the poorest adults is consistent after Heckman's selection bias correction.

Furthermore, at the 5% level of significance, employment has a substantial influence on the likelihood of individuals in using mobile banking digital financial services. Implying employed individuals are 37.3% more likely than jobless counterparts to use digital financial services ($\beta=0.373$, $p<0.05$).

Aging Nonlinear Effects: Age-related mixed-effect logit is not significant ($p = 0.432$) because of the bias caused by household-level heterogeneity. Regarding these biases, Heckman selection is strongly correct in representing the actual on-ground reality of digital equity in finance across all age groups. Specifically in this case, Heckman's selection equation in Table 4, line 5, indicates each additional year of age increases mobile ownership probability by 0.114 units ($\beta=0.114$, $p<0.001$). while the age square negative quadratic term ($\beta=-0.0012$, $P<0.001$) indicates diminishing returns to age. The turning points occur at 47.5 years.

$$\text{Age} = \frac{0.114}{2 \times 0.0012} \approx 47.5 \text{ years.}$$

The meaning is that mobile ownership likelihood peaks around age 47.5 and declines afterward, reflecting lower tech adoption among older citizens. From a financial behavior perspective, the result implies younger adults drive both mobile ownership and usage , aligning with their greater tech familiarity; older users may face usability challenges, probably distrust of digital platforms, or prefer traditional financial services. This finding retains the above hypotheses.

5.3. Regional Disparities

Regional disparities are equally pronounced: residents of Somali region demonstrate 2.3 times higher log odds of adoption (β=2.27, p<0.001) compared to adults in Addis Ababa, likely due to Somalia's reliance on cross-border trading and on diaspora remittances. In contrast, regions like Afar show no significant gains (β=0.256, p<0.01). This finding validates Hypothesis 5 (Mustafa et al., 2023).This unique Somali case refutes the hypothesis that people in relatively developed urban places (such as Addis Ababa) are more likely to use digital financial services than those in less developed areas. While failing to reject previous hypotheses for regions such as Gambella and BG, as demonstrated, they are negative users, which persist even after the Heckman selection bias adjustment outcome model.

The Somali region's findings Provides new insights into digital finance inclusion with education. Specifically, the region's high DFS adoption and high DFL but low FL paradoxes suggest that individuals may become adept with digital tools such as mobile money applications without a formal education. The findings align with previous research by Endashaw and Shumetie (2023), Gas (2017), Moret (2016), and McBride and Liyala (2021) on Somali region adults' cross-border commercial activity with Somalia, Djibouti, and Kenya, including the influence of diasporas. Furthermore, this conclusion correlates to the key principles of Social Learning Theory (Bandura, 1977) and the diffusion of innovations (Rogers, 2003), as writers stated learning happens through observation, imitation, social interaction, and users' perceived ease of use and rewards.

By showing a neighbor how to use a payment app, for example, DFL can spread virtually through peer networks, paving the ways for digital service adoption even in situations where FL is not present. From 72% Rural Kenyans who use M-Pesa only 34% know compound interest(Global Findex,2021), while urban Indian middle-aged professionals are aware of inflation and savings, but only 22% use digital wallets due to lack of trust(Joshi et al. 2019 and Chawla & Joshi 2019).

6. Conclusion and Recommendations

6.1. Conclusion

This study demonstrated the critical role of adult dual literacy drivers via digital and financial literacy upskilling (DFL/FL) in bridging Ethiopia's financial exclusion to inclusion. Particularly focused on underserved rural residents, women, low-income groups, the unemployed, and those with skill deficiencies.

The hybrid approach robustly confirms that hierarchical socioeconomic disparities and emerging digital exclusion facilitated by mobile technology continue inequality, with rural residents facing significant barriers to accessing financial resources and women lagging behind men in using digital mobile banking services. The aging effect on digital finance is more favorable for the young than the old, making aging challenging. Regional disparities persist, which is uniquely revealed by the Somali region's higher mobile banking adoption without having strong FL reflecting uneven policy practices.

Furthermore, both bivariate and hybrid regression analyses consistently showed that DFL was the most important predictor of digital financial services inclusion. In line with Ethiopia's Digital & Financial Inclusive Ecosystem Strategic Solution (2021–2030). On top of that, it revealed that implementing DFL tools synergistically with general and financial education can drive significantly marginalized communities to take advantage of mobile technology. Thus, this paper contextualized DFL/FL, interrelated concepts, as key enabler tools for inclusion aspirations aligned to the on-ground reality of exclusion, contributing to the transition paths to robust, sustainable, inclusive development.

6.2. Recommendations:

To address both persistent inequality and the emerging digital divide, policymakers and regulators should consider the following actionable recommendations.

First, expand (redesign) comprehensive dual digital first upskilling (DL/FL) training and educational programs for diverse demographics, including rural residents, women, and unemployed youth. Emphasize the practical use of digital tools and use of IFB-shariah compliant products and align Digital and financial education in school curricula to cultivate early financial awareness and decision-making skills. Partner with local Iddir and Equb networks to launch literacy programs grounded in platform cooperativeness concepts.

Second, regional differences necessitate specific strategies for promoting adult financial inclusion in marginalized regions like Gambella, Afar, BG, etc. Legislators should reevaluate regionally focused programs that tackle regional financial inclusion issues. Ensure financial services providers' strategies and approaches are tailored to local languages and cultural nuances, avoiding the inclusion-exclusion paradox of de-risking.

Thirdly, promote affordable access to mobile technology: Reduce costs and taxes on mobile devices and data services to make technology more affordable, particularly targeting lower-income individuals to increase mobile money adoptions. Leveraging the social learning experience of the Somali region's high adoption and usage.

Fourth. Gender and rural community-intentional policy-making: Develop and enforce policies that specifically aim at closing the gender/rurality gap in financial inclusion, which includes ensuring underserved rural women have access to digital tools and financial education programs. e.g., integrating Islamic micro-products into Telebirr, encouraging the use of sharia-compliant financial products for diverse religions, and making the service religiosity-neutral. This includes introducing a regulatory framework under NBE, with Sharia-compliant liquidity management tools.

Finally, active financial community corroboration is needed to tackle the disruptive effect of digitalization. Stakeholders should collaborate on innovative fintech regulation, improving internet connectivity in remote areas, and addressing the digital divide. Adaptive, exclusion risk-sensitive regulatory frameworks and incentives that encourage responsible and ethical investments in digital financial services, uphold social values, and ensure consumer protection and accessibility for diverse citizen groups.

Limitation and Future Research

This study's main limitation is the reliance on single-year cross-sectional ESS 2018/19 data, which may not reflect recent structural changes in Ethiopia's financial sector. Future research should use longitudinal post-2019 data and encourage interdisciplinary collaboration to better assess evolving trends in digital literacy, digital financial services, and holistic financial inclusion. This will offer a deeper, incremental understanding of the impacts of digital literacy, technology, and socioeconomic developments.

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Table 16: The definitions of variables, symbols, and hypotheses

Variables	Symbol /abbrev.	Measurements	Hypotheses	Sources
Digital Financial Service Adoption & Usage.	DFSU	Use of Digital Financial service, Binary (0=No, 1=Yes), Outcome variable	from DFL and FL (+)	ESS4, 2018/19
Digital Financial Literacy Score	DFL	Key1 variable by the PCA score of the individual self-reported ability to use (Mobile banking, Online banking , ATM .)	+	Lyons et al. (2020), Golden and Cordie (2022), and Ozili (2021c)
Financial Literacy Score	FL	Key2, Multidimensional measured by the PCA score of the individual aggregated FL scores. Indicators of FK, FA, and FB)	+	Lyons et al. (2020), Golden and Cordie (2022), and Ozili (2021c)
Gender	Female or Male	Binary 1=Female ;0=Male	-/+	Demirgüç-Kunt et al. ,(2018)
Age and Age 2	A & A2	Continuous variables in number of years and its square	A(+), A2(-)	Khmous, & Besim (2020), Zşuca (2019), and Ozili (2021)
Educational Attainment	Educ	Continuous variable: Years of schooling attended	+	World Bank (2022)
Income Frequency of Saving ≥600ETB, Weekly, Monthly.		Categorical, a proxy of, on average income, the person's ability to save ≥600 ETB at least once, weekly, monthly.	+	Lyons et al. (2020); and Demirgüç-Kunt et al. (2018)
Employment	EMP	Binary(1=employed; 0=Unemployed)	+	Lyons, et al (2020)
Mobile Phone Ownership	Mobile	Binary (1=owns mobile; 0=does not own)	+	Demirgüç-Kunt, et al., 2022
Place of Residence	Place (Rural Vs. Urban)	Binary (1 = Rural if person identify as Rural resident, other 0= Urban	Rural(-) & Urban (-)	Yang, J., et al. (2020), Shinkafi, A. (2019)
Geographic Region	Region	Category variable for geographic regions (Tigray, Afar, Amhara, Oromia, Somali, SNNP[23]	Varies by regions (+/-)	Yang, J., et al. (2020), World Bank (2022)
Household_Id		Unique identifier (clustering).		

Source: Authors compiled based Ethiopia ESS 18/19 variables and Prior literature's, 2025

[23] Since 2023, the SNNP region has been divided into four separate regions: Sidama, Southwest Ethiopia, South Ethiopia, and Central Ethiopia.

Table 17: Digital and Financial Literacy by Region

DFL BY Region	Mean 1	Mean 2	diff (M2-M1)	t value	*p value	*Cohen's d , 95%CI
AFAR	6.20%	2.80%	3.50%	3	0.001	0.145
AHMARA	6.30%	4.20%	2.10%	2.2	0.03	0.087
OROMIA	5.80%	10.00%	-4.30%	-2.75	0.006	-0.178
SOMALI	6.00%	11.50%	-5.50%	-1.95	0.052	-0.231
BG	6.10%	4.80%	1.30%	.9	0.379	0.056
SNNP	6.00%	6.60%	-0.50%	-.4	0.687	-0.022
GAMBELLA	6.40%	2.30%	4.10%	4.65	0.001	0.169
HARAR	6.00%	6.40%	-0.30%	-.3	0.777	-0.014
TIGRAY	6.10%	6.00%	0.10%	.1	0.913	0.005
DD	6.00%	6.90%	-0.90%	-.9	.373	-0.039
AA	6.00%	6.20%	-0.20%	-.25	0.799	-0.008

DFL BY Region	Mean 1	Mean 2	diff (M2-M1)	t/z	*p value	*Cohen's d, 95%CI
AFAR	0.50%	-7.20%	7.70%	4.55	0.001	0.136
AHMARA	0.20%	-1.70%	1.80%	1.35	0.178	0.033
OROMIA	1.10%	-8.80%	10.00%	6.45	0.001	0.176
SOMALI	2.70%	-26.10%	28.80%	19.65	0.001	0.514
BG	-0.10%	0.80%	-0.90%	-.5	0.635	-0.015
SNNP	0.50%	-4.20%	4.60%	3.2	0.002	0.082
GAMBELLA	-0.10%	1.10%	-1.10%	-.6	0.538	-0.020
HARAR	-0.20%	1.90%	-2.10%	-1.1	0.279	-0.037
TIGRAY	0.10%	-0.90%	1.00%	.65	0.515	0.017
DD	-1.00%	10.30%	-11.30%	-7.3	0.001	-0.199
AA	-4.00%	25.20%	-29.00%	-18.75	0.001	-0.522

NB: DFL/FL Gap, difference reported as percentage (*%) mean 2-mean 1 (M2-M1).

Navigating African Economic Governance: Political and Legal Dynamics and Trajectories

Binyam Yitay [1] [2] , Seife T. K[3]

Abstract

The Abuja Treaty, envisioned as the cornerstone for African economic and political integration towards a unified economic community, has been in effect for thirty years. Despite its developmental aspirations and initial Afro-optimism, the treaty's objectives, particularly the establishment of foundational institutions like the African Central Bank and the African Monetary Union, necessary for the effectiveness and full operationalization of the Continental Free Trade Area, remain largely unmet. This paper critically examines the structural and legal impediments that have hindered the advancement of African economic governance. It analyzes the trajectory of African economic integration, evaluating the roles, prospects, and challenges within the current legal and institutional architecture. Utilizing a qualitative research approach and discourse analysis, the study aims to identify the root causes of the implementation gap and to propose actionable policy recommendations at national, sub-regional, and continental levels. Moreover, it explores legal mechanisms to enhance intra-African economic transactions and proposes legal remedies to address existing challenges. Ultimately, this paper seeks to answer the fundamental question of why Africa has not achieved the intended outcomes of its economic governance framework and to delineate strategies for realizing a self-reliant, competitive, and influential Africa within the global economic system.

Key Words: African Economic Governance, Abuja Treaty, Political governance, Legal frameworks

[1] PhD, Independent Researcher
[2] Correspondent author, E-mail: bininabute@gmail.com or +251913757816
[3] Professor, Director CGITAS, University of Johannesburg

1. Background

African economic integration has a long history. Both the African Union (AU) and its predecessor, the Organization of African Unity (OAU), which was Africa's first post-independence continental institution, have adopted ambitious integration schemes. The Abuja Treaty was adopted in 1991, at a time when deep economic integration was believed to contain the answers to Africa's economic woes. Its ultimate objective was to establish the African Economic Community (AEC), the deepest form of economic integration. The establishment of the AEC entailed six stages, with integration taking place through intergovernmental enactments, not market-led integration. The Abuja Treaty entered into force on 12 May 1994 and foresaw political unity on the African continent.

The aims of the Abuja Treaty have not been achieved (Biswarao,2005). It has set the bar too high in terms of national sovereignty sacrifices and deep economic integration commitments. The RECs' overlapping memberships and low levels of industrialization in the member states contributed to the delays and challenges. Many of these problems are still not resolved.

In 2012, the AU decided to establish a continental FTA to which all 55 Member States of the AU would belong. This arrangement became known as the African Continental Free Trade Area (AfCFTA). It tackles the problems of Africa and sets the bar lower than the Abuja Treaty; only a continent-wide FTA is foreseen. The existing REC, FTAs and Customs unions will continue to function based on Art 19(2) AfCFTA founding Agreement, 2012 & Art 8(2) of AfCFTA Protocol on Trade in Goods (African Union, 2021). The AfCFTA founding Agreement also adopts, for the first time, the preservation of the acquis (what has already been established remains applicable) as one of the founding principles of African integration as enshrined under Art 5(f) AfCFTA founding Agreement (African Union, 2012).The AfCFTA has been adopted as a framework for Africa's industrialization and the development of value chains. These are new priorities. The AfCFTA Agreement also includes Protocols on Trade in Services, Digital Trade, and one on Women and Youth in Trade. The African Union has adopted critical programs under Agenda 2063, which have the objectives of attaining an inclusive and sustainable development. Agenda 2063 enshrined key initiatives that accelerate Africa's economic growth and development in areas of infrastructure, education, science, technology, arts, culture as well as initiatives to secure peace on the continent. One of Agenda 2063's projects is the AfCFTA. It aims at boosting trade among African nations through mutually beneficial trade agreements, and it directly touches the areas of trade (goods and services), investment, intellectual property rights, competition policy, digital trade, and women and youth involvement in trade.

Indeed, the main objective of AfCFTA is to create a single market for goods and services. Such objectives will be facilitated by free movement of people, a step-by-step elimination of tariffs and non-tariff trade barriers, customs, liberalization of trade in services, promotion of trade and investment cooperation, and other aspects of economic integration. AfCFTA will be the world's largest FTA in terms of comprising 55 countries,1.3 billion people of Africa and an aggregate GDP of USD$3.4 trillion (ECA,2025). Bearing in mind the growing population and innovative young entrepreneurs, the AfCFTA potential would have more and more than expected today.

There are differences between the AfCFTA and the AEC, which flow from different integration strategies and different historical contexts. The AU decision to establish the AfCFTA was taken more than 20 years after the adoption of the Abuja Treaty. Continental and multilateral conditions changed quite markedly during the preceding two decades. The Abuja Treaty has a time-bound integration agenda with provisions on supra-national institutions. The AfCFTA is member-driven and does not establish an international organization. The AfCFTA objectives are to “progressively” liberalize trade in goods and services and to “cooperate” in other trade-related areas. The creation of a liberalized market for goods and services will require “successive rounds of negotiations”. The Abuja Treaty does not explicitly provide for a continent-wide FTA, as the AfCFTA does. According to Article 33 of the Abuja Treaty, it is left to the parties to the Abuja Treaty to adopt rules of origin for trade in goods. As per Article 13 of AfCFTA Protocol on Trade in Goods, rules of origin must be negotiated and adopted before trade in goods among the AfCFTA State Parties can begin. Under the AfCFTA the REC, FTAs and customs unions will continue.

Under the Abuja Treaty the RECs will, by implication, disappear as the level of integration deepens and an African customs union is formed during stage four. Under the Abuja Treaty, the Member States agree to achieve the free movement of persons as per Article 43 (OAU, 1991). The AfCFTA Agreement does not contain provisions on the free movement of persons or the right to residence. Yet, the AfCFTA Protocol on Trade in Services does provide for cross-border movement of service consumers, which frequently allows for experts to deliver services in other countries. The Abuja treaty does establish a separate entity, whereas AfCFTA has an independent legal personality headquartered in Accra, Ghana.

The relationship between the AfCFTA and the AEC is not officially clarified. The Abuja Treaty was ratified and entered into force, but seems to serve more of an inspirational function now. The AfCFTA is more pragmatic and shaped by the challenges of the day. It is member-driven, and decisions are taken by consensus. There is a huge discourse about the new trade opportunities and benefits that will come about once the African Continental Free Trade Area (AfCFTA) is up and running. It is often asked what the AfCFTA, as such, will be able to deliver. There seems to be an expectation that the AfCFTA will be an organisation with independent institutions, specific executive powers, and an original mandate. In order to leap up such integration principles, a critical assessment of the AfCFTA legal framework and political dimensions of regional integration is mandatory. Under such context, this paper, therefore, dealt with the emerging prospects and bottlenecks of Africa's regional integration. More specifically, the paper will closely probe the political and legal cumbersome that associated with the progress of regional integration in Africa, with a specific focus on AfCFTA. Additionally, this paper will discuss the provisions of AfCFTA, the institutions associated with it, and the political aspects of African Economic Governance.

2. Political Bottlenecks

Regional integration covers the full range of public sector activity, including not only the coordination of economic policies, but also regional security, human rights, education, health, election observation mission, research, technology, and natural resource management (e.g trans boundary rivers, wildlife). Regional economic integration is a subset of possible regional integration (Sally, 2011). Varynen (2003) argued that regional integration is a multidimensional process (i.e. economic, cultural, and environmental). Regional integration, thus, should be viewed as a holistic approach rather than a pure economic matter. The degree of regional integration depends upon the willingness and commitment of independent sovereign states to share their socio-economic and political power.

Beyond trade and tariffs, regional integration should be conceived of as a dialectical unity of social, economic and political processes (Slocum & Langenhove, 2004). If regional integration has economic purpose only, the role of the regional scheme in most cases has nothing to do other than creating infrastructures where commodities exchanged at a reasonable price. In this regard, exchanges and markets are set up to facilitate movements of goods and people, and special attention is paid to tariff matters.

It seems that consensus existed among theorists on the vital role politics play in regional integration. This is so true for regions like Africa, where undemocratic exercises remain a challenge of attaining the prescribed goals of integration. Unconstitutional changes of government have been prevalent and witnessed in the recent upheavals in West Africa and remain as the challenges for regional aspirations of ECOWAS. Antagonism in the Horn of Africa also hindered the ambitious regional goals of IGAD as one of the RECs and a building block of AfCFTA. The SADC region, known for its relatively political stability, has been tempted by recurrent conflicts in Congo.

Regional integration can and should play a greater role in addressing issues such as democratic participation, respect for basic rights, education, social security and poverty reduction (Robert, 2004). The extent to which a region incorporates them into its regional integration scheme is an indication not only of its commitment to these ideals but also of its potential to realize a fairer distribution of integration's benefits to its citizens.

According to Kimuyu (1999), the need for regional integration in the Africa relies on a mechanism for resolving conflicts among cross-border countries. Draper et. al (2005) noted that tyranny, lack of transparency, arbitrary use of state power, and overemphasis on state-to-state relationships rather than people-to-people, as the reasons why regional integration lags in Africa. Accordingly, one of the preconditions for regional economic integration is democratic governance. Fredrick (2015) noted that the political dimension of a region should be sought as the prerequisite for successful regional integration.

Additionally, RECs that lack the mechanism of monitoring and imposing sanctions, is unlikely to trespass on the sovereignty of member states. The failure of RECs starts from this. The recent case of ECOWAS and Burkina Faso proved this logic. According to regime theory, states will better fast-track the integration process, if they would give a certain portion of their power to a regional organization that could monitor activities as well as sanction a state that disobeys the regional laws (Fredrick, 2015). It is undeniable that African countries are not ready to empower the organization by forgoing their sovereignty.

Regime theory, thus, illustrated one of the reasons of the ineffective performance of RECs in Africa. The AU has promoted the principle of non-interference that bars the organization from addressing the domestic problems of member states. RECs are a replica of the AU that it strongly defends the principle of non-interference.

The continent of Africa is notorious for the Darfur crisis that only ended after twenty years of destruction, including a genocide that killed over 2 million South Sudanese (CIA, 2025). This resulted in the splitting of Sudan into two sovereign countries. The lack of peace and security is related to the regime of an undemocratic culture and a lack of democratic institutions that deal with disputes through discussion and round-table negotiations. The existence of toothless democratic institutions remains the cause of use of force as a mechanism to address disputes and conflicts. Recently, it has been observed that member states are pushing for the promotion of democratic practices. There are new beginnings of participating RECs in the democratic process of countries, such as observing election missions. RECs should be equipped with legal, institutional, and the privileges of involvement in other political dynamics of member states.

According to the World Bank study (2014), regional integration agreements can promote regional peace and ultimately lead to political union. Similarly, increased trade reduces the likelihood of conflict: doubling trade between two countries lowers the risk of conflict between them by about 17% (ECA, 2025). IGAD thus should facilitate the harmonization of policy, in order to bring sustainable peace, security and socio-economic development in the region.

However, political will necessitates the realization of the free movement of people. RECs have developed and adopted a migration policy. A regional protocol that promotes free movement of people. Yet, member states are tepid to implement the protocol. The implementation of the protocol, however, will take time to execute. It needs the compromise of legal machineries of all member states which include border control laws, visa regulations etc. Regional integration requires political will in the first place. Member states have to implement decisions that are taken at annual summits of RECs. Incorporation of regional legislation into domestic legal systems also requires political will. Members have to smooth their relationship in order to get closer and deliberate a common regional discourse. In addition, member states have to avoid mistrust, resentment among each other in order to make the region united and competitive in the global market.

In order for the integration process to move forward, member states have to genuinely believe in it and its progress. They have to acknowledge that integration is a tedious but achievable process. The establishment of AfCFTA as a continental institution is not enough for the achievement of regionalization. Rather, member states should address the political will and commitment of AfCFTA, providing it with broad and clear responsibilities and mandates.

3. Legal Challenges

In order to attain regional aspirations, legal frameworks, policies, and institutions are available for the efficient implementation of AfCFTA. The legal framework of AfCFTA is governed by rules and regulations that facilitate the goods and services of trading parties. The legal regime strived for the promotion, enforcement of the rights and duties of intra-African trade partners. The major legal aspects of AfCFTA include:

- dispute resolution in breach of contracts,
- intellectual property rights,
- unfair competition mechanisms,
- consumer protection,
- Promotion of the right to livelihood of women and the youth.

The AfCFTA has legal instruments that cover trade in services in selected priority areas. The will AfCFTA legal bases also include issues of competition, investment, intellectual property rights, digital trade and women and the youth. If it is necessary, other subsidiary legislation will be enacted. Most interestingly, regional blocs are considered as the building blocks of AfCFTA, which have their own legal instruments.

Article 10 of the AfCFTA Agreement says the general assembly will have the ultimate power to oversee, guide and interpret the trading agreements and decisions will be made through consensus of members of the general assembly of AU. The AfCFTA had structures including the General Assembly, Council of Ministers, the Committee of Senior Trade Officials, and the secretariat, which was deemed independent but financially dependent upon the African Union. The Secretariat does not have privilege, diplomatic immunity, unlike other specialized bodies of the African Union such as the African Peer Review Mechanism (APRM). The legal provision of AfCFTA also does not give a separate entity for RECs, rather, they are represented in the Committee of Senior Trade Officials just as advisors. It seems fair to expect considerable institutional expansion and adjustment in the AfCFTA. This will be necessary in order to ensure opportunities for continent-wide free trade materialise and for achieving the general objectives listed under Article 3 of the

AfCFTA Founding Agreement.

One of the key legal provisions of AfCFTA is dispute settlement. Estrada (2009) documented that regional integration creates reciprocal benefits by enthroning a peaceful environment, which in turn works as insurance against any form of disputes among member states, trade disputes included. Article 20 of the AfCFTA Founding Agreement provides for a Dispute Settlement Mechanism as part of the overall AfCFTA design as follows:

1. A Dispute Settlement Mechanism is hereby established and shall apply to the settlement of disputes arising between State Parties.
2. The Dispute Settlement Mechanism shall be administered in accordance with the Protocol on Rules and Procedures on the Settlement of Disputes.
3. The Protocol on Rules and Procedures on the Settlement of Disputes shall establish, inter alia, a Dispute Settlement Body.

The Dispute Settlement Body (DSB) is composed of representatives of the State Parties. It has the authority to establish Dispute Settlement Panels and an Appellate Body, to adopt Panel and Appellate Body reports, to maintain surveillance of implementation of rulings and recommendations of the Panels and Appellate Body, and to authorise the suspension of concessions and other obligations under the AfCFTA Agreement. The DSB of the AfCFTA has attended to the outstanding tasks such as the adoption of rules of procedure, drawing up a roster for Panelists, and appointing the Members of the Appellate Body. The relevant decisions now need to be adopted by the AfCFTA structures, such as the Council of Ministers, in order for this Mechanism to become operational (Erasmus,2025).

Since the AfCFTA Agreement is officially in force since the 30th of May 2019, it may be feasible, in principle, to use the AfCFTA Protocol on Rules and Procedures on the Settlement of Disputes, to settle disputes among the State Parties in accordance with the procedures set out in the Protocol. However, trade in goods and services under the AfCFTA are not yet possible. The required tariff schedules, rules of origin and conditions for trade in the five priority services areas are still being negotiated.

Disputes about related AfCFTA matters such as trade facilitation, customs administration, and the non-discrimination principle might arise, but the settlement thereof will be more of a theoretical than a practical nature. Most of the trade in goods and services on the continent will continue under existing RECs arrangements.

It will make more sense for the trading parties to such disputes to use the RECs Courts or dispute settlement mechanisms for settling such disputes.

The typical advantage of a dispute settlement system forming part of a single undertaking trade regime is that legal certainty and predictability become systemically enshrined (Abdi & Seid, 2013). These benefits all parties involved in cross-border trade, investment, and consumption. Article 4 of the AfCFTA Dispute Settlement Protocol says the AfCFTA dispute settlement mechanism “is a central element in providing security and predictability to the regional trading system. The dispute settlement mechanism shall preserve the rights and obligations of State Parties under the Agreement and clarify the existing provisions of the Agreement in accordance with customary rules of interpretation of public international law”.

Only the AfCFTA State Parties, African Union Members that have ratified the AfCFTA Agreement will be able to file applications. Private parties and firms are the entities normally affected by unlawful state action, but will not have standing under this dispute settlement arrangement. Nothing prevents their states of nationality or those with sufficient connection from filing a case against another state party. One of the implications is that private parties and firms should push for their own states to take up cases on their behalf. There are examples of domestic arrangements where private parties and firms have rights vis-à-vis their own governments and are entitled to invoke protection via international litigation effectively instituted on their behalf. This does not happen locally.

The AfCFTA dispute settlement mechanism is modelled on the Dispute Settlement Understanding (DSU) of the World Trade Organisation (WTO), but provides a framework to develop a unique dispute settlement regime, jurisprudence for the continent, although it will exist alongside the REC dispute settlement systems. Jurisdictional boundaries will have to be demarcated with care. International courts only have jurisdiction over those matters covered by the legal instruments falling under their jurisdiction. In respect of intra-African trade issues, it might be possible that more than one forum could have jurisdiction. If two African countries, members of both the WTO, a particular REC, and the AfCFTA, have a dispute over a mineral issue, the application for enforcing the relevant rights might be brought under WTO rules, before the relevant REC Court, or under the AfCFTA Dispute Settlement Mechanism. The main reason is that, in respect of mining issues, the same principles can be applied under these agreements. The deciding factor is whether the forum in question has jurisdiction over the matter and whether the applicant and respondent have standing. An AU state party that has invoked the rules and procedures of the AfCFTA Dispute Settlement Protocol shall not invoke another forum for dispute settlement on the same matter.

A dispute settlement proceeding shall be considered to have been initiated in accordance with the AfCFTA Protocol when the complaining party requests consultations as per Article 7 of this Protocol. State parties to a dispute may at any time voluntarily undertake good offices, conciliation, or mediation for settling a dispute. Whether the AfCFTA State Parties will ever actively use the AfCFTA Dispute Settlement Mechanism is another matter. They prefer to settle their trade-related differences through discussions, consultations or by allowing for derogations in particular instances. This has been the practice under the rules of those RECs with their own dispute settlement mechanisms and Courts. International arbitration is not used to settle trade disputes either (Erasmus, 2021). It seems unlikely that the practice under the AfCFTA will be different. If matters should turn out another way, it could bring about a very important change in how African governments pursue economic integration and trade liberalisation amongst themselves. It will also promote and protect the rights of private parties, importers, exporters, consumers, and investors. A rules-based trade regime will, in effect, be brought about.

As indicated earlier, the implementation of the Dispute Settlement Mechanism of the African Continental Free Trade Area (AfCFTA) is governed by the Protocol on Rules and Procedures on the Settlement of Disputes and have the following institutions: The Dispute Settlement Body (DSB), Panels, and the Appellate Body (AB). The AfCFTA Secretariat, which is one of the main AfCFTA institutions, will play an important role in terms of providing logistical and practical support services, including to AfCFTA State Parties when required.

The DSB has been established in accordance with Article 20 of the AfCFTA Agreement and has to administer the AfCFTA Dispute Settlement Protocol. It is composed of representatives of all the State Parties and has the authority to establish Dispute Settlement Panels and an AB, to adopt Panel and AB reports, to maintain surveillance of implementation of rulings and recommendations of the Panels and AB, and to authorise the suspension of concessions and other obligations under the Agreement.

The DSB will take decisions by consensus, unless otherwise provided. The reverse consensus rule applies to the adoption of important matters, such as the adoption of Panel reports and AB rulings. This implies that an AB report shall be adopted by the

DSB and unconditionally accepted by the Parties to the dispute unless the DSB decides by consensus not to adopt the AB report. As highlighted in preceding pages, disputes under this Protocol commence when a complaining party invokes Article 7 of the Protocol and requests consultations to be held with another State Party, to reach an amicable resolution of a dispute. Where they fail to settle a dispute through consultations, the complaining party may refer the matter to the DSB, for a Panel to be established.

The secretariat shall establish and maintain an indicative list or roster of individuals who are willing and able to serve as Panelists. A Panel shall make an objective assessment of the matter before it, including the facts of the case and the applicability of the relevant provisions of the Agreement, and make findings to assist the DSB in making a recommendation and a decision. If a Party to a dispute appeals against the findings of a Panel, the matter goes to the Appellate Body (AB), which is a standing body and established by the DSB. It shall be composed of 7 persons, 3 of whom shall hear and decide an appeal, serving on a rotational basis. AB members are appointed for a four-year term, renewable once. Members of the AB shall not be affiliated to any government.

Where the DSB fails to appoint a person to fill the vacancy within 2 months, the Chairperson of the DSB shall, in consultations with the Secretariat, within a period of 1 month, fill the vacancy (African Union, 2019). This procedure will prevent the AfCFTA Dispute Settlement Mechanism from suffering the stalemate presently existing in the WTO, where the refusal by the United States to cooperate in the appointment of new AB members has caused an impasse. The WTO has no functioning AB at present.

This design indicates that the Dispute Settlement Understanding (DSU) of the WTO has served as the model for the AfCFTA's own Dispute Settlement Mechanism. This does not mean that it is a precise copy. There are differences in terms of procedures, membership, and jurisdiction. Disputes under the AfCFTA Protocol will, of course, involve disagreements between AfCFTA State Parties regarding the interpretation and application of the Agreement in relation to their rights and obligations. The AfCFTA Agreement is defined to mean the Agreement Establishing the AfCFTA and its Protocols, Annexes and Appendices, which shall form an integral part thereof. All AfCFTA State Parties are obligated to respect and give effect to the Dispute Settlement Mechanism. It forms a central element in providing security and predictability to the regional trading system. The dispute settlement mechanism shall preserve the rights and obligations of State Parties under the Agreement and clarify the existing provisions of the AfCFTA Agreement (African Union, 2012).

Disputes declared in terms of the AfCFTA Dispute Settlement Protocol can be settled during the consultation phase, which comes first and is compulsory. Article 7 of the AfCFTA Dispute Settlement Protocol provides that "in the course of consultations and before resorting to further action under this Protocol, State Parties shall attempt to obtain a satisfactory settlement of the dispute". The Parties involved in successful consultations will also decide how their settlement will be implemented and only they are bound by the terms of the settlement agreed upon by them. It will not create a precedent for others.

A Panel under AfCFTA considers the rebuttal submissions and arguments of the parties to a dispute and issues a draft report, to which the parties to a dispute shall submit their written comments. A final Panel report is then circulated. It shall be considered, adopted, and signed at a meeting of the DSB convened for that purpose, unless a party to the dispute formally notifies the DSB of its decision to appeal, or the DSB decides by consensus not to adopt the report. Such a procedure is called the reverse consensus rule.

In the final phase, the matter will be heard by the Appellate Body (AB). Appeals are limited to issues of law covered in the Panel Report and legal interpretations developed by a Panel. An AB report shall be adopted by the DSB and unconditionally accepted by the Parties to the dispute unless the DSB decides by consensus not to adopt the AB report within thirty days following its circulation to the State Parties. Where the Panel or the AB concludes that a measure complained of is inconsistent with the AfCFTA Agreement, it shall recommend that the state party concerned bring the measure into conformity with the Agreement. This is the actual remedy. The basic objective is for the Dispute Settlement Mechanism of the AfCFTA to "preserve the rights and obligations of the State Parties under the Agreement" by applying and clarifying the applicable legal provisions in light of the facts of a particular case. In addition to its recommendations, the Panel or the AB may suggest ways in which the State Party concerned could implement the recommendations. The State Parties shall promptly comply with the subsequent recommendations and rulings of the DSB.

The Dispute Settlement Protocol contains detailed provisions on the surveillance of measures taken to implement recommendations and rulings. Where the Parties to the dispute disagree as to whether the measures taken comply with the recommendations and rulings, such disagreement shall be decided through recourse to the same dispute settlement procedures, including, wherever possible, resort to the original Panel. The DSB shall keep the implementation of adopted recommendations or rulings under surveillance. It is the duty of the State Parties to fully implement the recommendations and rulings of the DSB. Compensation and the suspension of concessions or other obligations are temporary measures available to the aggrieved Party in the event that the accepted recommendations and rulings of the DSB are not implemented within a reasonable period of time.

The suspension of concessions or other obligations shall be temporary and shall only be applied in as far as it is consistent with the AfCFTA Agreement. This state of affairs shall only apply "until such a time as the inconsistency with the Agreement, or any other determined breach is removed, or that the State Party implements recommendations, or provides a solution to the injury caused, or occasioned by the non-compliance, or that a mutually satisfactory solution is reached". In the event that the rulings and recommendations of the DSB are not implemented within a reasonable period of time, the aggrieved party may request the DSB to impose temporary measures, which include compensation and the suspension of concessions. If the State Party concerned fails to bring its measure found to be inconsistent with the Agreement into compliance therewith or otherwise comply with the decisions and rulings within a reasonable period of time, the parties shall enter into negotiations with a view to developing mutually acceptable compensation. If no satisfactory compensation has been agreed upon within twenty days, a complaining party may request authorisation from the DSB to suspend the application to the State Party concerned of concessions or other obligations under the Agreement.

Ultimately, the matter can be referred to arbitration. The Parties to a dispute shall accept the arbitrator's decision as final, and the parties concerned shall not seek a second arbitration. The DSB shall be informed promptly of the decision of the arbitrator and shall, upon request, grant authorisation to suspend concessions or other obligations where the request is consistent with the decision of the arbitrator, unless the DSB decides by consensus to reject the request.

The AfCFTA Agreement contains a detailed dispute settlement Protocol. It is modelled on the Dispute Settlement Understanding (DSU) of the World Trade Organisation (WTO). Article 4 of this Protocol says "the dispute settlement mechanism of the AfCFTA is a central element in providing security and predictability to the regional trading system … and shall preserve the rights and obligations of State Parties under the Agreement and clarify the existing provisions of the Agreement in accordance with customary rules of interpretation of public international law.

Only AfCFTA State Parties have standing to file claims under this Protocol, which can be heard and decided by Panels and the Appellate Body of the AfCFTA. Since violations of obligations regarding trade in goods and in services in most instances impact on private firms, it is for the national governments of the relevant countries (if they are members of the WTO or the AfCFTA) to litigate against States adopting and implementing measures in violation of their obligations. This is standard practice where hundreds of cases have been decided under the DSU of the WTO since 1995, when the WTO was launched.

Whether the State Parties to the AfCFTA Agreement will actually declare disputes against each other in respect of the interpretation or implementation of the legal instruments of the AfCFTA, is another matter. They have not done so in respect of trade issues in terms of any of the REC Agreements under which they have been trading with each other for decades now. Some of these RECs (e.g. the EAC, COMESA, and ECOWAS) have their own Courts. The SADC Tribunal was abolished in 2010 after it had ruled against Zimbabwe for expropriating private land without compensation (Page, 2012). These courts frequently rule on applications brought by private parties, which often deal with human rights issues. There have been a few cases about trade measures of Member States. It is likely that there will be more such cases.

When States never use the courts that they have established as part of their trade and integration arrangements, the legal certainty and predictability generated through adjudication will remain absent. This is unfortunate because it undermines the rules-based nature of these arrangements and of investor confidence. It also puts deeper integration schemes in jeopardy. That raises the obvious question: Why do African Governments not litigate against each other over trade issues? They will do so when border issues are at stake. It has been said that it is a sign of disrespect for other sovereign African States to drag them to court (ECA, 2006). This does not sound convincing. Litigation need not be hostile. Persistent disputes and accusations cannot be good for mutual respect or for trade. It would be better to get uncertainty about the relevant legal obligations out of the way and continue with business as before. And formal consultations are, in any case, the first phase of a dispute settlement procedure. Apparently, African governments use consultations for managing the status quo and finding "political solutions" (Balassa, 1961). When this happens, there is no transparency and no legal precedent for planning and executing commercial transactions.

However, formal dispute settlement in the African context is a complicated matter. The parties to these arrangements face difficult domestic challenges, which they prefer to address by exercising national policy space over the use of trade instruments such as the import tariff. Legal obligations to liberalise trade make this problematic. Governance capacity is another challenge. Only two African countries (South Africa and Egypt) have operational trade remedy and safeguard systems in place (Ousseni, 2012). Competition regulation is another such example. If trade remedies and competition were in place, it would be possible to deal with unfair trade practices by firms and surges in the importation of goods in a predictable and rules-based manner. The national regulation of services and service providers is central to the implementation of obligations regarding the liberalisation of trade in services, but functions in terms of national laws. Hopefully, the AfCFTA will see concerted efforts to improve trade governance. It has, for example, a detailed Annex on trade remedies and safeguards and provisions to coordinate the regulation of services traded under the AfCFTA.

There remains an unanswered question whether AfCFTA regime brings about a new approach and a willingness to use continental dispute settlement mechanisms or not. The judgments of the REC Courts show that dispute settlement can bring clarity, certainty, and guidelines about compliance. There is a growing body of case law on matters such as the interpretation of African trade agreements and how the Vienna Convention on the Law of Treaties can be used, the nature of obligations when deeper integration regimes such as customs unions are implemented, variable geometry, national treatment and whether specific Parties to a REC regime can suspend obligations inter partes because obligations are not “cast in stone”. At least two cases can be cited: the rulings by respectively the COMESA Court of Justice in Polytol Paint and adhesives Manufacturing Co. Ltd versus the Republic of Mauritius and by the EAC Court of Justice in British American Tobacco versus the Attorney General of Uganda. The former dealt with a bilateral increase in tariffs in violation of a decision by COMESA structures to liberalise trade in goods. The latter discussed excise duties in a customs union imposed on products imported from a Partner State but not on like domestic goods. These are issues that frequently arise in the pursuit of economic integration and trade liberalisation on the continent.

On the other hand, a coinciding membership remains one of the major problems of regional integration in Africa where of the 53 African countries, 26 are members of two regional communities, and 20 are members of three; 1 country (Democratic Republic of Congo) belongs to four; only 6 countries maintain membership in just one regional organization (ECA,2025). However, due to overlapping membership, partners of some RECs consider them as a political group than a development partner of regional integration (Draper & et al, 2007). For example many programmes of IGAD are also run by COMESA. Thus, partners considered the money to be given for IGAD as duplication. The lack of rationalization among different regional blocs creates confusion among development partners (Yitay & Tsoaledi, 2017).

Estrada (2009) argues that regional integration may contribute to regional frictions between competing blocs through creating multiple legal frameworks and various dispute settlement mechanisms as well as absorbing other multilateral arrangements. This is true especially in regions where coinciding membership is rampant. Overlapping RECs membership is widespread. This makes the application of trade remedies more complicated. It also brings other disadvantages, such as conflicting rules of origin, different procedures for customs, transport, and standards. Overlapping REC membership adds costs to commerce across borders and constitutes a trade barrier in its own right. One of the general objectives of the AfCFTA is to resolve the challenges of multiple and overlapping memberships.

The RECs have a long history within the narrative of African political cooperation and economic integration (Biswarao, 2005). RECs are also referred to as the building blocks of the AfCFTA. Yet, it could be argued that although the same eight configurations are recognized as the RECs, their roles in separate configurations are not the same. Over time, some of them have changed quite markedly. Their membership is constantly changing, and overlapping membership across RECs is an important feature. Some of them are pursuing deep integration agendas. Others have not yet even formed FTAs.

The RECs are not a homogenous group and cannot be expected to contribute to the continent's integration in similar fashion. They must also adapt to new developments and challenges and are expected to play different roles as the debate about and the African economic integration agenda develop. We suggest that the legal instruments of particular arrangements that employ the RECs as building blocks should be consulted to understand their roles in specific contexts.

RECs are regional groupings of African states. The RECs have developed individually and have different roles and structures. Generally, the purpose of the RECs is to facilitate regional economic integration between members of the individual sub-regions and through the wider African Economic Community (AEC), which was established under the Abuja Treaty. The 1980 Lagos Plan of Action for the Development of Africa and the Abuja Treaty proposed the creation of RECs as the basis for wider African integration, with a view to regional and eventual continental integration. The RECs are increasingly involved in coordinating AU Member States' interests in wider areas such as peace, security, development and governance.

There are different expectations about being building blocks of African regional arrangements. In respect of the AEC, the Abuja Treaty mentions a step-by-step programme of how all the RECs will move up the ladder of deeper integration. In the early stages, RECs are to establish FTAs and then Customs Unions, following which a continental customs union is to be established. A continental common market is then to be established, through the adoption of common policies in areas such as agriculture, transport, communications and energy, as well as harmonization of monetary, financial and fiscal policies, to bring the AEC into being. They will then presumably disappear. This has not happened, and four of the eight RECs have not yet formed FTAs.

The AfCFTA Agreement has added and a new role for the RECs. It provides that only REC, FTAs are building blocks for the AfCFTA. This Agreement also adds an important qualification by providing that existing CUs and other African trade arrangements that have attained among themselves higher levels of regional integration than under the AfCFTA, shall continue and maintain such higher levels of integration among themselves. The AfCFTA does not intend to abolish any of the RECs. This makes sense from another angle, over time, some of the RECs have grown into anchor points of intra-African trade.

The expectations expressed in continental legal instruments such as the Abuja Treaty and the AfCFTA Agreement constitute one context for discussing the role of the RECs. The other very relevant one is the internal agenda of specific RECs and their internal legal obligations. This implies that those RECs that have grown into customs unions will and must protect the integrity of their common external tariff. They therefore make tariff reduction offers under the AfCFTA negotiations collectively. Intra-RECs' needs and dynamics will have a direct effect on what tariff reductions will be offered. They will protect the gains already achieved because these bring important regional and global trade benefits.

Overlapping membership configurations are a major problem. This results in duplication, additional costs, and the dilution of the regional focus. One of the general objectives of the AfCFTA is to "resolve the challenges of multiple and overlapping memberships and expedite the regional and continental integration processes" (Alex, 2015). It does not, however, provide for a blueprint on how to achieve this objective. The clarification of the role of the AfCFTA's building blocks should be on its to-do list. Overlapping membership remains one of the major legal challenges of regional integration in Africa. Overlapping membership is cumbersome to apply uniform legal standards among member countries of Africa. There is a need to harmonise legal frameworks, instruments, and tools between RECs of Africa and be ready to govern by continent wide applicable legal rules.

4. Conclusions and Recommendations

As the major regional integration initiative, The AfCFTA remains the most important legal framework with the potential to integrate countries of Africa into regional and global value chains, enhancing their opportunities of transforming their economies, achieving the Sustainable Development Goals and implementing Agenda 2063: The Africa We Want, of the African Union. In order to achieve meaningful integration the legal and political bottlenecks of regional integration needs to be addressed.

Uncertainty is the enemy of endeavours to promote effective regional integration and trade. Business enterprises must count on predictable outcomes when making investments and pursuing commercial ventures within national jurisdictions and across state borders. The ability of the private sector to deal with risk factors requires, amongst other things, reliable legal environments. This includes transparent laws and regulations and the availability of legal remedies when rights are infringed or threatened. These should exist at national, regional, and continental levels, especially now that the first steps are being taken to start trading under the AfCFTA. As has often been observed of the AfCFTA, it has tremendous potential for boosting intra-African trade "if properly implemented". Ultimately, regional integration efforts should be underpinned by inter-state arrangements consisting of appropriate and enabling legal frameworks.

Effective and legitimate dispute resolution mechanisms should also be part and parcel of regional integration efforts. When differences arise about whether the right procedures have been followed or obligations in trade agreements have been respected by officials operating at borders or within national jurisdictions, they should be resolved through the objective and impartial application of mutually agreed norms. The parties to such disputes must accept the results of adjudication or other dispute settlement processes as fair, final, and binding. These basic practices are an integral part of good governance and the rule of law. Trade remedies and safeguards are used by governments to deal with unfair trade practices and unforeseen consequences when trade in goods is liberalised. However, they must comply with specific requirements and must be justified. African countries seldom use them.

Several explanations for Africa's limited use of anti-dumping, countervailing and safeguard measures have been offered. One of them is that African States lack the required technical capacity. Trade remedy investigations are said to be cumbersome and costly. Another one is that most African States do not have the national legislation and institutions to undertake investigations and implement trade remedies and safeguard measures.

It is true that the necessary national legislation and investigating authorities must exist in order to investigate applications for trade remedies and safeguards and to impose the permissible measures. But this does not require costly and sophisticated structures. The laws of several African States already provide for these investigations and for imposing anti-dumping duties. National laws on customs and excise are examples. They often contain provisions for undertaking anti-dumping investigations and for levying anti-dumping duties. Competition commissions may, in some cases, investigate anti-dumping practices as predatory pricing cases, but do not have jurisdiction over trade issues. Their ability to undertake investigations related to unfair practices of firms can, however, serve as a starting point for developing capacity involving investigations into unfair trade practices.

When the AfCFTA is properly implemented, there will be an opportunity to undertake concrete steps to assist the State Parties in addressing domestic needs in respect of trade remedy governance. Article 11 of Annex 9, calls on the AfCFTA Secretariat to assist State Parties with the establishment of Investigating Authorities and the adoption of the necessary legislation. But drafting new laws for AfCFTA State Parties will not be enough. The State Parties and REC structures should also be supported in respect of trade data collection. Stakeholders such as private firms must be included in developing the required initiatives. The private sector is responsible for submitting requests for trade remedy investigations.

The inclusion of trade remedy and safeguard provisions in the AfCFTA Agreement signals an important message. When governments employ these measures, they must comply with the applicable rules and procedures. Private firms can apply for them. The inclusion of detailed trade remedy and safeguard provisions in the AfCFTA

Agreement could result in domestic trade regulatory measures becoming more transparent, rules-based, and justiciable. Arbitrary and discretionary actions will become less frequent and due process of law will increase and ultimately cases will be entertained in local (and regional) courts.

On the other hand, politics as one of the major drivers of regional integration, has to be considered in a very critical intellectual rigor. The political elites have to firmly believe in the integration process and step by step or progressive realization of AfCFTA's objectives. The decisions made by RECs and AfCFTA should be observed. In considering the previous insights, the paper will make recommendations as follows:

- Concerted efforts in forging a partnership of harmonization of legal frameworks among RECs to effectively implement AfCFTA and the Abuja treaty,
- Clarification on the roles, mandates, duties and responsibilities of institutions that were created for implementing the functions of AfCFTA,
- Advocate for Ministers to enact directives that support the implementation of AfCFTA,
- Avoiding duplication of regional programmes through reducing overlapping membership that will spill over in reducing the already depleted resources,
- Designing domestic resource mobilization mechanisms to ensure sustainable means of financial and capital resources,
- Fostering culture of tolerance, democracy, harmony, civic virtues among AU member states as well as empowerment of women, marginalized sections of the society and the youth to arrive on inclusive regional integration agenda as the per the ratified Protocols of AfCFTA,
- Rendering political solutions for problems that could not addressed through conventional means,
- Lobbying for increased financial, technical and capital assistance from the international community to support the financial needs of institutions that not only help them to function properly rather foster their independence/autonomous,

- Enacting legislations that promote digital economy, innovation and responsible use of Artificial Intelligence,
- Promote people to people, social and cultural exchanges as an effective means of consolidating regional cooperation, understanding and common regional makeup,
- Create awareness on AfCFTA, the Abuja Treaty and other continental initiatives for entrepreneurs, informal traders and relevant continental free trade stakeholders,
- Draw lessons, best practices from other free trade arrangements such as ASEAN, EU, and USMCA.

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Policy Drivers and Novel Approaches for Transforming Urban Migration Governance and Sustainable Development in IGAD Countries: Lessons from Ethiopia

Eyob Esatu[1] and Abraham Asha[2]

Abstract

The East and Horn of Africa region continues to face major challenges in managing mixed migration, driven by limited regular migration pathways, weak border governance, constrained economic opportunities, and persistent instability that fuels trafficking and smuggling networks. This study aims to identify policy drivers and innovative approaches to strengthen urban migration governance across the Horn of Africa and IGAD countries, using both qualitative and quantitative methods. Migration and urbanization are increasingly interconnected: migration contributes significantly to urban growth, while cities attract large numbers of migrants, refugees, and IDPs. When poorly managed, this places immense pressure on housing, services, and infrastructure, often forcing migrants into informal settlements and prolonged insecurity without legal status. Despite COVID-19 disruptions, the region recorded around 674,242 irregular migrant movements in 2020–2021, with the Horn of Africa route accounting for half of these flows. Migration and urbanization also exert pressure on environmental systems through growing consumption, waste, and land-use changes, although evidence on environmental impacts remains mixed. While migration can drive sustainable development by enhancing skills, labor markets, investment, and cultural diversity, as emphasized in the 2030 Agenda, poor governance can expose migrants to risks and strain host cities. Many policy responses still apply a rural lens to urban migration challenges, as seen in Ethiopia's land lease policy, which overlooks livelihood needs of peri-urban displaced families who often end up in informal settlements. The study highlights the need for a whole-of-government and whole-of-society approach to ensure migration is integrated into policies on health, education, trade, and fiscal systems. Inclusive digital IDs, improved access to basic services, and rights-based border and labor policies are essential. Strengthening governance also requires

[1] Email: isdafrica2013@gmail.com Telephone: +251973345089; Affiliation: Organization for Innovation and Sustainable Development Africa

[2] PhD, Email: A.asha@africa-union.org Telephone:+251968457204

Affiliation: African Union Commission, Economic and Social Development Policies Section

effective implementation of the New Urban Agenda, revising outdated migration policies, and leveraging National Coordination Mechanisms. Policy directions should align with the Global Compact for Migration, the AU Migration Policy Framework, and regional instruments such as IGAD's migration frameworks and the free movement protocol. Reimagining migration governance in the region is critical to enhancing cooperation and addressing key areas, including data management, labor mobility, border systems, climate change, gender, and the integration of refugees and asylum seekers into urban communities.

Key Words: Policy Drivers, Novel Approaches, Urban Migration Governance, IGAD Countries

1. Introduction

The East and Horn of Africa region continues to grapple with challenges in managing mixed migration as a significant number of migrants move irregularly across and beyond the region. Limited options for regular migration, lack of strong border governance capacity of countries, limited economic opportunities, and continued instability enable the existing migrant trafficking and smuggling industry in the region to facilitate irregular migration. Despite the COVID-19 pandemic, there were approximately 674,242 recorded irregular movements of migrants within the region in 2020 and 2021. The Horn of Africa route accounted for 50% of the movements, while the Eastern, Southern, and Northern routes accounted for 40%, 9%, and 1%, respectively.

Governments in the region are working towards addressing this challenge through enhancing their migration policy-making capacities through the enactment of new migration policies and the revision of existing policies. A number of countries have also put in place National Coordination Mechanisms (NCMs), which play a major role in migration policy-making and implementation. These policy directions are informed by the Global Compact for Migration (GCM) and the African Union Migration Policy Framework and its Plan of Action (2018–2030. Migration policy frameworks by the Regional Economic Communities also play an important role, including the East African Community's Common Market Protocol, Intergovernmental Authority on Development (IGAD)'s regional migration policy framework (2012), and the free movement of persons protocol (2021).

Global and regional migration policy frameworks adopted or ratified by most countries in the region are not being domesticated and implemented in line with country-specific commitments. State fragility, regime changes, competing government priorities and capacity gaps are some of the reasons attributed to this disparity. Further, migration as an adaptation to climate change and migration data management are limitedly considered in adopted and draft national migration policies despite their centrality in contemporary migration dynamics in the region. Generally, data on migration is fragmented and there is a lack of policy coherence between migration policies addressing different migration issues, reinforced by coordination challenges amongst migration stakeholders at both national and local levels. Commendably, the Intergovernmental Authority on Development (IGAD) Member States have established National Coordination Mechanisms for migration (NCMs) that have been central to migration coordination. The NCMs are, however, not anchored in law and have limited mandates to formulate and monitor the implementation of policies. Reporting on migration is also generally poor, especially among law enforcement officials and the judiciary, who apply policy-related legislative frameworks differently and are not often privy to legislative updates, following policy formulation. Local government administrators, police and border officials commonly restrict, fine and/or detain non-nationals in unlawful or unnecessary manners contrary to legislative frameworks related to migration governance.

About 53% of African migrants remain in the region (Kamdem 2017). Eastern Africa in general accounts 71% of total emigration. Ethiopia, exceeding 1 million, is the major receiving country of intra-African international migrants. To effectively address urban migration and its impact on sustainable development in the Horn of Africa and IGAD countries, a multi-faceted approach combining policy, governance, and sustainable urban development strategies is needed. This includes integrating refugees into urban areas, strengthening regional migration policies, and focusing on long-term development-oriented integration rather than just care and maintenance.

One of the main challenges regarding migration governance is delineating which actors and policies are relevant to migration and how various actors and policies interact with non-migration policies to affect migration outcomes; migration trends may be influenced by various kinds of events and actions, such as economic policies or conflict. This background paper is structured by the aspects of migration governance highlighted in the definition above, using the case study of Ethiopia. These analytical ‘building blocks’ are intended to form an accurate impression of the current state of migration governance in Ethiopia. This study is therefore aimed at identifying policy drivers and novel approaches for transforming urban migration governance and sustainable development in the Horn of Africa and IGAD Countries case taking the country-specific urban migration governance context of Ethiopia. It is noted, however, that migration governance is continually evolving, particularly in complex migration environments such as Ethiopia, and therefore provides an overview of the urban migration governance situation specifically in IGAD countries.

2. Statement of the Problem

Urbanization in the Horn of Africa has distinct features that have shaped its growth over time. Urbanization and economic growth are closely related across several dimensions, but the relationship between the two is complex and non-linear in East Africa. Not all cities have similar levels of economic performance, and the measures needed to encourage economic development can vary from city to city. A host of factors contribute to urban productivity and help to determine whether cities will reach their productive potential. Geomorphology, land topography, geopolitical fragility subtended by Red Sea, unregulated population settlements, loose urban land policies, high slum congestion and low-paced industrialization are the major factors for rigid structural transformation and sustainable urbanization in Horn of Africa. When the urban population grows at 10% it gives the yield of labor productivity at a rate of 0.3%. This indicates there is very insignificant urban labor productivity that is hindering the pace of structural transformation in the urban areas of the region.

The Horn of Africa hosts high numbers of refugees and IDPs. By the end of 2022, the region hosted more than 4.7 million refugees and asylum seekers and more than 10 million IDPs (UNHCR 2023). In fact, “over two-thirds of all refugees and asylum seekers in Africa [3.5 million refugees] are hosted in Ethiopia, Kenya, Sudan and Uganda.” (Abebe 2021: 31). This number is likely to increase due to the ongoing conflicts in Ethiopia, Somalia, South Sudan and Sudan. The region is also affected by drought and other disasters that will displace another sizeable number of persons [Internal Displacement Monitoring Centre (IDMC) 2023].

Drivers of migration are ‘the factors which get migration going and keep it going once begun’ (Van Hear , 2012: 1). The Horn and IGAD region hosts the largest refugee population comes from South Sudan, followed by Somalia, Eritrea and Sudan. Whilst the contexts of their displacement differ, these are all protracted refugee situations that have been active for two decades or more in 26 refugee camps in Ethiopia (UNHCR, 2018b). Urban migration governance in IGAD countries faces significant challenges, including limited resources, inadequate infrastructure, and the need for effective urban planning to manage the influx of migrants and displaced populations. Many cities struggle to provide adequate services like housing and employment, leading to increased poverty, inequality, and social unrest. Urban migration governance Policies are largely not based on evidence and data, but rather on biased or polarized perspectives, to ensure effective and equitable solutions.

Many cities in the Horn of Africa are grappling with demographic growth and extreme inequalities. Inadequate social services infrastructures in urban centers of the Horn are critical challenges for migration management. Cities in the Horn of Africa are experiencing rapid demographic growth and extreme inequalities, with many lacking the capacity to provide essential services like housing, healthcare, education, water, and sanitation. The rapid influx of displaced populations strains urban infrastructure, leading to overcrowding, poor sanitation, and increased risk of diseases. Population displacement and conflict are among the most significant contemporary problems facing the Horn of Africa. Political instability, economic downturn and food inflation are critical in the urban metropolis of IGAD Countries.

Limited Financial and Technical Capacity are also key challenges for effective migration policies implementation and urban migrant services governance. Cities lack the financial resources and technical expertise to manage the increased pressure on urban infrastructure and services. National governments often do not adequately allocate budgets to address the needs of migrants and displaced populations, exacerbating the challenges faced by city authorities. Challenges of Integration and Social Cohesion are also the common problems of urban migration governance in the Horn. Displaced individuals and migrants often face difficulties accessing essential services and finding sustainable livelihoods, leading to marginalization and social exclusion. Conflicts between host communities and migrants or displaced populations can arise due to competition for resources and access to services in the cities.

3. Objectives of the Study

3.1. Major Objectives

The major objective of this paper is to identify key policy drivers and novel approaches for transforming urban migration governance and sustainable development in the Horn of Africa and IGAD Countries case taking the country-specific urban migration governance context of Ethiopia.

3.2. Specific Objectives

The Specific Objectives of the study include:

- To spotlight on the urban migration trends and governance in IGAD Region of Africa
- To describe policy drivers and novel approaches that can transform urban migration governance
- To examine the possible policy alternatives for spearheading the urban migration governance narrative
- To put ways forward to regularize effective urban migration policies and governance in the Horn

4. Methodologies of the Study

4.1. Description of Study Area

The IGAD region stretches over an area of 5.2 million km2 that comprises the countries of Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan and Uganda. The region has about 6960 Km of coastline with the Indian Ocean, Gulf of Aden, Gulf of Toudjoura and the Red Sea. Also, the IGAD region has a total of 6910 Km of international borders with Egypt, Libya, Chad, the Central African Republic, the Democratic Republic of Congo, Rwanda and Tanzania. Map 1 above shows the region. Some 70 percent of the IGAD region is made up of Arid and Semi-Arid Lands (ASALs), which receive less than 600 mm of rainfall annually. The rest of the region has a great variety of climates and landscapes, including cool highlands, swamp areas, tropical rainforests and other features typical of an equatorial region. Furthermore, the region possesses diverse ecosystems and agro-ecological zones at different altitudes ranging from 150 meters below sea level (Dalul) to about 4600 meters above sea level (Mount Kenya). Socio-economically, most of the IGAD Member States belong to the world's Least Developed Countries (LDCs) and share similar economic growth rates and social ethnic groups across their borders, which could be a good opportunity for regional integration, if appropriately utilized. Figure below shows the geographic location of IGAD Region in Africa.

Figure 1: Map of IGAD Region

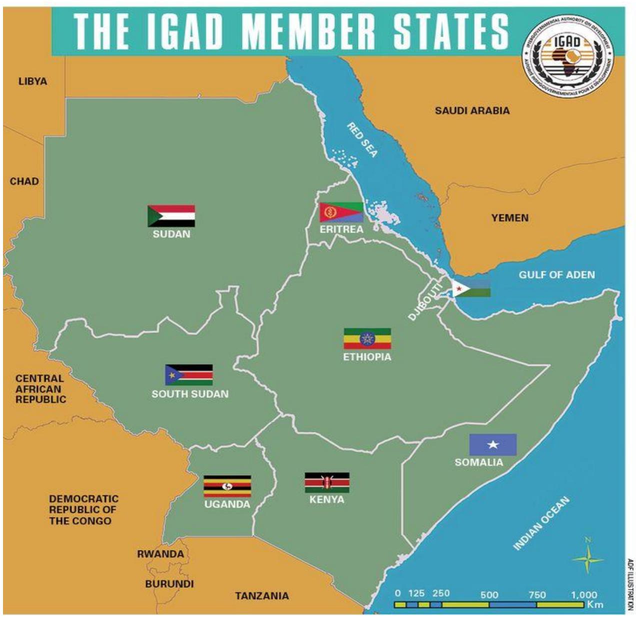

Figure 2: Location Map of IGAD Countries

Urban migration governance in Africa involves managing the complex interplay between migration and urbanization, which requires addressing both the challenges and opportunities associated with these interconnected processes. Effective governance necessitates a multi-faceted approach, encompassing data collection and analysis, policy development, institutional frameworks, and collaboration among stakeholders. There are three categories of factors/drivers that contribute to migration in and out of Africa: (Underlying factors/ Root Causes; Proximate Factors (drivers)/ Triggers of migration; Mediating /Facilitating factors (policy drivers).

4.2. Theoretical Models used for the Study

There are various theories of policy drivers that influence the urban migration and governance structures. The Neo-Classical Economic Theory of Migration states that people move from rural to urban areas due to wage differentials. Workers migrate for economic reasons, from low-wage, labor-surplus regions to high-wage, labor-scarce regions. Push-Pull Framework: Decision to migrate is determined by push factors at origin or pull factors at destination, and intervening obstacles (e.g. long distance, immigration laws, psychological and economic cost).

Migration Hump Theory advocates that there is a relationship between migration trends and socio-economic development. New Home Economics of Labor, supports the perspective that migration is undertaken to diversify household income and as an insurance strategy. On the other hand Migration network theory puts its lexical justification that migration is facilitated by social networks between earlier migrants at the destination and potential migrants at the destination.

4.3. Sampling Techniques

The study implemented simple random sampling techniques. Respondents were selected from different representatives of diplomatic and professional communities across six regional clusters of the Horn of Africa. The technique enabled involvement of top-level managers, diplomatic communities, migration officers/experts and urban policy makers from the regional cluster ministries accountable for urban migration governance and urbanization proportionally.

4.4. Methods of Data Collection

A qualitative approach was adopted for this study in both data collection and analysis. The study aimed at gaining a qualitative in-depth understanding of the role of IGAD in forced migration response using the different perspectives existing in the literature. This study is based mainly on secondary materials collected from various sources. The data was collected from documentary materials such as textbooks and journal articles on refugees, forced migration, regional integration, (sub) regional organizations in Africa especially the Horn of Africa, magazines, newspapers, legal instruments, protocols and reports of UN, UNHCR, International Organization for Migration (IOM), African Union (AU) and IGAD and the internet sources.

The study was undertaken between June and October 2024 and draws from extant literature, migration policies and field data. Key informant interviews and focus group discussions were conducted with the involvement of diplomatic communities, policy makers and migration agencies professionals residing in Ethiopia from IGAD region were consulted. Interviews were conducted with the AU, IGAD and EAC officials and government stakeholders from Djibouti, Ethiopia, Kenya, Somalia, South Sudan, Sudan, Uganda and Tanzania. The key informants were largely drawn from national government ministries/ agencies, INGOs, CSOs, development partners and academia.

4.5. Methods of Data Analysis

In terms of analysis of data, the study used descriptive and analytical techniques. Therefore, the research was based on a systematic analysis of the content of policy documents on Horn of African Urban Migration. The data collected were subjected to textual and content analysis (Creswell 2009). The published journals and documents were subjected to the four major questions: authenticity, credibility, representativeness and meaningfulness (Scott 1990 cited by Payne & Payne (2004). The analysis involved subjecting documents to external and internal criticisms. External criticism aimed to discover whether a document was both genuine and authentic. Internal criticism was about subjecting the contents of policy documents to rigorous analysis and interpretation. The contexts and future focuses of IGAD's recent main initiatives in form of policies, declarations, plans of action, conferences and meeting proceedings in its response to urban migration governance in the Horn of Africa were systematically analyzed.

4.6. Scope of the Study

The subject of this research is urbanization and urban migration governance in IGAD Region. This study assesses the reasons why urban migration governance in the region is inefficient and innovative approaches that can accelerate structural transformation and urbanization in the IGAD Region. It does not take into account the urbanization and urban migration governance characteristics of other African regions. The study touched pointed some common African issues, though it concentrated its scope on the dynamics of urbanization and migration in the Horn of Africa, focusing on Structural Transformation of Urban migration governance perspectives.

5. Results and Discussions

The proportion of the world population living in towns and cities rose from about 30% in 1950 to 47% in 2000 and then 54% in 2015. This figure is projected to rise to about 66% by 2050 (United Nations Population Division, 2014), with most of this urban growth occurring in Africa and Asia. The rapid urbanization and the resulting pressure on employment and social amenities have led to a largely negative policy position of African governments and metropolitan authorities on rural-urban migration and urbanization (Awumbila et al, 2014). Urbanization contributes to better economic outcomes and higher living standards. It shows that across most socio-economic dimensions, cities significantly outperform the countries in which they are located. Urbanization accounts for approximately 30% of the growth in per capita gross domestic product over the past 20 years. GAD's total population size was 281.7 million in 2019, and in 2024, the IGAD region's urban population is increasing, with a projected growth of 36.6% by 2043, though still below Africa's average according to ISS African Futures. Specific countries within IGAD, like Djibouti and, in the future, Somalia, are projected to have more than half their populations living in urban areas. The overall trend reflects a gradual urbanization across the region, but with significant variations among member states. The IGAD region has experienced a significant increase in both international and internal migration, with a large portion of migrants settling in urban areas. For example, migrants contribute 44% of Ethiopia's urban population, and a substantial share of internal migration is directed towards urban areas, with a significant portion of migrants experiencing unemployment in urban destinations, according to a report from UNFPA.

Consequently, the gains from urbanization on economic performance and quality of life extend beyond city boundaries, also benefiting rural areas. Urbanization in the East African region has distinct features that have shaped its growth over time, mainly through growing rural–urban migration. Around 58 %of the urban population in East Africa lived in slums. The share was higher in South Sudan, where nearly the entire amount of urban residents (91.4 percent) were living in slums. East Africa is dominated by intermediary peri-urban Cities (small to medium-sized cities that facilitate urban-rural linkages) compared to other cities. These cities play a crucial role in connecting urban and rural areas and act as hubs for goods, services, and job creation. Between 2000 and 2018, urbanization in the region grew by 4.5 percent (OECD,2022). The figure below shows urban growth dynamics.

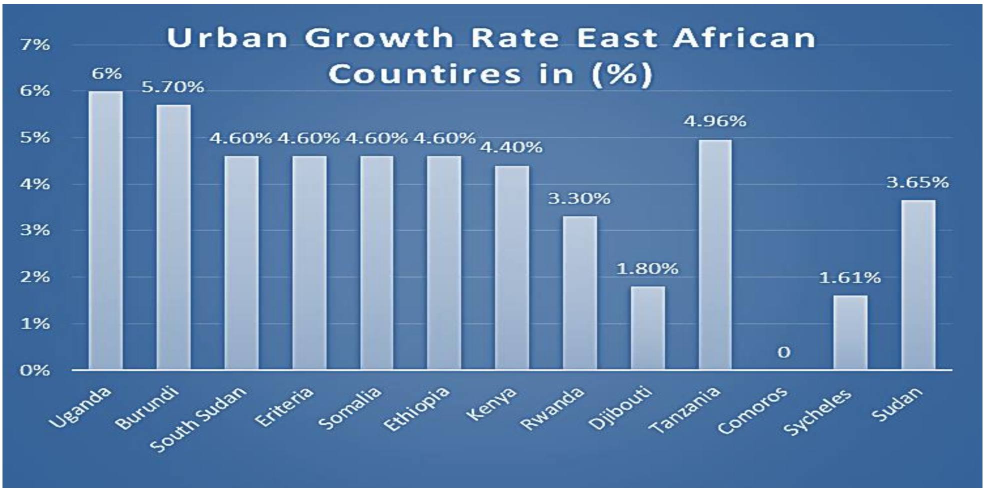

Figure 1: Rate of Urbanization in IGAD Region of Africa

Source: Statista(2000-2018), WB, 2024 and Tradingeconomics.com 2024

By 2050, it's projected that over 60% of Africa's population will reside in urban areas, up from approximately 40% in 2024. Urbanization and economic growth are closely related across several dimensions, but the relationship between the two is complex and non-linear in East Africa. Not all cities have similar levels of economic performance, and the measures needed to encourage economic development can vary from city to city. A host of factors contribute to urban productivity and help to determine whether cities will reach their productive potential. The types of interventions and investments a city most urgently needs depend on its context, opportunities and the specific deficits countries face. Urban migration governance is one of the factors that constrain urban transformation and sustainable development, particularly in the IGAD Region.

The IGAD region is characterized by migratory movements driven by multiple political, economic, and environmental factors, hosting roughly 4.5 million refugees & asylum seekers. In 2019, 26.3% of IGAD's population lived in urban centers, below the average of 42.8% for Africa. By 2043, the urban population will have risen to 36.6%. Among IGAD's member countries, only Djibouti had more urban inhabitants, 78.2% of the population, than rural inhabitants in 2019, and by 2043, Somalia will join Djibouti to be the only country in the region to have more than half of its population living in urban areas. South Sudan will continue to have the largest rural population over the forecast horizon, reaching 73.6% in 2043, as its urban population will only grow by 6.1 percentage points. Ethiopia will see the largest growth in its urban population, which will increase by 12.1 percentage points to 33.1% by 2043.

Country Variations in urbanization in different countries in the Horn of Africa exhibit varying rates of urban growth. For instance, Uganda and Burundi had the fastest urban growth rates, at 6% and 5.7%, respectively. Djibouti, while having a lower growth rate of 1.6 percent, remained the most urbanized country in East Africa, with a share of nearly 78% of the urban population in 2018. Postcolonial impact is accountable for the growth of small subsidiary cities. Despite the largely negative view of rural-urban migration, urban areas provide livelihood opportunities for migrants. There is a need for city authorities to consider the interests of migrants in the process of urban planning. The 2024 STATAFRICA report indicates that the IGAD region, encompassing Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan, and Uganda, has a total population exceeding 230 million. This region is characterized by high natural population growth rates. The STATAFRICA report also highlights the region's overall positive economic performance, with GDP growth exceeding 5%. IGAD's role in promoting regional integration through cross-border trade and infrastructure, strengthening peace and security, and addressing climate resilience is also emphasized.

Although political narratives and media images suggest an “exodus” of Africans to Europe, Africa has the lowest intercontinental outmigration rates of all world regions (Flahaux and De Haas 2016; UN 2017). Apparently, emigration accounts for only 20% of Africa’s population flux due to various factors like the EU Externalization Policy. In 2024, urban migration in the Horn of Africa is characterized by both intra-regional movement and migration to other countries. Significant flows are observed within the Horn of Africa, particularly towards the Arabian Peninsula, with Ethiopia being a major origin of migrants. Increased urban strain is noted due to rising displacement and migration, driven by factors like conflict, climate change, and economic opportunities, according to a report by the Intergovernmental Authority on Development (IGAD).

Accordingly, the 2018-2027 Action Plan advocates economic integration, political union and the free movement of people and goods, aligning the AU 2063 Agenda.

The study confirmed 20% of African states adapted a national migration strategy and an inter-ministerial coordination mechanism on free movement of people, social safety and human security (IOM, 2024). Regionally, the state of access to social services regardless of the legal status of migrants, West Africa accounts 61%; Southern Africa 50%; North Africa 100%; East Africa 44% and Central Africa 67%. This indicates they observed improved paces of positive premises on the migration prospectus of Africa, implying migration governance in Africa should be strengthened to realize continental security, human safety, and sustainable development.

The Eastern Route, described as one of the busiest and riskiest migration corridors in the world, is traveled by hundreds of thousands per year, mostly from Ethiopia, Eritrea, and Somalia. Migrants to the Gulf States expect to earn five times what they could in their country of origin. Approximately 300,000 migrants left Ethiopia for Djibouti and Somalia's shores in 2023. Over 93,500 migrants from the Horn arrived in Yemen during this period a 26-percent increase from the previous year. Migration flows along this route are expected to increase in 2024. In addition to the life-threatening environmental hazards (such as dehydration, exposure, and drowning), hundreds were killed by Saudi authorities at the Saudi-Yemen border between March 2022 and June 2023. Migrants were shot at close range, subjected to mortar attacks and other explosives, and were raped or forced to rape fellow travelers. Anti-migrant sentiment and a lack of legal protections for migrants remain serious threats in the Gulf States.

To effectively manage urban migration and promote sustainable development in the Horn of Africa and IGAD countries, policy drivers must focus on equitable access to basic services, fostering social cohesion, and addressing the root causes of migration and displacement, while simultaneously supporting innovative urban planning strategies. Novel approaches include strengthening regional cooperation, leveraging technology for data collection and analysis, and integrating migration into broader development plans. Political factors: Quality of governance, discrimination or persecution, levels of security and policy incentives (Visa regimes) are key migration driving factors in the Horn. Demographic factors like population density and structure and risk of disease related to high fertility rate are also drivers of urban migration in IGAD Countries. Environmental factors are considerably push rural–urban migration and is also considered as a strategy to deal slow-onset environmental processes (e.g. drought, land degradation) and rapid-onset environmental events (floods, earthquakes) (Teye and Owusu, 2016).

The domestication of regional migration frameworks to allow for safe and orderly migration within the region has not fully taken off despite available data indicating that most migrants from the region move within the region. IGAD's Free Movement Protocol (FMP) – recently endorsed by the Member States – is yet to be domesticated. EAC's FMP has on the contrary, facilitated visa-free migration flows between Member State countries. The harmonization of labor and employment legislation, and the right of establishment for citizens of the community has, however, been slow to take off. Notwithstanding, there are efforts to create complementary policies to promote the movement of workers, as seen in the draft EAC Labor Migration Policy. The policy addresses the recognition of educational attainments, the harmonization of social security benefits amongst the Member States, and the regulation of the movement of family members 2223. There is a need for relevant stakeholders to capitalize on Regional Consultative Processes (RCPs) on migration and lobby for the adoption and domestication of IGAD and EAC policies and laws by the Member States.

Although the rate of natural increase in towns (as a result of high fertility), as well as reclassification of settlements into urban areas, accounts for a large percentage of urbanization in Africa, significant long-term migration into urban settlements accounts for a significant proportion of urban growth. The vast majority of the additional urban dwellers will continue to add to the intermediate and small cities. This implies that the need for urban management is greatest in these intermediate-sized and smaller cities (UN-Habitat, 2014). IGAD Protocols on Free Movement of Persons and Transhumance, endorsed in 2020, are yet to be domesticated by Member States. IGAD is, however, currently designing a regional labor migration agreement that will benefit the countries that are sending immigrants to the Gulf states. Anti-trafficking and smuggling policy initiatives have also emerged to counter national and international human trafficking, including forced labor.

According to UNHCR (2018), the Horn of Africa had more than 4.3 million and 9 million refugees and IDPs, respectively. These were generated mainly by South Sudan, Somalia, Sudan and Eritrea. Due to increasing numbers, member states faced a challenge of providing basic healthcare services. Furthermore, there were cross-border health threats and pandemics like Ebola, Marburg, Cholera and HIV/AIDS, among others. There was therefore a need for member states to come together and respond to these common cross-border health risks. Urbanization can have both positive and negative effects on the health of migrants and families. The main benefits are associated with easier access to hospitals, clinics and health services in general. Also, access to information on modern health practices. Negative Health Effects in urban settings include a poor environment and housing can affect health. Contamination of water sources can cause diarrheal diseases, with the polluted air also affecting urban migrants' respiratory diseases and outbreaks of epidemics in host countries.

Instead of planning for urban growth and providing infrastructure and services for the poor, policy prescriptions focused on discouraging people from moving to urban areas in IGAD region. Several slum dwellers are forcibly evicted from their homes each year to make way for infrastructure projects and migrate to urban centers for private development. Given the benefits that migrants get from slums, they are likely to continue to move to these places unless the fundamental causes of migration, such as inequalities in economic development and high fertility, are controlled. Urban authorities must consider the interests of migrants when planning rather than assuming that migrants can be discouraged from moving to the city.

Despite the increased digitization of data in the HoA region, the availability of migration data remains extremely patchy and is generally focused on regular migration across various border points. Kenya, Rwanda and Tanzania recently conducted their national census and commendably collected data on migrant stocks in their countries and on remittances. Data on TiP and SoM, internal displacement, and return migration is, however, glaringly fragmented, and can be linked to the general absence of country-specific policies that address these dynamics in the region. Comprehensive data on labour migration is also lacking despite unemployment, especially amongst the youth, skill development, and skill transfer emerging as policy priorities within the region. What is particularly needed is harmonized macro data collected across all relevant ministries to allow for the mapping of various migration trends and the extrapolation of the same to the wider HoA region. Such integrated data is not only important to gain a more fundamental insight into who is moving, why, how, and where they are moving to but will contribute to robust and coherent policy debates and reporting mechanisms for better migration management. The availability of comprehensive data on migration also pertains to the possibility of linking migration to development frameworks in a coherent manner, consequently garnering national governments' sustained interest in migration policy formulation and implementation.

The migrant urban population in the IGAD region is complex and varied, with significant flows of refugees and internally displaced persons. As of late 2024, the region hosts approximately 5 million refugees and asylum-seekers, with South Sudan being the largest source of refugees. Additionally, there are over 19 million internally displaced persons in the region, primarily due to conflict and natural disasters. Within the IGAD region, urban areas, particularly in Ethiopia, are significant destinations for these migrants, with Addis Ababa hosting a substantial refugee population. Thus, urban migration governance is grappled with over-weighted social infrastructures and amnesty services to migrants in the Horn of Africa.

The high number of refugees remains a big burden to hosting countries. The number of international migrants in the IGAD region has significantly increased. In 2010, there were 3.1 million migrants, and this number rose to 6.5 million in 2019, according to the IGAD Migration Statistics Report. This represents an annual growth rate of 7.4%. There is a high demand for services like health and education. These refugees are also in need of employment opportunities. Abebe (2021: 22) gives some statistics to show the increase in the levels of refugee students' enrolment in schools in Ethiopia. In Ethiopia, in 2017, 116,566 of the 344,330 school-aged refugees were enrolled. Three years later, in 2020, 213,921 of the 315,411 school-aged refugees were enrolled. This means the enrolment rate has significantly increased from 34% to 67.6%.

Rural-Urban Migration across borders and main cities because of environment-related factors like drought, famine, and floods is a key characteristic of the region, but has not secured a solid space in migration policy discussions at the country level. South Sudan, for instance, has witnessed massive displacement in the recent past as a result of floods, but its Durable Solutions Framework is not coherent with climate change concerns. Somalia, Sudan and Uganda commendably have IDP policies, while Burundi and Kenya have laws on the same. These frameworks, however, do not comprehensively address climate change and its long-term effects on migration. The IGAD-EAC 2022 Kampala Ministerial Declaration on Migration, Environment & Climate Change, aimed at tackling climate change-induced migration and displacement in HoA, is a step in the right direction and should be harnessed to encourage Member states and non-government stakeholders to center climate change in migration policy discussions. IGAD's Free Movement Protocol also marks a significant step in addressing the protection gap of growing numbers of people in the region displaced by disasters, who often do not qualify for refugee status or other forms of international protection.

Cities authorities are often unprepared to respond to the influx of displaced households and increased rural-to-urban migration amidst the many competing challenges and priorities they face. Many cities in the Horn of Africa are facing demographic growth and extreme inequalities. In spite of this, they have a severe shortage of financial and technical capacity to provide adequate basic socio-economic services and affordable housing to their growing citizenry. On top of this, the national government’s budget allocation does not take into consideration population figures affected by displacement and migration. Policymakers and humanitarian and development actors’ responses to displacement and migration are largely through a rural lens. Many contexts also suffer from a lack of data to track displaced populations in urban areas and the impacts that displacement and migration have on urban systems.

Migrant populations are not integrating socially and economically well in IGAD Region. The policies neglected that their potential contribution of the urban migrant population is tremendous if they are well-tapped. Thus, there is a need to understand and explore cities and towns’ contexts, including the political dynamics, and roles of city actors, and identify the specific needs of cities and provide tailored solutions so that they can effectively support migrants and populations and reap the potential that migrants and refugees can present for the development of cities and towns in the IGAD region. Inclusive migrant governance and integration of migrant communities into the host population is a key approach for adapting noble approaches for migrant governance, social transformation, and sustainable development in IGAD Countries.

Promoting greater access to rights and meaningful participation among migrants and displaced populations in cities and urban areas (effectiveness, meaningful participation, inclusivity, accountability and coherence of policy processes and outcomes). It also includes access to human rights (work, movement, documentation etc.), protection, prevention of exploitative environment; decision-making rules and processes; accountability and transparency; inclusivity – gender, disability, age, minority groups; disaster risk reduction/Early Warning and Early Action (EWEA); planning and resource allocation decisions such as city master planning processes; alignment among regional and national policy and legal frameworks with urban policy and legal frameworks.

Ethiopia's experiences in urban governance highlight the need for a nuanced approach to decentralization, focusing on strengthening local government capacity and promoting inclusive decision-making. The Urban Governance and Decentralization Program (UGDP) supports the Ethiopian Government in implementing an extensive decentralization process. A key lesson is the importance of tailoring interventions to the specific needs of each city, recognizing that a "one-size-fits-all" approach is ineffective. Furthermore, ensuring that local governments have sufficient resources and operational autonomy in collaboration with UNHCR is making productive results in realizing safe urban migrants' management, effective migrant services governance structures and sustainable development in Ethiopia by integrating the needs of urban migrants with those of host communities in the cities.

6. Conclusion and Recommendations

6.1. Conclusion

The Horn of Africa is witnessing rapid urbanization, with rural-urban migration continuing to play an important role in the urbanization process. In 2012, at its 45th Ordinary Session of the Council of Ministers in Addis Ababa, Ethiopia, IGAD adopted a Regional Migration Policy Framework, inspired by the AU Migration Policy Framework for Africa (2006). The policy acknowledges the challenges and experiences of the IGAD region most notably civil wars and conflicts that have generated refugee flows (IGAD 2012: 6). It is noted that "the policy framework serves to provide the necessary guidelines and principals to assist governments in the formulation of their own national migration policies as well as, their implementation in accordance with their own priorities and resources" (IGAD 2012: 6).

The history of population growth and human settlement in Africa is the result of the mass movement of population within and across the borders of the African continent. Daily transhumance of pastoralists crossing the borders in search of pastures for their livestock, merchants in trade routes bringing salt from north Ethiopia into Egypt and camels from Morocco to Burkina Faso are rhetorical dynamics of the nature of migration in Africa. The key takeaways are that Africa's Migration Governance Policy Framework is still underperforming at 20% of countries adopted the African Migration Policy. As a result, an average of less 60% of migrants are socially safe, and free movement of people policy is not yet in traction, except few countries started to exercise visa-free entry.

While urban migration and urbanization bring new challenges, such as pressure on employment and social services, urban zones also represent a source of opportunities for migrants in terms of livelihoods and the possibility of being involved in entrepreneurial projects. Current policy prescriptions that tend to slow the rate of urban growth by discouraging people from moving to urban areas and implementing slum clearing policies are bound to fail, unless the underlying drivers of rural-urban migration are addressed. Sustainable Development Goal 11, commits to "make cities and human settlements inclusive, safe, resilient and sustainable by 2030" (UNDP, 2015), and thus provides the opportunity for African governments to change the negative perception of "cities as vessels of problems" to cities as "accelerators and facilitators of sustainable urbanization and development" as UN Habitat (2014) urges. It is hoped that city authorities will consider the interests of all categories of migrants in designing urban policies.

6.2. Recommendations

Regime changes and state fragility particularly act as setbacks to migration policy processes as new governments often have differing priorities, coupled with the transfer of senior government officials whose capacities had been built. Government officials in policy formulation and implementation to ensure continuity. This approach should be taken at both the local and national levels. National Governments should adopt a whole-of-government and whole-of-society approach to policy formulation to ensure policy coherence, especially as regards climate change and development-focused policies. National Governments should further anchor National Coordination Mechanisms for Migration (NCMs) in law to allow all relevant government and non-government stakeholders to coordinate on migration effectively. This will ensure the formulation of coherent policies and policy implementation monitoring.

Governments, with the support of International Partners, should set up infrastructure to allow for the harmonized collection of migration data. Rich data will allow for the formulation of informed Labour Migration, Trafficking in Persons (TiP), Smuggling of Migrants (SoM) and Return and Reintegration policies and laws. International Partners should also support national and local governments in appraising their staff on these policies and laws. Enhancing access to resources to promote productive capacities and self-reliance of migrants and displacement-affected communities, urbanization and social cohesion. The sub theme also addresses issues around coping mechanisms and adaptations of migrants and displaced individuals and communities in urban settings; social cohesion; access to basic services and social protection; social networks; participation; housing, land, and property; livelihood opportunities including 4 CALL FOR ABSTRACT | IGAD economic empowerment programs in relation to increasing opportunities for self-reliance; migrant settlements and urbanism including migrants' contribution to the growth of cities and urban areas; policies on integration, assimilation, and cultural tolerance; qualification, skills development, and migration.

Governments in IGAD Region should adapt national migration policies that are currently in draft form. Partners and RECs should implement and capitalize on capacity-building exercises and Regional Consultative Processes (RCPs) to lobby for the same. This should go along with supporting National Governments to design context-specific urban migration implementation roadmaps. International partners need to lobby National Governments to share their Progress Declaration on the Implementation of the GCM. These reports can be used to identify migration policy gaps that can be addressed through financial, technical, and programmatic interventions. Therefore, academies, think tanks, civil societies, and communities of practice actively steer the adaptation of this policy implementation by all African member states.

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Wheat Cluster Farming in Amhara Regional States of Ethiopia: An Approach to Improve Smallholders Wheat Output Commercialization?

Hassen Nurhussen Ahmed[1], Dawit Alemu[2], Lemma Zemedu[3], Kedir Jemal[4]

Abstract

In Ethiopia, wheat cluster farming has gained popularity in recent years due to its potential to transform the agricultural sector and improve the livelihoods of wheat producers. This study aimed to identify the key determinants of farm household participation in wheat cluster farming and output commercialization and to evaluate the impact of cluster farming on wheat output commercialization level. The study was conducted in the Amhara region of Ethiopia, using household-level survey data collected from 383 wheat-producing farm households selected through multistage sampling during the 2022/23 production year. Descriptive statistics and Endogenous Switching Regression (ESR) models were employed for data analysis. The participation equation of the model indicates that the farm household head's education status, access to formal credit services, frequency of extension contacts, distance from rural weather roads, wheat farm size, land fragmentation (index), livestock size (TLU), cluster farming awareness, and wheat farm distance to the nearby wheat cluster farms significantly influence farm household participation in wheat cluster farming. On the other hand, the outcome equation shows that the farm household head's education status, access to formal credit services, frequency of extension contacts, cooperative membership, distance from rural weather roads, wheat farm size, and land fragmentation (index) significantly affect the output commercialization of wheat cluster farming participants. The estimated average treatment effect on the treated (ATT), average treatment effect on the untreated (ATU), and transitional heterogeneity (TH) are 5.0%, 1.9%, and 3.1%, respectively, all of which are positive and statistically significant at the 1% level, confirming the positive impact of the cluster farming approach on wheat output commercialization. Therefore, government and non-government policies and interventions aimed at enhancing institutional support for rural farmers, improving rural road infrastructure, increasing market access, and promoting land consolidation are crucial for boosting farm household participation in wheat cluster farming and output commercialization.

Keywords: Cluster farming; Wheat; Commercialization; ESR; and ATT

[1] Haramaya University, PhD Candidate; Email: hasseno2005@gmail.com; Mobile Phone: +251912720961

[2] PhD, Agricultural Economics, Country Representative, Stitching Wageningen Research Ethiopia (SWR Ethiopia)

[3] PhD, Agricultural Economics, Ethiopian Institute of Agricultural Research

[4] PhD, Agricultural Economics, Haramaya University

1. Introduction

Agriculture is the key sector in Ethiopia's economic and political spheres as it constitutes over 70% of export receipts and employs 73% of the labor force (UNDP, 2018). The sector contributes 32.4% to the GDP in which crop production constitutes the lion share, accounting for 65.6% (NBE, 2022). It serves as the primary livelihood for nearly 80% of the rural population (World Bank, 2020). Maize, teff, barley, wheat, and sorghum are the major food crops grown across the country and encompasses a significant portion of the total cereal crop area and production nationwide accounting to 95 and 96.0% respectively (CSA, 2022)

Wheat is an important crop that serves as food and source of income in Ethiopia. Nationally, it accounts 18.68 and 19.97% of the total cereal crops area coverage and production respectively. Though, the country ranks second in terms of total wheat production area and production in Africa (USDA, 2025b), it remains net importer of wheat products (USDA, 2025a). This is due to rapid growth in demand for wheat products (Abate & Walelign, 2023), low level of technology adoption (Oliyad et al., 2024) and smallholder producers' efficiency (Silva et al., 2021) resulting low productivity and commercialization. For instance, the national average of wheat productivity was 3.11 tons per ha during 2021/22 production year (CSA, 2022) which is far below the world average of 3.59 tons (USDA, 2025b) and the average marketed proportion was only 24.37% (CSA, 2021).

Amhara region is one of the largest wheat crop producers in the country. The crop accounts 18.89 and 19.57% of the total cereal crops area coverage and production respectively indicating how the crop is important in the region. However, wheat productivity and level of commercialization in the region is low. In 2021/22 production year, its average productivity was 2.87 tons per hectare which is far below the national average productivity (CSA, 2022). Moreover, 64.2% of wheat output is used for consumption while a small proportion (16.4%) is sold in the market and the remaining is used for seed and other purpose indicating how commercialization of the crop is low CSA, 2021).

To make the agriculture sector continue its vital role in economic growth, transformation of smallholder farming from subsistence to commercial production is a key issue (Tesfaye et al., 2017). The main drivers that speed up such transformation process are economic growth, urbanization, and the withdrawal of labor from the sector (Pingali, 1997; Pingali & Rosegrant, 1995).

The concept, agricultural commercialization is complex and multidimensional and hence, there exist various definitions with varying degrees of emphasis (Boka, 2017; Moti et al., 2009). Agricultural commercialization can take place in output (increased marketed surplus), input (increased use of purchased agricultural inputs) or both side of production and considers both staple and cash crops (Pingali, 1997; von Braun, 1995). Govereh et al. (1999), defined it as the proportion of agricultural production sold in the market and involves a transition from subsistence-oriented production to highly market-oriented production system (both production and input use).

Commercial transformation of smallholder agriculture is an indispensable pathway towards economic growth and development for most developing countries relying on agriculture (Kilimani et al., 2022; von Braun, 1995). There are several research reports that revealed the importance of commercialization on improving farm households' productivity and income. For instance, Adam et al. (2010) and Alelign et al. (2017) reported that smallholder producers with high commercial-oriented farming had better crop productivity. In addition, Cazzuffi et al. (2020) and Tabe Ojong et al. (2022) reported the positive effect of agricultural commercialization on farm household assets accumulation, livestock ownership and income. And hence, there is a need to devise alternative policies, strategies and or programs that improve commercialization. Cluster approach (an effective approach in the manufacturing sector), is believed to be a promising key policy alternative that could boost smallholder commercialization (Guyo et al., 2023).

Clusters are largely recognized as one of the drivers that lead to renewed economic growth and bring competitiveness in the less developed areas (Zheliazkov et al., 2015). It highly promotes collaborative and cooperative activities that help to address a broad range of economic, social, and ecological problems to ensure rural recovery and sustainability (Rosenfeld, 2009). Porter (1990) emphasizes that geographic and spatial distribution, and the economic sector of the cluster are the basic attributes to be considered in defining the term cluster. The scholar defined it as, a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities. Schmitz (1992) relates the issue of cluster to agglomeration and according to him, a cluster is a geographic and sectoral agglomeration of enterprises.

Similarly, an agriculture-based cluster is one form of clusters which is defined as a concentration of producers, agribusinesses and institutions that are engaged in the same agricultural (crop or livestock) or agro-industrial subsector. They are established to address common challenges and pursue opportunities through interconnected and value chain networks (FAO, 2010). Literatures support the importance of cluster approach on improving productivity, delivery of extension services, training, services (like financial services), improved technology, strengthening producers' collective action, creating market linkage, and facilitating use of mechanization and commercialization.

Cluster approach reduces barrier in terms of access to inputs, services, staff, and skills required (Schouten & Heijman, 2012). In addition, it makes delivery of training to cluster members and experience sharing between clusters easy, which makes cluster participants better off in using improved technologies (Axalan et al., 2011; Karki et al., 2021). It also strengthens producers' collective action and bargaining position (Kilelu et al., 2017; Poulton et al., 2010) and this is crucial for small-scale producers to remain competitive, overcome the limitations of access to services, and mitigate different risk sources (Molema et al., 2016; Poulton et al., 2010). The approach is found to be vital in facilitating the delivery of extension services, improved technologies, creating market linkage, and the use of agricultural mechanization (Addisu & Dawit, 2021).

Farming in clusters facilitates small-scale farmers' engagement in higher productivity practices that are more market-oriented with higher value-added production (FAO, 2010), mitigate market risk due to their collective power (Hao et al., 2018) and facilitate market reach (Martinidis et al., 2021). Cluster farming helps farm households to achieve economies of scale, which lower costs per unit produced because of lower transport costs, competing input suppliers and specialization. It provides incentives for entry to a market because of easy access to information about opportunities (Schouten & Heijman, 2012). It also plays a significant role in improving major cereal crops (wheat, teff, maize and barley), producing farm households' level of market participation (Louhichi et al., 2019). All these things contribute to improvement in the output commercialization level.

The Ethiopian government introduced the agricultural commercialization cluster (ACC) initiative program in 2017. It is expected to serve as an institutional support service and play a central role in the transformation process of agriculture and improvement in smallholders' livelihood (ATA, 2018). Enhancement in farm productivity, production competitiveness and linkages amongst value chain actors are the main target of the program in the process of smallholder agriculture transformation (ATA, 2017; Louhichi et al., 2019). Wheat crop is among the program target commodities while Amhara regional state is one of the target areas. To facilitate diffusion of research outputs, make modern technology affordable, improve bargaining power and market linkage to smallholder producers, the farmer production cluster (FPC) was introduced as a sub-set of the ACC in 2019. To make farm households achieve farm scale, 30-200 farmers are clustered together on adjacent land to farm as one (ATA, 2019). The Ethiopian government sets a strong ambition to achieve self-sufficiency in wheat products and improve its commercialization. To achieve this, using cluster farming in wheat production is recognized as the best approach.

However, though the issue of cluster farming was introduced as a government program with the aim of improving smallholder producers' livelihoods through improvements in technology adoption, productivity, and commercialization, studies on the impact of cluster farming on wheat output commercialization remain minimal. Since its introduction as an alternative farming approach in Ethiopia, studies conducted by some scholars show the positive association between cluster farming and commercialization. For instance, producing teff in clusters significantly improves teff commercialization level among smallholder producers (Birara et al., 2024). Similarly, farming high-acreage crops (such as teff, wheat, maize, barley, and sesame) in clusters has a positive effect on commercialization (Guyo et al., 2023).

Therefore, this study tried to address the questions: what factors influence participation in wheat cluster farming? What are the major wheat output commercialization determinants? does the newly introduced farming approach have a significant contribution towards improvement in wheat output commercialization? With this, the study contributes in enriching literature on the impact of the cluster farming approach on wheat output commercialization. And, it will also serve as an important input for policy makers and development workers focusing on wheat crop (a cereal crop that has strong attention by the government) and scaling up of what cluster farming approach.

2. Research Methodology

2.1. Study Area

The study was conducted in Amhara regional state, Ethiopia, particularly in the West and East Gojjam administrative zones. The region is the second-largest and most populous national regional state under the federal democratic republic of Ethiopia. It is one of the major wheat-producing regions, accounting for 33.79% and 31.41% of the national wheat area coverage and production, respectively (CSA, 2022). Moreover, the region is one of the selected pilot areas for the implementation of cluster farming, and currently, the full-scale-up of cluster farming has started. The region is known for its diverse agroecological conditions, which make it suitable to produce a large variety of crops and livestock resources (Setotaw et al., 2020). West Gojjam Zone is one of the administrative zones of the region with a total population of 2.107 million. The overwhelming majority (91%) of the population lived in the rural areas whose sources of livelihood primarily depend on agriculture (CSA, 2007). Its current administrative center is Finote Selam, which is in the northwest of Ethiopia at 387 km from Addis Ababa and 176 km from Barhir Dar. The zone is located between $10^{\circ}16'$ to $11^{\circ}54'$ North Latitude and $36^{\circ}30'$ to $37^{\circ}5'$ East Longitudes and has a total area of 13,280 square kilometers and its elevation varies from 1500 to 3500 m.a.s.l (Habtemariam et al., 2016). The zone is known by the production of cereal and pulse crops. It is among the major wheat-producing zones in Amhara region and accounts 8.22% and 8.88% of the regional wheat area coverage and production, respectively (CSA, 2022). Similarly, East Gojam Zone is the other administrative zones of the region, where, Debre Markos is its administrative center. The total population in the zone was 2.154 million, of which 90% lived in rural areas whose sources of livelihood primarily depends on agriculture (CSA, 2007). Geographically, it lies at $10^{\circ}20'$ North Latitude and $37^{\circ}20'$East Longitudes, covers different topographic features with elevations ranging from 800 to 4200 m.a.s.l. (Wallelign et al., 2018). The zone has mainly unimodal type of rainfall pattern where the average annual rainfall varies from 900 to 1800 mm and its average temperature ranges from 7.5 ℃ to 27 ℃ (Setotaw et al., 2020). It is one of the major producers of grain crops in the region. In particular, the zone contributes the largest share in terms of area coverage as well as production of wheat crop, which is 24.16% and 27.59%, respectively (CSA, 2022).

2.2. Sampling Methods and Sample Size Determination

To select representative sample respondents for the interview, the study employed a multi-stage sampling procedure. The first step involved selecting two zones (West Gojjam and East Gojjam) in consultation with the regional bureau of agriculture experts and by referring to the ATA farmers cluster electronic data source. In doing so, the criteria included were availability of wheat production, area coverage, number of clusters established, and accessibility of the areas (in terms of transport and security). Second, in collaboration with the selected zonal and woreda agricultural office experts, as well as by referring ATA electronic data source, the list of potential woredas and kebeles were identified. Thirdly, a total of five woredas: three from East Gojjam (Debre Elias, Baso Liben and Gozamin) and two from West Gojjam (Dembecha and Wenberma) were selected randomly. In addition, a total of ten kebeles (two from each woreda) were selected randomly. Fourthly, a list of smallholder wheat producer households (including their cluster farming participation status) was identified in consultation with kebele development agents and administrative experts. Finally, sample respondents were selected randomly based on the proportion of farm households in the selected kebeles. In the process of woreda and kebele selection, the lottery method was used to secure randomization. Whereas, a table of random numbers was employed in the process of sample farm household selection. The final sample size was determined using the sample size formula developed by (Kothari, 2004), as specified below:

$$n = \frac{z^2 pqN}{e^2(N-1)+z^2 pq} \quad \textbf{(14)}$$

Where p represents proportion for the target population, q is$1-p$, z represents the value obtained from area under the standard normal curve, e is the acceptable error (level of precision), N is the total number of households in the study areas (woredas) and n is the required sample size. The problem with the above formula is obtaining the value of p and hence, the Author proposes two methods to get the value. The first is to take an initial estimate of p based on either personal judgement or a pilot survey result. The second method is to take the value of p equal to 0.5, which yields the most conservative sample size that yields at least the desired precision. Hence, considering time and resource limitations, the second method of estimating the value of p was considered to determine the required sample size.

Therefore, considering 5% acceptable error (level of precision) with a 95% confidence level (yielding a z value of 1.96), N is the total farm households which is 119,503 and setting the value of p as 0.5, the required sample size (n) becomes:

$$n = \frac{z^2 pqN}{e^2(N-1)+z^2 pq} = \frac{1.96^2 x 0.5 x(1-0.5) x 119{,}503}{0.05^2 x(119{,}503\ -1)+(1.96^2 x 0.5 x(1-0.5)} = 383$$

Therefore, the total number of sample farm households to be selected for interview was 383; 49.87% of the sampled farm households were participants in cluster farming, and the rest were non-participants. The details of the sampling process are presented as follows:

Table 1: Details of sample selection procedure

Zones	Selected weredas	Selected kebeles	Total HH number	Proportion	HH number selected
West Gojjam	Dembecha	Enewend	1534	0.095	36
		Wad	1362	0.084	32
	Wenberma	Markuma	1053	0.065	25
		Waz	1371	0.085	32
East Gojjam	Baso Liben	Limich	1782	0.110	42
		Dogem	1675	0.104	40
	Debre Elias	Guay	2010	0.124	48
		Yekegat	1,222	0.076	29
	Gozamin	Chertekel	2353	0.146	56
		Libanos	1807	0.112	43
Total	5	10	16169		383

2.3. Types of Data and Methods of Data Collection

The study employed both primary and secondary data. Discussions with relevant experts and reviews of annual reports, policy documents, and research papers in relation to agriculture, cluster farming, and commercialization were also made to compile the secondary data. On the other hand, primary data were collected in the 2023 production year mainly through a formal survey using a structured questionnaire and face-to-face interviews with selected farm household heads.

The primary data includes farm household characteristics (such as demographic and socioeconomic), village characteristics (such as institutional and infrastructural), wheat production data, and farm household cluster farming participation decisions. Well-trained enumerators and supervisors were employed to ensure effective and quality data collection. In addition, data were also collected through focus group discussions and discussions with respective experts to support the survey data.

2.4. Analytical Framework

Evaluation of a given program, approach and technology is made to assess results and help improve outcomes intended for the intervention (Olmos & Govindasamy, 2015). However, the application of quantitative techniques in evaluating the impact of an intervention based on non-experimental cross-sectional data remains a challenging issue. The challenge is mainly linked with difficulty in getting a proper counterfactual against which the impact is intended to be measured due to self-selection problems (Bekele et al., 2014; Menale et al., 2011). To effectively measure the impact of an intervention (participation in wheat cluster farming) on an outcome variable (wheat output and input commercialization), farm households' participation in wheat cluster farming must be random so that the groups (participants and nonparticipants) observable and unobservable characteristics have the same effect, and is attributable to the treatment. However, when group random assignment into treatment failed, their participation decision is affected by both observable and unobservable heterogeneity, such as skills and motivation (Bekele et al., 2014).

To deal with selection bias in an impact study using cross-sectional data different econometric approaches can be employe. The propensity score matching (PSM), which is the pioneer work of Rubin, 1973) is one of the approaches that is used when the problem of selection bias in observable variables is an issue. The instrumental variable (IV) approach is the other well-known approach that can help to deal with unobserved heterogeneity (Bekele et al., 2014; Wooldridge, 2002). However, this approach assumes that the impact would differ only by a constant term between treated and nontreated groups, though in real sense, the difference is more systematic due to the potential interaction between treatment and outcome determinants (Moti et al., 2016).

Since PSM does not require linearity, or parametric or distributional assumptions Heckman & Vytlacil, 2007), several scholars used propensity score matching (PSM) to deal with structural differences (basically based on observed variables) (Becerril & Abdulai, 2010; Menale et al., 2011). However, it is not a consistent estimator when there are unobservable variables that affect the treatment and outcome of interest simultaneously and does not take into account the effect of covariates on outcome variables (Moti et al., 2016). The Endogenous Switching Regression (ESR) model approach developed by (Lee, 1982) as a general model of the Heckman's selection correction model (Heckman, 1979), relaxes the assumptions imposed by PSM and IV approaches (Lokshin & Sajaia, 2004; Maddala, 1983; Wooldridge, 2002). Therefore, there is a need to select a method that takes into account observable and unobservable endogeneity by simultaneously estimating the participation and the outcome equations for each group and the effect of covariates on the outcome variable and that is the ESR.

2.5. Methods of Data Analysis

Descriptive statistics as well as an econometric model were used to analyze the data. The descriptive statistics include averages, percentages, and standard deviations. In addition, a t-test was employed to examine mean differences between groups, while a chi-square test was used to examine frequency differences. In addition to the ESR model results, the PSM results were presented to check the robustness of the estimated effects obtained from the ESR model.

2.5.1. Specification of the Econometric models

In this paper, the specification of the econometric model is derived from the theory of utility, a concept that is meant to be a measure of relative human satisfaction. Consequently, smallholder farm households make certain decisions, for instance, whether to participate or not in a certain new farming approach, such as cluster farming, based on the satisfaction that would be obtained from their labor in terms of returns (Adeoti et al., 2014). Hence, smallholder producers make decisions based on the objective of maximizing utility (U), subject to a set of constraints (Otekunrin et al., 2019). Thus, in this study, it is expected that smallholder wheat producers decide to participate in cluster farming (CF) approach when the expected utility received from participation (U_p) is greater than the utility received from non-participation (U_{np}) that is $U_p - U_{np} > 0$. Based on this theoretical framework, the mathematical and estimation procedures of the ESR model is specified following Bekele et al. (2014); Di Falco et al., (2011) and Moti et al. (2016) as follows:
Let A_i^* be the latent variable that captures the benefit from participating in CF approach by the ith farm household, and given as:

$$A_i^* = Z_i\beta + \varepsilon_i \; where \; A_i = \begin{cases} 1, & Z_i\beta + \varepsilon_i > 0 \\ 0, & otherwise \end{cases} \qquad (15)$$

where A_i^* is a binary variable equal to 1 if a wheat producing farm household participates in CF approach and 0 otherwise; Z_i is a vector of household, farm, institutional and village level variables that affect the decision to participate in CF approach or not, β is a vector of parameters to be estimated and ε_i is an error term normally and independently distributed with mean 0 and variance σ_ε^2. Equation 2 is labeled as participation or selection equation. Since farm households make their cluster farming participation decisions based on the expected utility or benefit of the outcome variable (in this case, wheat output commercialization level), the equation for the outcome variable of interest (Y_i) is expressed as:

$$Y_{1i} = X_i \alpha_1 + \mu_{1i}, if \ A_i = 1 \quad \textbf{(16)}$$

$$Y_{2i} = X_i \alpha_2 + \mu_{2i}, if \ A_i = 0 \quad \textbf{(17)}$$

Estimating the outcome equations (3 and 4) if there exist a correlation between the error terms (μ_{1i} and μ_{2i}) and the participation or selection equation (ε_i) (2) leads to biased estimates due to existence of endogeneity problem. Therefore, to take in to account the possible endogeneity problem, the model is specified as:

$$\text{Regime1: } \boldsymbol{Y_{1i} = X_{1i}\alpha_1 + \sigma_{1\varepsilon}\hat{\lambda}_{1i} + \eta_{1i}, if \ A_i = 1} \quad \textbf{(18)}$$

$$\text{Regime1: } \boldsymbol{Y_{2i} = X_{2i}\alpha_2 + \sigma_{2\varepsilon}\hat{\lambda}_{2i} + \eta_{1i}, if \ A_i = 0} \quad \textbf{(19)}$$

where Y_{1i} is a dependent variable representing wheat output commercialization level for CF participants and Y_{2i} for nonparticipants, X_i is a vector of household, farm, institutional and village level variables that affect outcome variable (wheat output commercialization level), α and σ are parameters to be estimated, $\hat{\lambda}_{1i} = \frac{\phi(Z_i\hat{\alpha}_i)}{\Phi(Z_i\hat{\alpha}_i)}$ and $\hat{\lambda}_{2i} = \frac{\phi(Z_i\hat{\alpha}_i)}{1-\Phi(Z_i\hat{\alpha}_i)}$ are the inverse Mill's ratios (IMRs) computed from the selection equation (2) to correct for selection bias in the second-stage estimation (outcome equations). η is an independently and identically distributed error term with mean zero and constant variance.

The error terms of the selection equation (ε_i), and the two output equations (μ_{1i} and μ_{2i}) are assumed to have a trivariate normal distribution with mean vector zero and the following covariance matrix:

$$cov(\varepsilon_i, \mu_{1i}, \mu_{2i}) = \begin{bmatrix} \sigma^2_{\mu_{2i}} & \sigma_{\mu_{1i}\mu_{2i}} & \sigma_{\mu_{1i}\varepsilon_i} \\ \sigma_{\mu_{1i}\mu_{2i}} & \sigma^2_{\mu_{1i}} & \sigma_{\mu_{1i}\varepsilon_i} \\ \sigma_{\mu_{2i}\varepsilon_i} & \sigma_{\mu_{1i}\varepsilon_i} & \sigma^2_{\varepsilon_i} \end{bmatrix} \quad \textbf{(20)}$$

Where $\sigma^2_{\mu_{2i}}$ and $\sigma^2_{\mu_{1i}}$ are the variances of the outcome equations for non-participant and participant farm households while $\sigma_{\mu_{2i}\varepsilon_i}$ and $\sigma_{\mu_{1i}\varepsilon_i}$ represent the covariance between ε_i , μ_{2i}, and ε_i, μ_{1i} respectively. If the selection equation error term (ε_i) is correlated with the participant and non-participant error terms (μ_{1i}, and μ_{2i} respectively), the expected values of μ_{1i}, and μ_{2i} conditional on the sample selection are non-zero. That is:

$$\boldsymbol{E(\mu_{1i}|A_i = 1) = \sigma_{\mu_{1i}\varepsilon_i}\frac{\phi(Z_i\hat{\alpha}_i)}{\Phi(Z_i\hat{\alpha}_i)} = \sigma_{\mu_{1i}\varepsilon_i}\hat{\lambda}_{1i}} \quad \textbf{(21)}$$

$$\boldsymbol{E(\mu_{2i}|A_i = 0) = \sigma_{\mu_{2i}\varepsilon_i}\frac{-\phi(Z_i\hat{\alpha}_i)}{1-\Phi(Z_i\hat{\alpha}_i)} = \sigma_{\mu_{2i}\varepsilon_i}\hat{\lambda}_{2i}} \quad \textbf{(22)}$$

Where ϕ and Φ are the probability density and the cumulative distribution function of the standard normal distribution, respectively. Hence, if $\sigma_{\mu_{1i}\varepsilon_i}$ and $\sigma_{\mu_{2i}\varepsilon_i}$ are statistically significant, this would be evidence that farm households' decision to participate in wheat cluster farming and wheat output commercialization level are correlated suggesting evidence of sample selection bias. This implies that, use of ordinary least square (OLS) to estimate the outcome equation would lead to biased and inconsistent results. Therefore, in such scenario the full information maximum likelihood (FILM) estimator can be used to fit an endogenous switching regression that simultaneously estimates the selection and outcome equations to generate consistent estimates.

Hence, the actual expected outcomes of cluster farming (CF) participant (Equation 10) and non-participant (Equation 11) farm households, and the counterfactual cases that the participants had they not participate (Equation 12) and the non-participants had they participate (Equation 13) can be compared using ESR and specified as:

$$E[Y_{1i}|X_{1i}, A_i = 1] = X_{1i}\alpha_1 + \sigma_{1\varepsilon}\hat{\lambda}_{1i} \quad \textbf{(23)}$$
$$E[Y_{2i}|X_{2i}, A_i = 0] = X_{2i}\alpha_2 + \sigma_{2\varepsilon}\hat{\lambda}_{2i} \quad \textbf{(24)}$$
$$E[Y_{2i}|X_{1i}, A_i = 1] = X_{1i}\alpha_2 + \sigma_{2\varepsilon}\hat{\lambda}_{1i} \quad \textbf{(25)}$$
$$E[Y_{1i}|X_{2i}, A_i = 0] = X_{2i}\alpha_1 + \sigma_{1\varepsilon}\hat{\lambda}_{2i} \quad \textbf{(26)}$$

Among the above equations, equations (10 and 11) are observed from survey data but, equations (12 and 13) are the counterfactual outcomes. Having this, following Heckman et al. (2001) and Di Falco et al. (2011) the average treatment effect on the treated (ATT), the average treatment effect on the untreated (ATU), base heterogeneity effect for participant (BH1) and nonparticipant (BH2) farm households, and transitional heterogeneity (TH) effect were computed as follows:

$$\boldsymbol{ATT = (10) - (12) = \left(X_{1i}\alpha_1 + \sigma_{1\varepsilon}\hat{\lambda}_{1i}\right) - \left(X_{1i}\alpha_2 + \sigma_{2\varepsilon}\hat{\lambda}_{1i}\right) = X_{1i}(\alpha_1 - \alpha_2) + \hat{\lambda}_{1i}(\sigma_{1\varepsilon} - \sigma_{2\varepsilon})} \quad \textbf{(27)}$$

$$\boldsymbol{ATU = (13) - (11) = \left(X_{2i}\alpha_1 + \sigma_{1\varepsilon}\hat{\lambda}_{2i}\right) - \left(X_{2i}\alpha_2 + \sigma_{2\varepsilon}\hat{\lambda}_{2i}\right) = X_{2i}(\alpha_1 - \alpha_2) + \hat{\lambda}_{2i}(\sigma_{1\varepsilon} - \sigma_{2\varepsilon})} \quad \textbf{(28)}$$

$$\boldsymbol{BH_1 = (10) - (13) = \left(X_{1i}\alpha_1 + \sigma_{1\varepsilon}\hat{\lambda}_{1i}\right) - \left(X_{2i}\alpha_1 + \sigma_{1\varepsilon}\hat{\lambda}_{2i}\right) = \alpha_1(X_{1i} - X_{2i}) + \sigma_{1\varepsilon}(\hat{\lambda}_{1i} - \hat{\lambda}_{2i})} \quad \textbf{(29)}$$

$$\boldsymbol{BH_2 = (12) - (11) = (X_{1i}\alpha_2 + \sigma_{2\varepsilon}\hat{\lambda}_{1i}) - (X_{2i}\alpha_2 + \sigma_{2\varepsilon}\hat{\lambda}_{2i}) = \alpha_2(X_{1i} - X_{2i}) + \sigma_{2\varepsilon}(\hat{\lambda}_{1i} - \hat{\lambda}_{2i})} \quad \textbf{(30)}$$

$$\boldsymbol{TH = ATT - ATU} \quad \textbf{(31)}$$

Table 2: Summary of Conditional Expectations, Treatment and Heterogeneity Effects

Subsample	Participation decision		Participation effect
	To participate	Not to participate	
wheat cluster farming participant	$(a)\ E[Y_{1i}\|X_{1i}, A_i = 1$	$(c)\ E[Y_{2i}\|X_{1i}, A_i = 1]$	ATT= $(a) - (c)$
wheat cluster farming nonparticipant	$(d)\ E[Y_{1i}\|X_{2i}, A_i = 0]$	$(b)\ E[Y_{2i}\|X_{2i}, A_i = 0]$	ATU= $(d) - (b)$
Heterogeneity effects	BH1=$(a) - (d)$	BH2= $(c) - (b)$	TH= ATT-ATU

To address the objective of evaluating the impact of wheat producing farm households' participation in cluster farming on wheat output commercialization level, there is a need to compute wheat output commercialization index (the value of the dependent variable in the outcome equation).

Therefore, taking the output perspectives in defining commercialization, the method of measuring household level commercialization index developed by von Braun (1995) and Strasberg et al. (1999) was used. Hence, the required wheat output commercialization index was computed as follows:

$$\boldsymbol{COCI_{HH_i} = \frac{S_i}{P_i}\, x\, 100} \quad \textbf{(32)}$$

Where, HH_i is household $i, (i = 1,2, \dots n)$, $COCI_{HH_i}$ represents wheat output commercialization index of the ith household, S_i is total value of wheat output obtained from sale in the market by the ith household and P_i is the gross value of wheat output produced by the ith farm household.

3. Results and Discussions

3.1. Descriptive summary of variables

This section provides an overview of wheat yield and input use characteristics. The overall average wheat yield in the study area is 2,891.22 kg per hectare, with cluster farming participants achieving better average yield compared to nonparticipants, as supported by the t-statistical test result. The overall average area covered by wheat is 0.56 ha with a significant difference between participants and non-participants at 1% significance level. Key inputs in wheat production include di-ammonium phosphate (DAP) fertilizer, urea, seeds, labor, and oxen power. The t-statistical test result indicates the existence of a significant difference in the average application of DAP and urea fertilizers in wheat production among participant and nonparticipant farm households at 1% level of significance. Labor usage averages 41.90 and 47.19 man-days among participants and nonparticipants, with a significant difference between them.

Table 3: Summary of wheat yield and production input use by treatment

Variables	Full sample (N=383)		Participant (n1=191)		Non-participant (n2=192)		Mean difference	t-value
	Mean	SD	Mean	SD	Mean	SD		
Wheat yield (kg)	2891.22	486.41	3078.70	402.13	2704.72	492.16	373.98	8.14***
Wheat area (ha)	0.56	0.21	0.64	0.20	0.48	0.18	0.16	8.02***
DAP fertilizer (kg)	114.28	31.60	118.91	31.66	109.68	30.95	9.24	2.89***
Urea fertilizer (kg)	124.01	39.85	136.03	39.25	112.06	36.83	23.96	6.16***
Seed rate (kg)	103.73	17.14	102.46	17.17	105.00	17.05	-2.54	1.46
Labor (man-day)	44.55	17.80	41.90	14.92	47.19	19.95	-5.29	2.94***
Oxen power use (oxen-day)	22.40	4.26	22.50	4.05	22.29	4.47	0.21	0.49

Source: Own computation from field survey data (2023)

*** represents statistically significant at 1% level of significance.

The Ethiopian government has prioritized cluster farming, particularly in the wheat sector, to enhance wheat commercialization. As shown in Table 4, the average level of wheat commercialization is 55% for cluster farming participants compared to 43% for nonparticipants. A t-test confirms a significant difference in commercialization levels between the two groups at the 1% significance level.

Table 4: Summary of descriptive statistics for outcome and continuous variables by treatment

Variables	Full sample (N=383)		Participant (n1=191)		Non participant (n2=192)		Mean difference	t-value
	Mean	SD	Mean	SD	Mean	SD		
Outcome variable								
Wheat output commercialization (index)	0.49	0.15	0.55	0.12	0.43	0.16	0.12	8.40***
Continuous explanatory variables								
Age (years)	43.97	0.15	44.32	7.53	43.62	7.63	0.70	0.90
Household size (AEU)	3.82	1.37	3.92	1.26	3.72	1.47	0.20	1.42
Extension contacts (frequency)	5.04	2.37	6.06	2.19	4.03	2.09	2.03	9.29***
Wheat land size (ha)	0.56	0.21	0.64	0.20	0.48	0.18	0.16	8.02***
Distance to rural weather roads (km)	1.89	1.52	1.47	1.07	2.31	1.76	-0.84	5.63***
Land fragmentation (Index)	0.57	0.38	0.54	0.52	0.60	0.12	-0.07	1.68*
Livestock size (TLU)	4.66	2.21	4.97	2.27	4.34	2.11	0.63	2.81***
Wheat farm distance to the nearby wheat cluster farms (km)	1.32	1.12	0.68	0.57	1.97	1.16	-1.29	13.78***
Distance from main market (km)	9.79	5.83	8.88	5.69	10.69	5.84	-1.81	3.08***

Source: Own computation from field survey data (2023)
* and *** represent statistically significant at 10 and 1% level of significance, respectively.

Cluster participants exhibit better average frequency of extension contact, larger wheat land size, and their wheat farm is close to the nearby wheat cluster farms, all statistically significant at the 1% level. Additionally, nonparticipant farmers are located significantly farther from rural weather roads and the main market, as confirmed by the t-test at 1% level. Furthermore, farm households owned multiple parcels of land as shown by the result of the land fragmentation index (an index that is computed through the Simpson index (SI) and measures the level of land fragmentation, in which a value close to zero indicates a higher level of consolidation and one indicates a higher level of fragmentation). The overall average land fragmentation index is 0.57 with a significant difference between participants and nonparticipants at the 10% level. In terms of livestock, the average size measured in tropical livestock units (TLU) is among participants and nonparticipants is 4.97 and 4.34 TLU. The t-statistical test shows a positive and significant mean difference between the two groups at the 1% significance level. Thus, the descriptive result highlights cluster farming participants are better in wheat commercialization level, resource access, and livestock holdings.

Table 5 summarizes the descriptive results of dummy explanatory variables used in the econometric model. The data reveal that a significant majority of the sample (94.8%) are male-headed households, while only 5.2% are female-headed. Concerning literacy, among the literate group, 55.6% are cluster farming participants, contrasting with only 45.7% of illiterate households who participate, highlighting the crucial role of education in participation. The chi-square (χ^2) test confirms a significant difference at the 10% level between literate and illiterate households' participation. Access to formal credit services is limited, with only 32.1% of households having access. The chi-square test again indicates a significant difference in participation based on access to formal credit at the 1% level, underscoring its importance for cluster farming involvement. In terms of farmers' cooperatives, a notable 88.3% of households are members, which plays a crucial role in accessing agricultural inputs. Awareness of cluster farming is also high, with 85.9% of households having awareness about it and there exists a significant difference in participation among the aware and non-aware farm households at the 1% level, reinforcing the importance of awareness in driving participation. Lastly, only 25.1% of households engage in off-farm activities, while the majority (74.9%) do not participate in such activities. This descriptive result highlights the importance of key factors such as literacy, access to credit, and cluster farming awareness on participation in wheat cluster farming among Ethiopian wheat-producing farm households.

Table 5: Summary of descriptive statistics for dummy explanatory variables by treatment

Variables		Full sample (N=383)		Cluster farming: Participant (n1=191)		Cluster farming: Non-participant (n2=192)		$\chi 2$-test
		Count	%	Count	%	Count	%	
Sex	Male	363	94.8	182	50.1	181	49.9	0.20
	Female	20	5.2	9	45.0	11	55.0	
Education status	Literate	162	42.3	90	55.6	72	44.4	3.63*
	Illiterate	221	57.7	101	45.7	110	54.3	
Access to formal credit	Yes	123	32.1	71	57.7	52	42.3	4.47**
	No	260	67.9	120	46.2	140	53.8	
Cooperative membership	Yes	338	88.3	167	49.4	171	50.6	0.25
	No	45	11.7	24	53.3	21	46.7	
Cluster farming awareness	Yes	329	85.9	174	52.9	155	47.1	8.5***
	No	54	12.5	17	68.5	37	31.5	
Involvement in off-farm activity	Yes	96	25.1	45	46.9	51	53.1	0.46
	No	287	74.9	146	50.9	141	49.1	

Source: Own computation from field survey data (2023)

*, ** and *** represents statistically significant at 10, 5 and 1% significance level respectively.

3.2. Wheat Cluster Farming Participation and Impact on Output Commercialization: Econometric Analysis

The econometric model employed to identify the participation and wheat output commercialization determinants as well as to evaluate the impact of wheat cluster farming participation on output commercialization level is Endogenous Switching Regression (ESR). Hence, before the final use of model outputs for interpretation, some statistical tests such as validity of the selected instruments, independence of the participation and outcome equations and the overall significance of the model were conducted.

The system of equations (the participation and outcome equations) may be identified through the nonlinearity of the selection correction term, λ (Lokshin & Glinskaya, 2008) or by adding at least one variable that is included in the participation equation but not in the outcome equation (Moti et al., 2016). Therefore, in this study, farm households cluster farming awareness and farm proximity to the nearby wheat cluster farming are included as exclusion or instrumental variables. keeping other factors constant, it is expected that farm household heads who have awareness about the benefits of cluster farming and whose farms are close to the nearby wheat cluster are more likely to participate than their counterparts. This is because the selected variables are among the key criteria in the process of cluster establishment and selection of participants in wheat cluster farming. These variables are expected to have a direct effect on farm households' participation in wheat cluster farming but not on the wheat output commercialization level.

Accordingly, to examine the validity of the selected instruments in the estimation of wheat cluster farming participation impact on output commercialization level (measured as an index), a falsification test was conducted. Hence, in the process of wheat output commercialization impact estimation, the test result supports that the included instrumental variables are jointly statistically significant at 1% level of significance in the participation decision (in selection equation: Chi2 = 75.26; p-value= 0.00) but not in the nonparticipant wheat output commercialization level outcome equation (in outcome equation: F-stat = 0.71; p-value = 0.50).

In addition, as presented in Table 6 below, the likelihood ratio test of independence ensures that the participation equation and outcome equations are dependent (Chi2 = 5.42; p-value= 0.02) that leads to rejection of the null hypothesis stating that the selection and outcome equations are independent. This test result supports the use of endogenous switching regression model. Furthermore, the Wald chi-square test result shows the overall model is significant at 1 % level of significance (Wald chi2 = 133.65; p-value = 0.00).

3.2.1. Determinants of Farm Households' Wheat Cluster Farming Participation

The selection equation result of the ESR model presented in Table 6 shows farm households' wheat cluster farming participation determinants. The result indicates that among the included explanatory variables, farm household education status, access to formal credit, frequency of extension contacts, cluster farming awareness, wheat farm size and number of livestock owned are the key variables that have a positive and significant influence. Whereas, farm households' residence distance to rural weather road, land fragmentation index and farm proximity to the nearby cluster have a significant and negative influence on farm households' participation in wheat cluster farming.

Education is an important tool that helps to facilitate farm households' access to information on agricultural production, production technologies, marketing, and prices. Accordingly, the finding of the study reveals that the education status of the farm household head has a positive role in improving the likelihood of farm households' participation in wheat cluster farming and is significant at 1% level of significance. The result is consistent with Birara et al. (2024) and Guyo & Tabe-Ojong (2024), who found similar results in a related study.

Arrangement of formal credit, provision of extension service and creating awareness on new or improved production technologies and farming approaches are among the common institutional support services delivered to farm households to facilitate implementation of improved or new farming approaches. The model result indicates that access to formal credit service has a positive and significant effect at 10% level of significance, implying that those farm households who have access to formal credit service have a better chance of participation in wheat cluster farming than those who do not have.

Participation in wheat cluster farming requires ability and willingness to apply comprehensive production packages and such requirement needs financial support to implement. In view of this and the governments attention towards wheat production, the positive effect of credit is not surprising and the result is in consistent with a related study conducted by Degefu et al. (2025).

Similarly, the study result indicates frequency of extension contacts has positive role in improving farm household heads' participation in wheat cluster farming and is significant at 1% level. The finding is in consistent with Chala & Fikiru (2021); Degefu et al. (2025); Guyo & Tabe-Ojong (2024). Likewise, farm households who have awareness about wheat cluster farming are more likely to participate as compared to those who are not and its effect is significant at 1% level. Cluster farming approach needs a series of awareness creation training to different stakeholders, particularly farm households, from its establishment to implementation. Such priori awareness creation training plays an important role in improving farm households' participation in cluster farming and this may be one of the possible reasons for the positive effect of farm households' cluster farming awareness on their participation decision in this study. Guyo & Tabe-Ojong (2024) found similar results that states farmers who have awareness on the importance of cluster crop production are more likely to participate in cluster crop production.

One of the most important rural infrastructures that facilitates farm households' membership in group activities like cluster farming is the rural road. In this study, distance to rural weather roads (km) has negative influence on farm households' participation in wheat cluster farming and is significant at 5% level. This entails farm households residing close to the nearby rural weather road tend to have more chance of participating in wheat cluster farming. The result is in line with studies conducted by Rehima et al. (2013) and Noad & Bamlaku (2017) whose finding shows an easy access to rural weather roads has an important contribution towards improvement in smallholder producers' market participation decisions.

Land size allocated to wheat cultivation is one of the key criteria to select participant farm households and establish a wheat production cluster. In line with this criterion, the finding of the study reveals that farm size allocated for wheat production has a positive effect on farm households' wheat cluster farming participation decision and is significant at 5% level of significance.

This positive result may be linked to the minimum land size requirement to participate in wheat cluster farming. This result is in consistent with Guyo & Tabe-Ojong (2024) whose research finding reveals that, in general, farm households cluster farming participation rate has a positive relationship with farm size. Land fragmentation (measured as index) has negative effect on wheat cluster farming participation and is significant at 5% level. Highland fragmentation causes a smaller size of multiple parcels of land and this hinders farm households to formally participating in wheat cluster farming.

Farm proximity to the nearby cluster (km) is one of the most important attributes that influences farm households' participation in wheat cluster farming. In this study, the variable is found to influence farm households' participation negatively and is significant at 1% level. The result implies those farm households having farm land far from the surrounding established wheat cluster tend to have less chance of participating in wheat cluster farming than their counterparts. This may be related to the concept of cluster farming (the cultivation of a given crop through grouping neighboring farms). The result is consistent with related studies conducted by Musa & Hiwot (2017) and Abera et al. (2024), whose study result reveals the importance of cooperatives' office distance on farm households' membership.

Livestock (measured in terms of TLU) has a positive role towards farm households' participation in wheat cluster farming and is significant effect at 5% level of significance. This implies that, farm households with a higher number of livestock have a better chance of participating in wheat cluster farming. This may be associated with the key role livestock has been playing as a source of wealth, income, food, and power for crop farming activities like ploughing and threshing for Ethiopian farm households. However, there is no consistent research report on the effect of livestock size (TLU) on farm households' participation in collective farming activities such as wheat cluster farming. For instance, Tesfamicheal et al. (2017) reported that livestock has positive effect whereas, Chala & Fikiru (2021) reported the variable has negative effect. Such inconsistent research result may be associated with the competitive nature of the two farming activities (crop and livestock) particularly when the size of livestock owned by farm household is large.

3.2.2. Determinants of Wheat Output Commercialization

Table 6 below presents the key explanatory variables that have a significant effect on wheat output commercialization among cluster farming participant and non-participant farm households.

Table 6: Endogenous switching regression results for wheat commercialization determinants

Variables	Participation (participant=1)		Wheat output commercialization level			
			Participant		Non participant	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Age (years)	0.035	0.024	0.000	0.001	-0.001	0.002
Sex (male=1)	-0.449	0.473	0.027	0.029	0.063*	0.033
Education status (literate=1)	0.780***	0.211	0.040***	0.015	0.004	0.018
Household size (AEU)	-0.220	0.143	-0.003	0.007	-0.003	0.010
Formal credit access (Yes=1)	0.348*	0.204	0.041***	0.013	0.037**	0.018
Extension contacts (frequency)	0.183***	0.055	0.006**	0.003	0.007*	0.004
Cooperative membership (Yes=1)	0.088	0.319	0.072***	0.025	0.044**	0.022
Distance to rural weather roads (km)	-0.209**	0.091	0.008	0.006	0.007	0.005
Distance from main market (km)	-0.026	0.020	-0.004***	0.001	-0.002	0.002
Wheat farm size (ha)	1.200**	0.597	0.216***	0.037	0.430***	0.047
Land fragmentation (index)	-1.983**	0.867	-0.021*	0.012	0.040	0.076
Livestock size (TLU)	0.096**	0.048	0.003	0.003	0.006**	0.003
Off farm activity involvement (Yes=1)	-0.147	0.230	-0.009	0.015	0.002	0.018
Cluster farming awareness (aware=1)	1.118**	0.457				
Farm proximity to nearby cluster (km)	-0.929***	0.118				
Constant	-0.897	1.099	0.254***	0.058	0.079	0.076
Model diagnosis parameters						
rho1(ρ_1)	0.394**	0.193				
rho2(ρ_2)	-0.264	0.170				
Log likelihood	259.66					
Wald chi2	133.65***					
LR test of independent equations: chi2	5.42**					

Source: Own computation from field survey data (2023)

*, ** and *** represent statistically significant at 10, 5 and 1% level of significance, respectively.

Farm households' demographic characteristics, such as sex and education status have important influence in crop production and marketing activities. The finding of this study shows that, sex of the farm household head (male=1) has a positive influence on wheat output commercialization level for non-participants in the wheat cluster farming and is significant at 10% level but its effect is insignificant for participants. The result implies that being male male-headed farm household tends to have a better level of wheat output and commercialization level compared to female-headed ones. This may be associated with women's limitations in access to resources, markets and traditional labour divisions that hinder their performance in wheat crop farming. This finding is in line with Birara et al. (2024), whose finding indicates that being male headed farm household plays a positive role in improving wheat output commercialization. Similarly, the education status of farm household head has a positive role towards enhancement in wheat output commercialization level for farm households producing wheat in a cluster approach and is significant at 1% significance level, but its effect is insignificant for nonparticipants. It is believed that literate farm households are active in adopting improved technologies, farming practices such as wheat cluster farming and the implementation process. And this is an important parameter to improve wheat productivity and production which leads to improvement in wheat commercialization level. The result is consistent with the findings of the study by Birara et al. (2020); Dubale et al. (2022); Lijalem et al. (2023).

Institutions that provide credit, extension and cooperative services play a critical role towards improvement in improving crop production and the marketing system in Ethiopia. Accordingly, the effect of farm households' access to formal credit on wheat output commercialization level is significant at 1 and 5% level of significance for cluster farming participants and non-participant farm households, respectively. This finding may be associated with the recent rise in price of production inputs such as fertilizer and improved wheat seeds, which demand the use of credit services to fulfill the input requirement of wheat production and the result is in line with (Tariku et al., 2021). Likewise, farm households' cooperative membership has a significant effect on wheat output commercialization level at the 1 and 5% level of significance among cluster farming participant and nonparticipant farmer households, respectively. This is because farmer cooperatives are among the key players in the process of agricultural input distribution to farm households in Ethiopia and this demands farm households to be member of such cooperatives to easily and timely access agricultural inputs.

Such easy and on-time access to agricultural inputs contributes to timely implementation of wheat farming activities and enhance wheat yield. Keeping other factors constant, an increase in wheat yield leads to increment in the amount of wheat output supplied to the market and, this contributes to an enhancement in wheat output commercialization level. The result is in consistent with the result of a study by Yonnas (2020). Like the above two institutional variables, farm households' frequency of extension contacts has a significant role in enhancing wheat output commercialization level at 5 and 10% significance level for cluster farming participant and nonparticipant farm households, respectively. Effective delivery of agricultural extension services to farm households is among the key instruments to improve agricultural productivity in general and wheat productivity in particular in Ethiopia. Given the government's attention towards the wheat crop, the positive effect of this variable is not surprising and the result is in line with (Dubale et al., 2022; Tariku et al., 2021; Yonnas, 2020).

Farm households' residence distance from the main market was included as one variable to see its effect on wheat output commercialization level, and found it has a negative and significant effect at 1% level of significance for cluster farming participants but not for nonparticipants. The result implies that, keeping other factors constant, the level of wheat output commercialization is better for those farm households who reside relatively close to the nearby available main market than those who reside far from it. This may be linked to the reason that accessible marketplaces are part of critical infrastructures that help to reduce transaction costs associated with input and output marketing. The finding is in agreement with the findings of the study by Mabiratu et al. (2019); Tamrat et al. (2023); Yonnas (2020)

Land is one of the key production factors in the crop sector. In this study, size of land allocated for wheat production is found to have positive effect on wheat output commercialization level for both cluster farming participants and nonparticipants and is significant at 1% significance level. The finding is in consistent with the finding of Birara et al. (2020) whose study result entails that farm households that allocate a large farm for crop production tend to have more produce and this contributes to a better commercialization level.

Land fragmentation (measured as an index) has a negative effect on wheat output commercialization level for participant farm households and is significant at 10% significance level but its effect is insignificant for nonparticipants. There are two conflicting literatures concerning the importance of land fragmentation on production efficiency, productivity, land management, and risk mitigation (Tadesse, 2024). Literature by Tadesse (2024) and Veršinskas et al. (2021) argues higher level of land fragmentation results in low efficiency and productivity, which possibly leads to a lower level of wheat output commercialization and the result of this study is in support of this literature.

Livestock is an important asset for Ethiopian rural farm households and serves as source of food, income, wealth and power. In this study, livestock (measured as TLU) has a positive effect on wheat output commercialization level among non-participant farm households only and is significant at 5% level of significance. The finding entails that farm households with a relatively higher number of livestock have a higher wheat output commercialization level. This may be associated with the key role of livestock as a source of income that can be used to cover agricultural input costs, particularly in a state of high input prices. The finding is in line with the result of a study by (Adam & Dawit, 2015), which shows farm households with a better number of livestock have better productivity and marketable surplus and this encourages them to take a greater proportion of their produce to the market.

3.2.3. Impact of Cluster Farming on Wheat Output and Input Commercialization

Considering the recent introduction of the cluster farming approach in general and wheat cluster farming in particular, and the government's attention towards wheat commercialization, estimating the impact of the approach on wheat commercialization is the main interest of the paper. Accordingly, the ESR model result (Table 7) shows that farm households' wheat production in the cluster farming approach has a positive and significant impact on wheat output commercialization.

Table 18: Expected average wheat output commercialization, treatment, and heterogeneous effects

Outcome variable	Subsample	Participation decision		Participation effect
		To participate	Not to participate	
wheat output commercialization index	wheat cluster farming participant	**(a) 0.549 (0.005)**	**(c) 0.499 (0.008)**	ATT= 0.050*** (0.005)
	wheat cluster farming nonparticipant	**(d) 0.445 (0.005)**	**(b) 0.426 (0.007)**	ATU= 0.019*** (0.004)
	Heterogeneity effects	BH1= 0.104 (0.007)	BH2= 0.073 (0.011)	TH= 0.031*** (0.006)

Source: Own computation from field survey data (2023)

*** represents statistically significant at 1% level of significance.

Note: numbers in parentheses represents standard errors

As shown in the table above, wheat output commercialization level (measured in terms of index) is higher by 5% on average for farm households producing wheat in a cluster farming approach compared to their counterfactuals (a condition where these farm households would have been produced wheat under conventional farming approach) and this represents the average treatment effect on the treated (ATT). Similarly, on average, wheat output commercialization level for farm households producing wheat under a conventional farming approach would have been increased by 1.9% if these farm households had produced wheat in clusters and this is commonly termed as the average treatment effect on the untreated (ATU). Moreover, farm households' wheat production under the cluster farming approach results positive and significant transitional heterogeneity (TH) effect. This implies that the effect of wheat production under the cluster farming approach on the wheat output commercialization level is higher than the effect of wheat production under conventional farming. Such positive impact of cluster farming may be due to the role of the farming approach in terms of improving farm households' bargaining power and information sharing, access to improved agricultural technologies, market participation, access to different awareness creation trainings and access to rural institutional services like credit, extension, and cooperative services. In addition, the Ethiopian government's ambition towards scaling up of wheat cluster farming and wheat self-sufficiency in the country is expected to play a positive role in making cluster farming to result positive impact on wheat commercialization. The findings of the study are in line with Birara et al. (2024) and Guyo et al. (2023), whose finding reveals the positive impact of farming in a cluster approach on the commercialization level of major cereal crops and the Teff crop, respectively.

4. Conclusion and Recommendations

Recently, the issue of cluster farming in general and wheat cluster farming in particular has gained popularity in Ethiopia. By grouping wheat-producing smallholder farmers together and providing them with resources and training, this farming model is expected to improve yield, farmers' access to new markets and negotiate better prices for their output. This not only benefits individual farmers but also contributes to the overall economic growth of the country. This study tried to analyze the wheat cluster farming approach in relation to the wheat output commercialization level (measured in commercialization index). The study was conducted in the Amhara regional state of Ethiopia using household-level survey data collected from 383 randomly selected wheat-producing rural farm households selected through a multistage sampling method during the 2022/23 production year. The study employed the ESR econometric model in data analyses.

Based on the results of the study, the following conclusions are made. The overall average wheat commercialization level is 49%. Specifically, farm households producing wheat in a cluster farming approach have an output commercialization level of 55% whereas nonparticipants have 43%. The t-test confirms a significant difference in commercialization levels between the two groups at the 1% significance level, showing the positive role of the cluster farming approach towards improvement in the level of output commercialization. Keeping other factors constant, the key variables that have significant role in wheat producing farm households' participation in cluster farming are, farm household heads education status, access to formal credit service, frequency of extension contacts, wheat farm size, number of livestock (TLU), cluster farming awareness, residence distance from rural weather roads, land fragmentation level (index), and farm proximity to the surrounding clusters. All the variables have a positive role towards improvement in wheat-producing farm households' participation in cluster farming, except farm household heads' residence distance from rural weather roads, land fragmentation level (index), and wheat farm distance to the surrounding wheat clusters, which have a negative effect.

In addition, the findings of the study show that access to formal credit service, frequency of extension contacts, cooperative membership, and wheat farm size are variables that have a positive and significant effect on wheat output commercialization level (measured in index) for both wheat cluster farming participant and nonparticipant farm households.

On the other hand, variables such as the level of land fragmentation (index) and distance to rural all-weather road have negative and significant effect on wheat cluster farming participants' output commercialization level but education status has a positive and significant effect. Similarly, the age of the farm household head and livestock number owned have a positive and significant influence on improvement in wheat output commercialization only for nonparticipants.

Finally, since the main objective of the study is to evaluate the impact of farm households' participation in wheat cluster farming on output commercialization level, the result reveals that wheat-producing farm households' participation in cluster farming has a positive impact on wheat output commercialization level. Keeping other factors constant, the average effect of producing wheat in cluster farming approach (ATT) on the wheat output commercialization level is 5%. The average treatment effect on the untreated (ATU) is 1.9% implying that the wheat output commercialization level would increase by 1.9 % if those farm households producing wheat under conventional farming were to produce wheat in clusters. The transitional heterogeneity (TH) effect is 3.1 % which shows the importance of producing wheat in a cluster approach towards improvement in wheat output commercialization level. The t-test indicates that all of them (ATT, ATU and TH) are positive and significant at 1% level of significance.

Given the positive and significant impact of wheat cluster farming on improving the wheat output commercialization level, there is a need to create an enabling environment to encourage more farmers to participate in cluster-based wheat production. Collaborative efforts through the cluster farming approach can foster a more prosperous future for stakeholders in the wheat sector. Therefore, government and nongovernment interventions designed to enhance institutional support for rural farmers, improve rural road infrastructure, and promote land consolidation are important for increasing farm household participation in wheat cluster farming and boosting output commercialization level. However, in scaling up of wheat cluster farming, the issue of soil management must addressed, as the practice may lead to monocropping, potentially affecting long term soil fertility.

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Agriculture for Economic Development: The New Engine of Growth in Ethiopia

Kennedy Abebe Birru[1]

Abstract

This study is motivated by the persistent duality characterizing Ethiopia's agricultural sector. Despite its centrality to the economy, contributing significantly to GDP growth, poverty reduction, food security, and exports, the agricultural sector remains underdeveloped, marked by low productivity, a dominance of subsistence-oriented smallholders reliant on rain-fed farming, and traditional technologies. While numerous policy interventions have been aimed at transforming the sector, an agricultural revolution has yet to materialize, and poverty and food insecurity remain pressing developmental challenges. Against this backdrop, this paper comprehensively investigates the potential of Ethiopian agriculture to serve as an engine for long-run economic growth and structural transformation. Using an augmented ARDL bounds testing approach for cointegration modeling, along with Toda-Yamamoto and Frequency-Domain Granger causality tests covering the period 1962–2023, the study yields the following key findings. First, it established a significant positive long-run causal relationship running from agricultural productivity growth to GDP per capita growth, confirming agriculture's role as a growth escalator. Second, the study validated the Agricultural Export-Led Growth hypothesis, underscoring the critical role of agricultural exports in enhancing broader economic performance. Third, the study found strong linkages between agriculture and non-agricultural sectors, indicating that agricultural growth generates positive spillover effects, stimulating non-agricultural activity. Fourth, it provided robust evidence that agricultural productivity improvements are instrumental in facilitating structural transformation, primarily by releasing surplus labor to the industrial and service sectors. Finally, the study found that productivity growth originating in agriculture substantially impacts overall productivity growth more than non-agricultural sources. These robust findings collectively provide compelling evidence that agriculture holds a distinctive capacity to drive sustained economic growth and structural transformation in

[1] Kennedy is an independent consultant with a background in the banking and consultancy industry whose research interest focuses on structural transformation and economic growth, productivity analysis, impact evaluation of developmental interventions, and applied development economics. Email: kennedyecondevt@gmail.com
Mobile No: +251915044613 or +251915030564

Ethiopia. The overarching conclusion emerging from the empirical analysis is that the agricultural sector is the best engine of growth and structural change, particularly at an early stage of development, characterizing Ethiopia's economy. These findings underscore the viability of an agriculture-led developmental strategy in Ethiopia, thereby endorsing the "agriculture first for development hypothesis." The Policy implications highlight the necessity of prioritizing agricultural development and transformation to foster inclusive growth, drive industrial development, and facilitate structural transformation. This entails concerted efforts to boost agricultural productivity, transform smallholder farmers, diversify agricultural exports, and establish robust intersectoral linkages. Conversely, a development strategy that neglects agriculture during the early stages of transformation would hinder overall progress.

Keywords: Agricultural Growth, Agricultural Productivity, Agricultural Export-Led Growth, Economic Growth, Structural Transformation, Agriculture-Led Development, Augmented ARDL Bounds Test, Granger causality, Ethiopia

1. Introduction

Since the 1950s, the role of agriculture in economic development has remained a subject of ongoing debate in both theoretical and empirical literature. This discourse can be broadly divided into two polarized perspectives. Much of the early development literature, grounded in dual-economy theories of development, portrayed agriculture as having limited potential to boost productivity and assigned it a passive role in the development process (Goodman and Hirschman, 1958; Jorgenson, 1961; Lewis, 1954; Ranis & Fei, 1961). According to this stance, agriculture primarily served as a source of surplus labor and capital for the modern sector. In contrast, proponents of agricultural primacy advocated by Johnston and Mellor (1961), positioned agriculture as a powerful growth escalator, emphasizing its dynamic multiplier effects on the overall economy. Despite its comparatively slower growth rate compared to other sectors, investments and policy reforms in agriculture were viewed as capable of accelerating overall economic growth and reducing poverty, especially in economies where agriculture holds significant relative importance.

Moreover, the predominant economic thought nowadays is that in the early stage of the development process, agricultural production and productivity growth play pivotal roles in driving industrial development and facilitating economic-wide transformation. Economic history also clearly demonstrates that almost no country (except Singapore and Hong Kong) has succeeded in its industrial revolution without a prior or simultaneous agricultural revolution. Thus, agricultural transformation is a precursor of the Industrial Revolution. Furthermore, empirical evidence shows that growth originating in agriculture is at least twice as effective in reducing poverty as GDP growth originating outside agriculture (World Bank, 2008). However, in recent years, skepticism about agriculture's role in development, particularly in Africa, has been growing among development scholars. This resurgence of pessimism coincides with limited success in increasing agricultural productivity and achieving agricultural transformation in African countries, alongside the recognition of new challenges the sector has faced in both local and global changes.

Recognizing the central role of agriculture in the early stages of development, the Ethiopian government adopted Agricultural Development-Led Industrialization (ADLI) in 1993 as a national strategy to catalyze economic transformation. ADLI aimed to boost agricultural productivity, raise the income of rural households, ensure food security, promote large-scale commercial farming, and generate marketable surpluses to fuel industrial growth. This strategy was further reinforced by subsequent development plans, including the Sustainable Development and Poverty Reduction Program (SDPRP, 2001–2005), the Program for Accelerated and Sustained Development to End Poverty (PASDEP, 2006–2010), the Growth and Transformation Plans (GTP I: 2011–2015; GTP II: 2016–2020), and the currently ongoing the Ten Years Perspective Development Plan (2021-2030). Despite some progress, particularly in increasing the productivity of cereal crops, the strategy largely fell short of its overarching objective of transforming Ethiopia's economy from a traditional agrarian economy to a modern industrial one.

In light of the above, Ethiopia's agricultural sector is best described as exhibiting a dualistic nature, a point that catches one's attention and motivates this research endeavor. On the one hand, despite Ethiopia's economy looking service-oriented in terms of GDP composition, it remains fundamentally agrarian in terms of both employment and export structure. The lion's share of the country's population is still engaged in agriculture and generates income from it. This trend is believed to remain unchanged in the years to come. Further, agricultural exports have remained Ethiopia's primary source of foreign exchange earnings. Thus, agriculture plays a crucial and multifaceted role in the Ethiopian economy, contributing significantly to GDP growth, poverty reduction, food security, export earnings, and serving as a primary source of labor and capital. Notably, agricultural GDP growth is the key driver behind Ethiopia's growth acceleration in recent decades.

On the other hand, despite the country's vast agricultural potential and numerous policy interventions aimed at its transformation, the hope for an agricultural revolution has yet to materialize. The sector remains underdeveloped, marked by low productivity, a dominance of subsistence-oriented smallholders reliant on rain-fed farming, and traditional technologies. Consequently, poverty and food insecurity persist as major development challenges of the nation. Not surprisingly, Ethiopia is still dependent on imports to satisfy domestic demand for agricultural products and raw materials. Furthermore, the sector has faced several constraints that revolve around land use and administration systems, access to high-quality inputs and finance, infrastructure facilities, efficient market systems, and research and extension services.

Against this backdrop of Ethiopia's complex and seemingly paradoxical agricultural dynamics, this study comprehensively investigates the potential of the agricultural sector to serve as an engine for long-run economic growth and structural transformation. It seeks to answer two central research questions: Does Ethiopian agriculture maintain unique capacities to act as an engine of growth and a catalyst for structural transformation? Is an Agriculture-Led-Development strategy the most viable pathway for Ethiopia's development? To address these questions with methodological rigor, the study implements a multi-analytical framework structured around five conceptually interrelated yet empirically distinct research objectives. First, it investigates the long-run causal relationship between agricultural productivity and economic growth. Second, it tests the validity of an Agricultural Export-Led Growth (AELG) hypothesis. Third, it examines the intersectoral linkages between the agricultural and non-agricultural sectors. Fourth, it explores the role of agricultural productivity in driving structural transformation. Finally, it examines the relative impact of agricultural and non-agricultural productivity on the aggregate productivity of the economy.

To achieve its objective, the study employed the augmented ARDL bounds testing approach for cointegration modeling, the Toda-Yamamoto Granger Non-causality test, and the Frequency-Domain Granger causality test as an empirical strategy covering the period 1962-2023.

Why this study? First, despite agriculture remaining a cornerstone of Ethiopia's economy and determined efforts aimed at its transformation, the anticipated agricultural revolution has not yet materialized. This shortfall raises critical developmental concerns and necessitates rigorous research to inform policymakers whether agriculture-led development remains a viable strategy, which is a fundamental reason justifying the necessity of conducting the study and its practical relevance.

Second, although extensive research has examined the role of agriculture in Ethiopia's economy, most have primarily focused on its linkage effect within the broader economy or its impact on poverty reduction, employing static analytical frameworks such as Computable General Equilibrium (CGE) models and input-output multipliers analysis, often relying on household-level survey data. However, there is a notable absence of time-series empirical research that comprehensively investigates the potential contribution of the agricultural sector as a driver of long-run economic growth and structural change. In particular, there is a lack of research that investigates how agricultural productivity contributes to aggregate productivity and structural transformation in Ethiopia. Thus, this paper contributes by filling that critical research gap in the literature. Third, previous research on the agriculture-growth nexus often relies solely on cointegration or regression analysis, failing to ascertain the nature and direction of bivariate Granger causality established among the variables. This methodological limitation may result in biased or misleading inferences. Additionally, the empirical evidence to date has been mixed and sometimes contradictory, resulting in a lack of consensus on the impact of agriculture on economic growth. Therefore, this study is an attempt to provide fresh evidence by addressing the methodological shortcomings of prior research using a more rigorous empirical strategy, in addition to resolving the inconclusive mixed results of earlier works.

Fourth, previous studies that thoroughly examine the "agriculture as an engine of growth" hypothesis within both closed and open economy contexts are almost nonexistent, a research gap this paper aims to address.

Finally, this study is the first to investigate the role of agriculture in economic development using the augmented ARDL bounds testing approach for cointegration. Unlike the traditional bounds test, which relies solely on the F-bound and t-bound tests, this novel approach employs a three-stage testing procedure, thereby providing robust evidence whether the relationship among the variables of interest is one of cointegration, degenerate cases, or no cointegration. This methodological innovation further strengthens the study's contribution to the literature.

In doing this, the current paper contributes to the existing theoretical and empirical literature in the following ways. First, the current study which explores the macro relevance of the agricultural sector from multiple dimensions (i.e., agricultural productivity nexus economic growth, validating agricultural export-led growth hypothesis, the linkage effect of agriculture with nonagricultural sectors, the role of agricultural productivity in driving structural transformation, and the relative impact of agricultural and non-agricultural productivity on aggregate productivity) provides fresh evidence on the effectiveness and practical viability of agriculture-centered-development strategy particularly to Ethiopia's context which is valuable information that can be used as an input for guiding policy formulation and allocation of the scare resource for financing development.

Second, the current study contributes to the ongoing longstanding debate in the literature about agriculture's development contribution by supporting the predominant optimistic view, arguing that the agricultural sector is the best engine of growth and structural change for developing economies like Ethiopia, which is found at an early stage of development. Third, this study contributes methodologically by employing a novel econometric technique (i.e., the augmented ARDL bounds testing approach for cointegration), which provides robust evidence about the status of the cointegrating relationship established among the variables of interest. Fourth, this study's contribution lies in the attempt made here to settle the inconclusive mixed results of previous studies, in addition to addressing their methodological limitations. Finally, the study contributes to the existing literature by exploring the "agriculture as an engine of growth" hypothesis under both closed-economy and open-economy contexts, thereby linking the closed-economy result with the results obtained under the open-economy framework.

The remainder of this paper is organized as follows. Section 2 briefly reviews the relevant literature. Section 3 is devoted to the methodology, which includes data sources and variable description, empirical model, and empirical strategy employed in the study. Section 4 details the empirical results. Finally, section 5 provides conclusions and policy implications.

2. Literature Review

The discourse on the importance of agriculture in economic growth and development has evolved. Within academic circles, this discourse is essentially dichotomized into two contrasting viewpoints. Advocates of agricultural primacy posit that agriculture plays an indispensable role in fostering both overall economic advancement and improving the conditions of the poor (Adelman, 1984; Andersson and Till, 2018;

Christiaensen et al., 2011; Hwa, 1988; Johnston and Mellor, 1961; Lipton, 2012; Ravallion and Chen, 2005; Till, 2023; Timmer, 1988). They substantiate their stance by referencing historical precedent and empirical studies (Diao et al., 2007; Gollin et al., 2002; Mellor, 1999; Timmer, 1988). Conversely, skeptics of agriculture's role in development contend that it is unlikely to significantly reduce poverty or foster sustained income growth in poor nations (Ashley and Maxwell, 2001; Collier and Dercon, 2009). They raise doubts about the efficiency of agricultural growth in poverty reduction (Hasan and Quibria, 2004), its historical precedence in driving development (Ellis,2004), and its role as a primary driver of growth in now-developed countries (Dercon and Gollin, 2014). Thus, in contemporary scholarly discourse, agriculture is viewed both as a catalyst for development and as a component that might not be as crucial as previously thought.

Various theoretical perspectives have influenced the ongoing debate. The "fifth wheel" school suggests agriculture alone doesn't drive economic development, but its neglect could impede progress. The Chicago school emphasizes rationality and anti-distortions in economic policies. Another perspective focuses on agriculture's role in trade, seeing it either as a hindrance or a boost. Lastly, there is the view of agriculture as a potential growth driver. One aspect analyzes structural changes, while another highlights its capacity to enhance the domestic market, as articulated by Adelman (1984) in her concept of Agricultural Demand-Led Industrialization (ADLI).

On a macro level, literature addressing the role of agriculture in broader economic growth and development investigates various facets, including its direct contribution to growth, its indirect impact on boosting output and productivity across different sectors, its influence on exports, its linkage and multiplier effects, and its role in facilitating structural transformation through agricultural productivity. Building upon the pioneering work of Johnston and Mellor (1961), significant empirical research has been conducted utilizing diverse methodologies. These include approaches such as CGE models and semi-parametric input-output multiplier analysis, as exemplified by studies from Thurlow and van Seventer (2002), Dorosh and Haggblade (2003), Diao and Dorosh (2007), Pauw and Thurlow (2011), and Dorosh and Thurlow (2012). Furthermore, econometric inquiries, as evidenced by studies from Bravo-Ortega and Lederman (2005), Tiffin and Irz (2006), and Self and Grabowski (2007), along with growth accounting analyses conducted by Martin and Mitra (2001), Gulati et al. (2005), and Bosworth and Collins (2008), contribute significantly to comprehending the dynamics of agriculture within the developmental process.

In Ethiopia's case, there are some macro studies conducted to explore the importance of the agricultural sector, but arrived at inconclusive mixed evidence.

Gizaw, Abafita, and Merra (2022) examined the role of coffee exports in Ethiopia's economic growth from 1980 to 2017, applying the Johansen cointegration test, VECM, IRF, and Granger causality tests. The results of the study reveal that while coffee exports do not significantly affect economic growth in the short term, they have a strong positive impact in the long run. Granger causality results indicate a bidirectional relationship between coffee exports and economic growth, and the IRF confirms the long-run growth-enhancing effect. The study recommends that a long-run policy towards exports in general and coffee export in particular is believed to have a significant impact on economic growth.

Alemayehu and Tilahun (2021) investigated whether agricultural exports drive economic growth in Ethiopia using secondary time series data (1997–2018) and applying the Engel–Granger cointegration and Granger causality tests. The results indicated no long-run relationship between agricultural exports and economic growth, and no causal link in either direction. In contrast to the findings of the previous study, this study concluded that neither the export-led growth model nor the growth-led export model applies to Ethiopia.

Degu (2019) examined intersectoral linkages in Ethiopia (1975–2017) using the cointegration test, VECM, Granger causality, impulse response, and variance decomposition analyses. The study found a stable long-run relationship among agriculture, industry, and services, with agriculture and services driving long-run industrial growth. In the short run, the industry had two-way causal links with both agriculture and services. The findings highlight agriculture's central role in stimulating other sectors, suggesting strategies like Agricultural Development Led Industrialization (ADLI).

Yimer (2023) investigated the long-run relationship between Ethiopia's agriculture, industry, and service sectors using the cointegrated vector autoregressive (CVAR) methodology for the period 1981–2011. The findings reveal that the service sector is a key driver of economic growth, positively influencing both agriculture and industry, as evidenced by the long-run impact matrix. The study recommends targeted service-sector investments for economy-wide gains.

Ademe and Mehare (2023) analyzed agricultural transformation and inter-sectoral linkages in Ethiopia using data from the World Bank and FAOSTAT (1981-2019). They found that agricultural transformation had not fully met goals in sustainability, productivity, technical innovation, food self-sufficiency, and agro-industry growth, highlighting the need for market-oriented, mechanized farming. The Vector Error Correction Model (VECM) revealed that in the short term, the industrial sector negatively affected agriculture, while agriculture positively impacted industry. In the long term, the relationship between the sectors was significantly positive, underscoring the importance of adopting new agricultural technologies.

Alemu et al. (2003) used Granger causality tests to explore the connection between agriculture and the broader economy. They reveal that before 1975, there was a strong mutual influence between agriculture, manufacturing, and services. However, from 1978 to 1998, agriculture's impact diminished due to socialist policies and economic shifts. Since 1989, easing policy constraints on agriculture has bolstered its positive influence on manufacturing growth.

Mellor and Dorosh (2010) examined the importance of agricultural growth as a means of accelerating Ethiopia’s economic transformation through a literature review and growth multiplier analysis. They argue that substantial agricultural growth can boost employment and reduce poverty while preventing megacity slums.

Till (2022) studied Ethiopia's growth from 2002 to 2010, focusing on agriculture's role. Their semi-input-output multiplier analysis compared the agricultural and manufacturing sectors' growth linkages. The study found strong and consistent growth linkages in agriculture, indicating its primary role in Ethiopia's growth during the studied period.

Diao et al. (2007) study agriculture's crucial role in Ethiopia's development and poverty alleviation. They utilize a fixed-price semi-input-output model and a flexible-price model for this analysis, concluding that agricultural growth can drive overall economic growth and poverty reduction more effectively than non-agricultural growth, especially within staple crop sectors. They stress the need for non-agricultural sectors to grow to match rising agricultural supply and demand, to prevent falling agricultural prices from undermining growth and poverty reduction efforts.

Tsehay, Adane, and Feto (2022) used SAM multiplier analysis to study the connections between agriculture and agro-processing in Ethiopia from 2005 to 2016. Their findings revealed a weak linkage between the agricultural and agro-processing sectors in Ethiopia.

In summary, our literature review highlights at least the following key gaps that justify the rationale for conducting the current study and its significant contribution. First, there is a notable scarcity of time series rigorous research comprehensively examining the "agriculture as an engine of growth" hypothesis in Ethiopia. Second, previous studies that explored the macro relevance of agricultural productivity in driving aggregate productivity and spurring structural transformation are almost nonexistent. Third, most of the previous studies focused on the linkage effect, typically using a static CGE model or input-output multiplier analysis. Fourth, prior studies have suffered from methodological limitations and have produced inconclusive mixed results. This gap in the literature highlights the necessity of conducting the current study and its contributions as well.

3. Methodology

This section briefly discusses the research methodology utilized for the study to achieve its objective. It encompasses the data source and description of variables, the empirical model, and details the empirical strategy employed by the study.

3.1. Data Source and Description of Variables

The empirical analysis of the study is based on a sixty-two-year (1962-2023) time series dataset collected on the variables of interest, which is mainly sourced from: the Economic Transformation Database (ETD), the Ethiopian Economic Association (EEA) database, the National Bank of Ethiopia, and the World Development Indicators (WDI) database.

Table 1: Description of Variables

List of Variables' names	Denotation	Measurement
Growth in Real GDP	g_{GDP}	Annualized percentage change in the total value-added of an economy.
Growth in Real GDP Per Capita	$g_{GDPpercapita}$	Gross domestic product divided by midyear population, which is then converted to the annual growth rate.
Real Agricultural Value Added	AVA	It is the sum of crop, livestock, forestry, hunting, and fishing production.
Real Nonagricultural Value Added	NonAVA	It is the total value-added of an economy after deducting agricultural value-added.
Growth in Real Agricultural Export	$g_{AgrExport}$	The sum of Coffee, Oilseeds, Pluses, Fruit and Vegetable, Live Animal, and Chat export, which is then converted to the annual growth rate.
Growth in Nonagricultural Employment	$g_{NonAgrEmp}$	Annualized percentage change in the total number of the labor force that is working in all sectors, excluding the agricultural labor force.
Growth in Agricultural Labor Productivity	$g_{P_{Agr}}$	Agricultural real value added divided by total agricultural employment, which is then converted to the annual growth rate.
Growth in Nonagricultural Labor Productivity	$g_{P_{NonAgr}}$	Nonagricultural real value added divided by total nonagricultural employment, which is then converted to the annual growth rate.
Growth in aggregate labor productivity	$g_{P_{Tot}}$	Total real value added of an economy divided by total employment, which is then converted to the annual growth rate
Total Capital Stock	K	Proxy by Gross fixed capital formation.
Labor Force	L	The total of the economically active working-age population

Notes: All national account data are in the 2015 base year price in local currency units.

3.2. Empirical Model

This paper empirically investigates the potential contribution of the agricultural sector as a driving force of long-run economic growth and structural transformation in the Ethiopian context by evaluating the macroeconomic importance of agriculture from multiple dimensions. Specifically, the empirical analysis focuses on: (i) investigating the causal relationship between agricultural productivity growth and economic growth, (ii) testing the agricultural export-led growth hypothesis, (iii) examining the intersectoral linkages between the agricultural and non-agricultural sectors, (iv) exploring the role of agricultural productivity in driving structural transformation, and (v) assessing the contribution of agricultural productivity relative to non-aggregate productivity in driving aggregate productivity of the economy.

To accomplish this, the study is anchored in the theoretical framework developed by Johnston and Mellor (1961), which identifies five key mechanisms through which agriculture can stimulate economic growth: labor transfer, food supply, demand for industrial goods, domestic savings, and foreign exchange from exports. This framework is reinforced by a broad body of empirical literature, including studies by Gardner (2003), Tiffin and Irz (2006), Gollin, Parente, and Rogerson (2002), Self and Grabowski (2007), Diao et al. (2007), and Vollrath (2009), all of which emphasize the central role of agricultural production and productivity growth in promoting sustained economic growth and driving structural transformation.

Building upon this theoretical and empirical foundation, the current study formulates and estimates five empirical models corresponding to its five core objectives.

The first empirical exercise in this study aimed to examine the contribution of agricultural productivity growth as a driver of long-run economic growth. To this end, following the established approaches in the literature, the empirical model to be estimated is specified as follows:

$$g_{GDPpercapita} = \beta_1 + \beta_2 g_{P_{Agr}} \quad \textbf{(1)}$$

Where $g_{GDPpercapita}$ and $g_{P_{Agr}}$ are the growth of GDP per capita and agricultural labor productivity growth, respectively. Here, β_1 is the constant term and β_2 is the long-run elasticity coefficient, which measures the elasticity of GDP per capita growth with respect to agricultural productivity growth. The estimated elasticity coefficient indicates the strength and size of the impact of agricultural productivity growth on GDP per capita growth.

To support the hypothesis that agricultural productivity growth is the key driver of long-run economic growth, it is necessary to establish a cointegrated long-run relationship between the two variables. Furthermore, the long-run elasticity coefficient must be both statistically significant and positive. As a final condition, there must be evidence of causality running from agricultural productivity growth to GDP per capita growth.

The second objective of this study is to examine the contribution of agriculture to economic growth within an open-economy framework by empirically testing the agricultural export-led growth (AELG) hypothesis in Ethiopia. The AELG hypothesis posits that growth in agricultural exports can serve as a key driver of overall economic growth, particularly in developing countries like Ethiopia, where agriculture constitutes a primary source of foreign exchange earnings. Numerous empirical studies have supported this view, showing that agricultural export growth has played a significant role in promoting GDP growth and rural development (Bleaney, Gemmell, and Greenaway, 1995; Gbetnkom and Khan, 2002; Verter and Bečvářová, 2014; Verter, 2015; Diao et al., 2010; Rapsomanikis, 2015). Building on this literature, the present study tests the validity of the agricultural export-led growth hypothesis in Ethiopia by analyzing the causal relationship between GDP growth and agricultural export growth. Accordingly, the baseline empirical model to be estimated can be expressed as follows:

$$g_{GDP} = \beta_3 + \beta_4 g_{AgrExport} \qquad \textbf{(2)}$$

Where g_{GDP} and $g_{AgrExport}$ are the growth of GDP and agricultural export, respectively, and β_3 is the intercept and β_4 is the long-run elasticity coefficient, which measures the elasticity of GDP growth to agricultural export growth. To support the AELG hypothesis, it is necessary to establish a cointegrated long-run relationship between the two variables. Furthermore, the long-run elasticity coefficient must be both statistically significant and positive. As a sufficient condition, there must be evidence of causality running from agricultural export growth to GDP growth.

The third objective of the study is to examine the intersectoral linkages between the agricultural and non-agricultural sectors. To this end, in line with the established approach in the literature, we estimate a model in which non-agricultural value added is regressed on agricultural value added, while controlling for capital and labor inputs. All variables are transformed into their natural logarithmic forms to allow for the interpretation of the estimated coefficients as elasticities. Thus, the baseline empirical model is specified as follows:

$$\ln NonAVA = \beta_5 + \beta_6 \ln AVA + \beta_7 \ln K + \beta_8 \ln L \quad \textbf{(3)}$$

Where $\ln NonAVA$, $\ln AVA$, $\ln K$, and $\ln L$ are the natural logarithms of non-agricultural value added, agricultural value added, capital stock, and labor force, respectively. Here, β_5 is the intercept, while β_6, β_7, and β_8 capture the elasticities of non-agricultural value added to agricultural value added, capital stock, and labor force, respectively.

To validate the hypothesis that growth in agricultural output generates positive spillover effects on the non-agricultural sector, it is necessary to establish a cointegrated long-run relationship among the variables. Furthermore, the estimated long-run elasticity coefficients must be positive and statistically significant. Finally, the presence of a causal relationship from agricultural to non-agricultural value added must also be verified.

Recent literature in development economics increasingly highlights the pivotal role of agricultural productivity improvements in enhancing overall productivity and facilitating structural transformation, owing to their extensive multiplier effects on both the demand and supply sides of the economy. This perspective is supported by empirical studies (e.g., Christiaensen et al., 2011; Otchia, 2014; Bustos et al., 2020; Gollin, 2021). Building on this framework, the fourth objective of this study is to examine the extent to which improvement in agricultural productivity facilitates structural transformation (proxied by employment growth in non-agricultural sectors). To this end, the baseline empirical model is specified as:

$$g_{NonAgrEmp} = \beta_9 + \beta_{10} g_{P_{Agr}} \quad \textbf{(4)}$$

Where $g_{NonAgrEmp}$ and $g_{P_{Agr}}$denotes the growth of employment in the non-agricultural sector and agricultural labor productivity growth, respectively. Here, β_9 is the constant term and β_{10} is the long-run elasticity coefficient, which measures the elasticity of employment growth in nonagricultural sectors to agricultural productivity growth.

To support the hypothesis that agricultural productivity improvement facilitates structural transformation, it is essential to establish a cointegrated long-run relationship between the two variables. Moreover, the estimated long-run elasticity coefficient must be statistically significant and positive. Finally, empirical evidence of causality from agricultural productivity growth to nonagricultural employment growth is required.

Much empirical evidence suggests that agricultural growth is at least twice as effective as non-agricultural growth in promoting overall economic performance and reducing poverty. In line with this perspective, the final objective of this study is to investigate the relative contributions of productivity growth in the agricultural and non-agricultural sectors to aggregate productivity growth. To this end, and building on established approaches in the literature, we estimate an empirical model in which economy-wide labor productivity growth is regressed on sectoral labor productivity growth in the agricultural and non-agricultural sectors. The baseline specification of the model is presented as follows:

$$g_{P_{Total}} = \beta_{11} + \beta_{12} g_{P_{Agr}} + \beta_{13} g_{P_{NonAgr}} \tag{5}$$

Where $g_{P_{Total}}$, $g_{P_{Agr}}$, and $g_{P_{NonAgr}}$ denotes aggregate labor productivity growth, and agricultural and nonagricultural labor productivity growth, respectively. Here, β_{12} and β_{13} are long-run elasticity coefficients, which measure the elasticity of overall productivity growth to agricultural and nonagricultural productivity growth, respectively. These elasticity estimates provide a quantitative measure of the relative strength and contribution of the agricultural and non-agricultural productivity growth in driving the overall productivity of the economy.

3.3. Empirical Strategy

This study, to achieve its objective, guided by the data-generating process of our variables of interest and to address the methodological limitation observed in previous empirical works, employed the augmented ARDL bounds testing approach for the cointegration modeling framework, Toda-Yamamoto Granger Non-Causality test, and Frequency-Domain Granger Causality test as an ideal empirical strategy that best fits and serves for its purpose.

Justification for choosing the augmented ARDL bounds test for cointegration modeling framework: The augmented ARDL bounds test for cointegration modeling framework is chosen in this study at least for three rational reasons. Firstly, the result obtained from preliminary examination of the data generating process of our variables of interest using standard unit root tests reveals that some of the variables are stationary at a level while the other become stationary after first differencing (I (1)), which means our variables of interest follow a mixed order of integration. Unlike traditional cointegration methods, which require all variables to be I (1), the ARDL model accommodates a mixed order integration so long as none of the variables is I (2) or higher, which is one of the fundamental reasons that justify the appropriateness of the ARDL modeling framework for this study. Second, the ARDL modeling framework offers several advantages over traditional approaches: it can be used with a mixture of I (0) and I (1) data, provides unbiased estimates of the long-run model and valid t-statistics even when the regressors are endogenous, allows different lags for variables, facilitates simultaneous estimation of short and long-run dynamics, suits both small and large sample sizes, and maintains simplicity in implementation and interpretation.

Third, the conventional ARDL bounds test for cointegration introduced by Pesaran et al. (2001) relies on the joint significance F-bounds test on all lagged-level variables and the t-bounds test on the lagged level of the dependent variable. However, this method operates under the strict assumption of an I (1) dependent variable to rule out the occurrence of degenerate cases and ensure a valid conclusion. Yet, when the dependent variable is I (0), determining the long-run relationship between the dependent and independent variables becomes challenging, even if the F-statistic exceeds the upper critical bound in the bounds test procedure. The reason is that, with I (0) dependent variable, the series will necessarily be stationary. This means that in jointly testing for long-run relationships via the F statistic, the fact that the computed F value is above the upper bound might just reflect the stationarity of the dependent variable.

To address this weakness with the well-used bounds testing procedure, McNown et al. (2018) introduced an additional new test to test the significance of the coefficients on the lagged levels of independent variables. The advantage of the additional test is to overcome the reliance on the assumption of an I (1) dependent variable to rule out the degenerate case. This reduces the risk of false conclusions based on standard unit root tests that have low power. Therefore, the augmented bounds test for cointegration is an extension of the conventional bounds test for cointegration and involves a three-stage testing procedure. And by application of all three ARDL bounds tests (i.e., the joint significance F-bounds test on all lagged level variables, the t-bounds test of parametric significance on the lagged level of the dependent variable, and the new Wald-test of parametric significance on the lagged level of the independent variables), it is possible to gain better insight into whether the relationship between the dependent and the distributed lag explanatory variables is one of cointegration, non-cointegration or a degenerate case.

As previously highlighted, the result obtained from the preliminary examination of the stationarity of our variables of interest indicates that our variables of interest exhibit a mixed order of integration. More specifically, the unit root test results underscore that some of the dependent variables used in the current study (i.e., GDP per capita growth and employment growth in the non-agricultural sector) are I (0) or stationary at the level. In such circumstances, the standard bounds testing procedure hardly provides a full picture of the cointegration status between the variables of interest and may lead to a wrong inference. Therefore, the current study employed the augmented ARDL bounds test for cointegration, which involves a three-stage testing procedure, to gain a clear picture of the cointegration status established among our variables of interest and make a valid inference, which is the fundamental reason justifying the appropriateness of the augmented ARDL bounds test for the cointegration modeling for this study.

Procedures involved in the augmented ARDL bounds test for cointegration modeling framework are: carrying unit root test to ensure that none of the variables are I (2) or higher, determining the deterministic specification, specifying ARDL optimum lag structure, conducting a diagnostic test to ensure none of the assumption underlying the ARDL model is violated, perform bounds test for cointegration which involves three stage testing procedure, If there is cointegration, then estimate both the long run and the short run dynamic coefficients, and If there is no cointegration, then only estimate the short run ARDL model.

For simplicity, we preferred to show the bounds testing procedure using only our first empirical model stated in equation (1), in which GDP per capita growth is regressed on agricultural productivity growth.

The basic form of the ARDL representation of our first empirical model, as stated in equation (1) with p lags of the dependent variable and q lags of the distributed lag explanatory variable, can be expressed as follows:

$$ARDL\ (p,q) = g_{GDPpercapita_t} = c_0 + \sum_{i=1}^{p} \omega_i\, g_{GDPpercapita_{t-i}} + \sum_{i=0}^{q} \varphi_i\, g_{P_{Agr}{}_{t-i}} + \mu_t \quad \textbf{(6)}$$

The existence of a cointegrating long-run relationship between the dependent and independent variables is tested based on the Conditional Error Correction (CEC) representation of the ARDL model, which is specified as follows:

$$\Delta g_{GDPpercapita_t} = \alpha_0 + \alpha_1 g_{GDPpercapita_{t-1}} + \alpha_2 g_{P_{Agr}{}_{t-1}} + \sum_{i=1}^{p-1} \delta_{1i} \Delta g_{GDPpercapia_{t-i}} + \sum_{i=0}^{q-1} \delta_{2i} \Delta g_{P_{Agr}{}_{t-i}} + \varepsilon_t \quad \textbf{(7)}$$

Where α_1 and α_2 are long-run parameters and δ_i is the short-run dynamic coefficient. To examine the presence of cointegration between the dependent and independent variables, the augmented bounds testing procedure involves performing three tests (the F-bounds test on all lagged level variables, the t-bounds test on the lagged level of the dependent variable, and the Wald-test coefficient restriction on the lagged level of the independent variable).

Performing the F-bound test involves testing the following hypothesis based on the CEC representation as stated in equation (7):

$H_{0,1}: \alpha_0 = \alpha_1 = \alpha_2 = 0$ against

$H_{1,1}: \alpha_i \neq 0$

Once the F-bounds test statistic is computed, the value is compared to two asymptotic critical values corresponding to the polar cases of all variables being I (0) or all variables being I (1). If the F-bounds test statistic is above the upper critical value, we reject the null hypothesis of no cointegration and accept the alternative of cointegration is possible.

The rejection of the F-bounds test null hypothesis, leading to three possible alternative hypotheses, only one of which confirms the existence of a non-degenerating useful cointegrating relationship. To ascertain which of the three alternatives emerges, an additional t-bounds test proposed by Banerjee et al. (1998) on the parameter significance of the lagged level of the dependent variable or the speed of adjustment coefficient must be performed. The t-bounds test t-statistic tests whether the speed-of-adjustment coefficient equals zero (null hypothesis) or less than zero and significant (alternative hypothesis).

Performing the t-bounds test involves testing the following hypothesis:

$H_{0,2}: \alpha_1 = 0$ against

$H_{1,2}: \alpha_1 \neq 0$

The decision criteria involve rejection of the null hypothesis when the t-bound statistic in absolute value is bigger than the absolute value of both the upper and lower critical bound values at any conventional level of significance considered. As outlined in Pesaran et al. (2001), the rejection of the t-bounds test in the secondary stage confirms the existence of a cointegrating relationship but does not preclude that it is degenerate. To rule out degenerate cointegration, a joint test of parameter significance on all coefficients associated with distributed lag explanatory variables in levels ought to be conducted. This can be done with a simple Wald-test coefficient restriction, which assumes the estimated coefficient for the distributed lag-regressed variable at a level equal to zero.

Performing the third stage test under the augmented bounds test involves testing the following hypothesis:

$H_{0,3}: \alpha_2 = 0$ against

$H_{1,3}: \alpha_2 \neq 0$

Under the augmented bounds testing procedure, there are three possible outcomes: If the null hypothesis. $H_{0,1}$ and$H_{0,2}$ are rejected but not $H_{0,3}$, implies a case of a degenerate lagged independent variable. This case implies an absence of cointegration. If the null hypothesis $H_{0,1}$ and $H_{0,3}$ are rejected but not $H_{0,2}$. We have a case of a degenerate lagged dependent variable. This case also implies an absence of cointegration. If the null hypothesis $H_{0,1}$, $H_{0,2}$ and $H_{0,3}$ are rejected, then there is non-degenerate useful cointegration.

From the augmented bounds testing procedure, if the null hypothesis is rejected under each of the three ARDL bounds tests and thus the existence of a cointegrating level relationship between the dependent and independent variables is confirmed, then the estimated long-run coefficient as stated in equation (1) can be derived from the CEC representation, which can be expressed as:

$$g_{GDPpercapita} = \beta_1 + \beta_2 g_{P_{Agr}}, where\ \beta_1 = -\frac{\alpha_0}{\alpha_1}\ and\ \beta_2 = -\frac{\alpha_2}{\alpha_1} \quad \textbf{(8)}$$

The corresponding EC representation short-run dynamic model can be specified as follows:

$$\Delta g_{GDPpercapita_t} = \lambda ECT_{t-1} + \sum_{i=1}^{p-1} \delta_{1i} \Delta g_{GDPpercapita_{t-i}} + \sum_{i=0}^{q-1} \delta_{2i} \Delta g_{P_{Agr_{t-i}}} + \varepsilon_t \quad \textbf{(9)}$$

Where λ and δ_i are the speed of adjustment coefficient and the short-run dynamic coefficients, respectively.

Justification for choosing the Toda-Yamamoto Granger Causality Test: Since the objective of the current paper is to examine the long-run and short-run causality relationship established among the variables of interest, the Toda-Yamamoto approach to the Granger causality test is used to verify the existence and directional of causality relationship established between the variables of interest This approach found to be superior to the standard Granger-causality tests. The Toda and Yamamoto (1995) procedure has an advantage in that it does not require precise knowledge of the integration properties of the system. It is applied even when there is no cointegration or stability, and when rank conditions are not satisfied, so long as the order of integration of the process does not exceed the true lag length of the model (Toda and Yamamoto, 1995; Ziramba, 2009). Toda and Yamamoto (1995) proposed a Granger non-causality test using a modified Wald test. The Toda-Yamamoto procedure is formulated in levels and tests general restrictions on the parameter matrices. The T-Y Granger causality approach estimates a $(k + d_{max})^{th}$-order VAR where k is the appropriate lag length of the VAR model and d_{max} denotes the maximum order of integration of the series in the model.

The Toda-Yamamoto Granger causality test representation of our first empirical model in equation (1) can be specified as:

$$g_{GDPpercapita_t} = c_0 + \sum_{i=1}^{k} \alpha_{1i}\, g_{GDPpercapita_{t-1}} + \sum_{i=k+1}^{k+d_{max}} \alpha_{2i}\, g_{GDPpercapita_{t-1}} + \sum_{i=1}^{k} \beta_{1i}\, g_{p_{Agr_{t-1}}} + \sum_{i=k+1}^{k+d_{max}} \beta_{2i}\, g_{P_{Agr_{t-1}}} + u_{1t} \quad \textbf{(10)}$$

$$\boldsymbol{g_{P_{Agr_t}} = c_0 + \sum_{i=1}^{k} \delta_{1i}\, g_{P_{Agr_{t-1}}} + \sum_{i=k+1}^{k+d_{max}} \delta_{2i}\, g_{P_{Agr_{t-1}}}} + \sum_{i=1}^{k} \theta_{1i}\, g_{GDPpercapita_{t-1}} + \sum_{i=k+1}^{k+d_{max}} \theta_{2i}\, g_{GDPpercapita_{t-1}} + u_{2t} \quad \textbf{(11)}$$

Frequency-Domain Granger Causality Test: To ensure the robustness of the result, we complemented the T-Y Granger causality test with the frequency-domain Granger causality test approach developed by Breitung and Candelon (2006). The frequency-domain Granger causality testing approach has additional novel advantages. It eliminates seasonal variations since it allows small samples of data. Further, it allows us to scrutinize the short, medium, and long-term causality relationship between the variables of interest.

4. Results and Discussions

This section presents and discusses the final results derived from estimating the empirical models outlined earlier, enabling a well-supported conclusion regarding the study's central research questions. As noted previously, the study pursued five interconnected objectives, each addressed independently to explore the core research inquiries. Consequently, this section is divided into six parts to present the empirical findings. The first part outlines and interprets the unit root test results. The second part reports and discusses the findings on the long-run causal relationship between agricultural productivity growth and economic growth. The third part details the evidence for or against the agricultural export-led growth hypothesis. The fourth part analyzes the results on the intersectoral linkages between the agricultural and non-agricultural sectors. The fifth part presents insights into whether agricultural productivity improvement facilitates structural transformation. Finally, the last part examines the relative contributions of agricultural and non-agricultural productivity to the economy-wide productivity.

4.1. Unit Root Test Result

The first and most important step in time series analysis is to explore the stationarity properties of the series used in the study. This is to ensure that the regression result is not spurious. Usually, the ARDL model bounds testing approach for cointegration does not require testing for unit roots in the series. However, when the variables are I (2) or higher, the ARDL model is rendered inapplicable. According to Ouattara (2004), in the presence of I (2) variables, the computed F-statistics provided by Pesaran et al. (2001) are not valid because the bounds test is based on the assumption that the variables are I (0) or I (1). Therefore, performing a unit root test is still necessary in the ARDL model to ensure none of the variables are second or higher order integrated, which is a prerequisite to continuing with the ARDL bounds testing approach for cointegration.

Table 2: Unit Root Test Result

Variables		**ADF**		**DF-GW**		**PP**		**Decision**
		Level	**Differenced**	**Level**	**Differenced**	**Level**	**Differenced**	
$g_{GDPpercapita}$	A	-2.27*	-6.59***	-2.29*	-5.85***	3.73***	10.82***	I (0)
	B	-3.61**	-6.71***	-2.62*	-4.65**	-4.01**	-11.63***	
$g_{P_{Agr}}$	A	-3.02***	-5.05***	-3.87***	-5.18***	-4.98***	-22.67***	I (0)
	B	-3.66***	-4.99***	-3.81***	-4.26***	-6.42***	-23.02***	
g_{GDP}	A	-0.71	-6.73***	-0.64	-6.53***	-1.27*	-6.87***	I (1)
	B	-1.98	-6.75***	-1.58	-6.51***	-2.24*	-7.11***	
$g_{AgrExport}$	A	-7.23***	-11.90***	-2.52*	-6.43***	-7.23***	-18.84***	I (0)
	B	-7.18***	-11.78***	-2.21*	-8.41***	-7.18***	-18.80***	
$\ln AVA$	A	-1.79	-11.38***	-1.79	-11.49***	-2.04	-18.63***	I (1)
	B	-1.95	-11.25***	-2.03	-11.49***	-2.15	-18.72***	
$\ln NonAVA$	A	-2.18	-6.73***	-1.98	-6.05***	-1.78	-14.61***	I (1)
	B	-1.32	-6.64***	-2.44	-6.66***	-2.49	-14.15***	
$\ln K$	A	-1.21	-6.06***	-2.29	-7.23***	-2.13	-18.03***	I (I)
	B	-1.66	-5.95***	-2.01	-4.82***	-2.29	-17.89***	
$\ln L$	A	-1.96	-6.92***	-1.73	-6.99***	-2.02	-39.44***	I (1)
	B	-2.03	-6.87***	-1.95	-6.98***	-2.03	-44.57***	
$g_{P_{Total}}$	A	-0.08	-6.67***	-0.82	-6.72***	-4.58***	-23.95***	I (1)
	B	-2.13	-6.70***	-1.64	-6.55***	-5.67***	24.96***	
$g_{P_{NonAgr}}$	A	-3.04**	-9.25***	-3.07***	-13.10***	-5.61***	-27.29***	I (0)
	B	-6.89**	-9.18***	-4.13***	-9.26***	-6.94***	-31.52***	
$g_{NonAgrEmp}$	A	-4.06***	-8.19***	-3.93***	-7.62***	-4.14***	-11.49***	I (0)
	B	-4.03***	-8.12***	-4.03***	-7.94***	-4.11***	-11.27***	

Notes: *, **, and *** denote the rejection of the null hypothesis in the respective tests at 10%, 5%, and 1% levels of significance, respectively. A and B represent the test specification for intercept and intercept with trend cases, respectively.

In the current study, therefore, Augmented Dickey-Fuller (ADF), DF-GLS, and the Phillips-Perron (PP) unit root tests are employed to determine the order of integration of the variables of interest and ascertain that none of the variables are I (2), which is a precondition for applying the ARDL modeling technique. The use of more than one unit root test is to ensure the robustness of the results.

Table 2 reports the unit root test results of the ADF, DF-GLS, and PP tests for intercept (denoted by A) and intercept with trend cases (denoted by B), both in level and first difference. The null hypothesis under each of the respective tests is that the series under consideration has a unit root or non-stationary at levels. The decision rule is that the null hypothesis (the series has a unit root) is rejected if the test statistic is statistically significant at any of the conventional levels of significance (1%, 5%, and 10%).

As shown in Table 2, there is a mixture of variables that are stationary at a level or I (0), as well as become stationary after first differencing or I (1). More specifically, the result suggests that the variables GDP growth, the economic-wide labor productivity growth, and the natural logarithmic of agricultural value added, non-agricultural value added, capital stock, and labor force are first-order integrated variables, and all the remaining variables are integrated of order zero or stationary at the level. However, none of the variables are second-order integrated (I (2)) or higher. This warrants the appropriateness of using the augmented ARDL bounds testing for cointegration modeling techniques for estimating the empirical models formulated for investigating the potential contribution of the agricultural sector as a driving force of long-run economic growth and structural transformation in Ethiopia.

4.2. Agriculture Productivity and Economic Growth

This section presents and elaborates on the empirical findings obtained from examining agriculture's role as a driver of long-run economic growth in Ethiopia. To do this, and in line with the established approach in the literature, we regressed GDP per capita growth ($g_{GDPpercapita}$) on agricultural labor productivity growth ($g_{P_{Agr}}$).

The discussion covers the results from optimal lag selection, the augmented bounds test for cointegration, model diagnostics test, stability tests, and analyses of long-run and short-run dynamic coefficients. It also includes results from the Toda-Yamamoto and Frequency-Domain Granger non-causality tests.

4.2.1. Lag Length Selection

The first step in the ARDL model bounds testing procedure is selecting the optimum lag length because the result of the bound test for cointegration is sensitive to lag length selection. Therefore, it is necessary to determine the optimal lag length, which is a prerequisite to continuing the ARDL bounds testing procedure to examine the existence of a cointegrating long-run relationship between the variables of interest.

In this study, to determine the optimal lag structure, the Akaike information criterion (AIC) is employed as it is more efficient in small sample sizes. The final decision is based on the smallest value of the AIC lag specification that fulfilled the diagnostic test for autocorrelation. Accordingly, out of the alternative models evaluated, the automatic selection procedure yielded an ARDL (4, 0) model with four lags for the dependent variable ($g_{GDPpercapita}$) and zero lag for the distributed lag explanatory variable ($g_{P_{Agr}}$).

4.2.2. Augmented Bounds Test for Cointegration

To ensure valid inference in ARDL modeling, the variables under investigation must be cointegrated; otherwise, the estimated coefficients may be spurious. Accordingly, this study employs the augmented ARDL bounds testing approach for cointegration, which involves a three-stage testing procedure (i.e., the joint significance F-bounds test on all lagged level variables, the t-bounds test of parametric significance on the lagged level of the dependent variable, and the Wald-test of parametric significance on the lagged level of the independent variables), to determine the existence of a cointegrating long-run relationship among the variables of interest.

Under the augmented bounds testing approach, there are four possible outcomes. First, if the F-bounds test is not significant, it indicates no cointegration. Second, if all three tests are significant, a non-degenerating useful cointegrating relationship is confirmed. Third, if the F-bound test and the t-bound test are significant but the Wald test is not, this suggests a degenerate lagged independent variable case, meaning no cointegration. Lastly, if the F-bound test and the Wald test are significant but the t-bound test is not, it points to a degenerate lagged dependent variable case, which also implies no cointegration.

Table 3 reports the result of the augmented bounds test for cointegration. It is evident from Table 3 that the F-bounds test statistic 42.125 is well beyond the upper critical bound value at all reasonable levels of significance, and a clear rejection of the null hypothesis of no cointegration using the restricted constant and no trend case.

Table 3: Result of the Augmented Bounds Test for Cointegration

Stage	Test Applied	Test Statistics	10%		5%		1%	
			I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
1^{st}	F-bounds	42.125	3.095	3.619	3.751	4.33	5.265	5.946
2^{nd}	t-bounds	-6.726	2.565	-2.924	-2.884	-3.259	-3.516	-3.913
3^{rd}	Wald-test	6.746	Df (1, 45)			Probability 0.01		

Source: Own Computation using STATA version 19.0

Recall that the rejection of the F-bounds tests null hypothesis leads to three possible alternative hypotheses, only one of which confirms the existence of a non-degenerating useful cointegrating relationship. To ascertain which of the three alternatives emerges, an additional t-bounds test of parametric significance on the lagged level of the dependent variable (the speed-of-adjustment coefficient) must be performed. Putting it differently, the t-bounds test t-statistic tests whether the speed-of-adjustment coefficient equals zero (null hypothesis) or less than zero and statistically significant (alternative hypothesis). The decision criteria involve rejection of the null hypothesis when the t-bound statistic in absolute value is bigger than the absolute value of both the upper and lower critical bound values at any conventional level of significance considered. As shown in Table 3, the absolute value of t-bounds statistic 6.726, is well above the absolute value of either of the critical bounds values at all conventional level of significance, and a clear rejection of the null hypothesis that assumes the speed-of-adjustment coefficient is equal to zero and by extension confirm that the speed of adjustment coefficient is negative and statistically significant.

As outlined in Pesaran et al. (2001), the rejection of the t-bounds test null hypothesis in the second stage confirms the existence of a cointegrating relationship, but does not preclude that it is degenerate. To rule out degenerate cointegration, a joint test of parameter significance on the lagged level of the independent variable(s) ought to be conducted. This can be done with a simple Wald-test coefficient restriction, which assumes the estimated coefficient for the distributed lag-regressed variable at a level equal to zero. The decision involves rejection of the null hypothesis if the p-value is less than a 5 percent significance level. Once again, it is noted from Table 3 that, with a p-value of 0.01, this test rejects the null hypothesis that assumes all tested coefficients are jointly zero, and by extension, confirms that the cointegrating relationship, which emerges, is sensible and not degenerate.

To sum up, the result obtained from the augmented bound testing approach for cointegration confirms the existence of a non-degenerating useful cointegrating long-run relationship between the dependent variable ($g_{GDPpercapita}$) and the distributed lag explanatory variables ($g_{P_{Agr}}$).

4.2.3. Diagnostics Test

Before estimating the long-run relationship and the short-run dynamics of the ARDL model, it is important to analyze the performance of the ARDL model estimates through the diagnostic tests. Table 4 presents the results obtained from testing the underlying assumption (i.e., normality is tested with the Jarque-Bera test, autocorrelation is tested with the Breusch-Godfrey Serial Correlation LM test, heteroscedasticity is tested with the Breusch-Pagan-Godfrey heteroscedasticity test, and model misspecification is tested with the Ramsey Reset test). The null hypothesis in the respective test mentioned above assumes the residual is normally distributed, no serial correlation of the residual, no problem with heteroscedasticity, and the model is correctly specified. The decision rule is that if the probability value computed under the respective test is less than a 5 percent significance level, the null hypothesis is rejected; otherwise, it is not.

Table 4: Model Diagnostic Test

Null Hypothesis	Test Applied	Statistic value	Probability
Error terms are normally distributed	Jarque-Bera	3.94	0.13
No serial correlation of the residual	Breusch-Godfrey LM test for autocorrelation	0.30	0.58
Homoscedasticity	Breusch-Pagan-Godfrey Heteroscedasticity Test	2.34	0.12
The model is correctly specified	Ramsey RESET Test	1.72	0.17

Source: Owen Computation using STATA version 19.0

As shown in Table 4, the p-value for the respective diagnostic tests is greater than 0.05, and thus the null hypothesis cannot be rejected in each case. The impossibility of rejecting the null hypothesis under the respective diagnostic tests confirms that the model passes all diagnostic tests. Specifically, the error term is normally distributed, no serial correlation of the residual, no problem with heteroscedasticity, and the model is correctly specified.

4.2.4. Stability Test

The presence of parameter stability is one of the econometric requirements for a well-specified and performing ARDL model (Murthy and Okunade, 2016). The stability of the regression coefficients evaluated by stability tests shows whether the regression equation is stable over time and suitable for making long-run decisions (Pesaran and Pesaran, 2009). To test for the stability of the short-run and long-run coefficients estimated by the ARDL model, the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests on the recursive residuals from the estimated ARDL model were performed. Figures 1 and 2 illustrate the results of these tests.

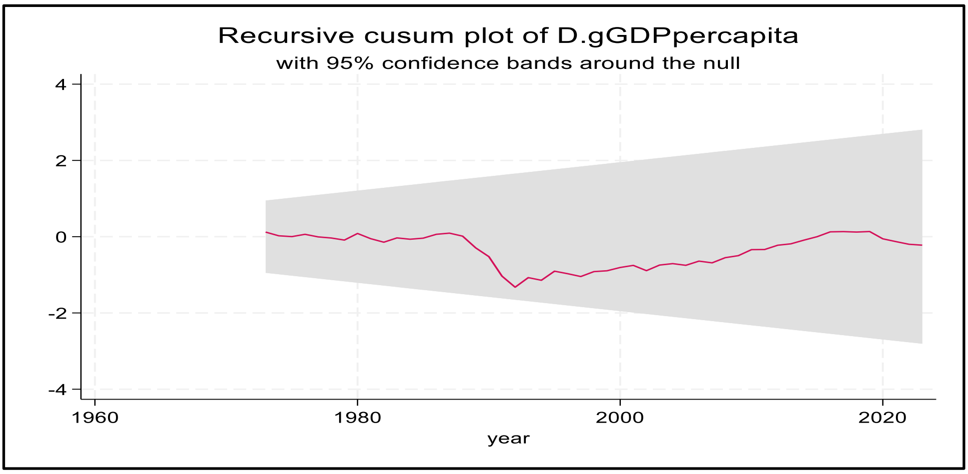

Figure 1: Plots of the cumulative sum of recursive residuals

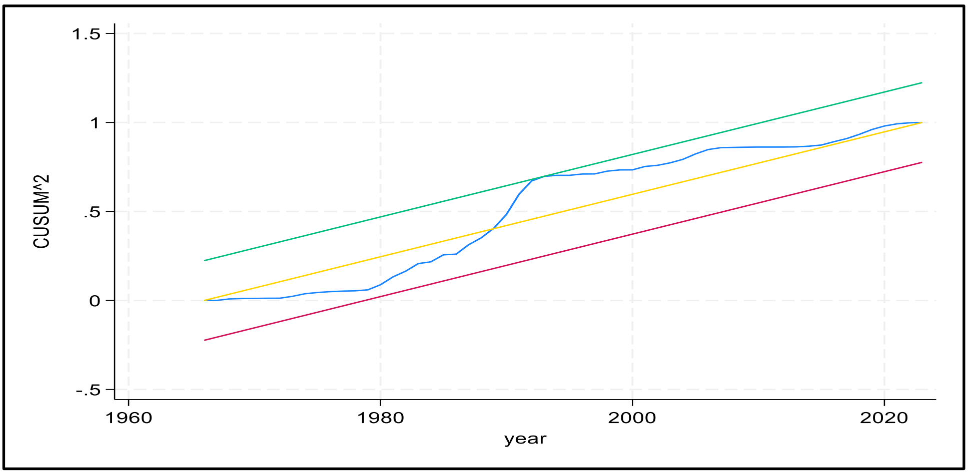

Figure 2: Plots of the cumulative sum of the squared recursive residual

As it is seen from Figure 1-2, the plots of CUSUM and CUSUMSQ statistics both lie between the critical bounds at a 5 percent significance level and do not cross the lower and upper critical limits in the estimated model. This indicates that the estimated coefficients have the desired characteristics of parameter stability over the sample period in the estimated model.

4.2.5. Long Run Coefficients Analysis

Having found evidence of cointegration and confirmed that the assumption underlying the ARDL model is not violated, the next step involves analyzing the coefficients of the long-run and short-run dynamics of the ARDL model. Table 5 presents the result of the estimated long-run coefficients alongside their corresponding standard error, t-statistics, and p-values.

Table 5: Long Run Coefficients

Dependent Variable: $g_{GDPpercapita}$				
Long Run Coefficients				
Variables	**Coefficients**	**Std. Error**	**t-Statistic**	**Prob.**
$g_{P_{Agr}}$	0.90	0.15	6.19	0.00
Constant	1.54	0.52	2.96	0.01
R-square	0.82		Adjusted R-square	0.81

Source: Owen Computation using STATA version 19.0

As shown in Table 5, the estimated long-run coefficient, which measures the elasticity of GDP per capita growth for agricultural productivity growth ($g_{P_{Agr}} = 0.9$), is positive and statistically significant at all conventional levels of significance. This confirms the existence of a significant positive long-run relationship between the dependent variable (GDP per capita growth) and the independent variable (agricultural productivity growth). Specifically, the results suggest that a 1 percentage point increase in the growth rate of agricultural productivity is associated with a 0.9 percentage point increase in GDP per capita growth in the long-run. The adjusted R-squared, which is 0.81, shows the overall goodness of the fitted model. Further, it implies that about 81 percent of the difference in the growth rate of GDP per capita is associated with a difference in agricultural productivity growth. The results indicate that agricultural productivity growth is a key driver of economic growth in Ethiopia. However, this is only suggestive; a definitive conclusion requires confirmation of the existence of a causal relationship from agricultural productivity growth to GDP per capita growth. The Granger causality test results, which will be examined in the next section, will help determine whether such a causal link exists.

4.2.6. Short Run Dynamic Coefficients Analysis

Once cointegration is established, the error correction model (ECM) is constructed to show the dynamic relationship among variables for the model from the short run to the long run equilibrium position. Table 6 gives the result of short-run dynamics associated with the ARDL (4, 0) model. The coefficient of the first lag of the error correction term (ECT_{t-1}) should be negative and statistically significant if the model can correct any of the shocks in the short run to the long-run equilibrium. As can be seen from Table 6, the negative and statistically significant estimate of ECT_{t-1}, support the result of the bound test, which confirmed a long-run equilibrium relationship between the variables under study.

Further, it reveals the speed of adjustment of the short-run to the long-run equilibrium position of the dependent variable. According to Table 6, the value of ECT_{t-1} is -0.70, meaning that 70 percent of any short-term deviation in GDP per capita growth from its long-term path is corrected within a year. This implies the speed of adjustment toward the equilibrium after a shock is too fast.

Table 6: Short Run Dynamic Coefficients Result

Dependent Variable: D ($g_{GDPpercapita}$) ARDL(4, 0)
Short Run Coefficients

Variables	Coefficients	Std. Error	t-Statistic	Prob.
ECT (-1)	-0.70	0.10	-6.73	0.00
D ($g_{GDPpercapita}$(-1))	0.02	0.11	0.17	0.86
D ($g_{GDPpercapita}$ (-2))	-0.12	0.09	-1.38	0.17
D ($g_{GDPpercapita}$(-3))	0.16	0.08	2.04	0.05
D ($g_{P_{Agr}}$)	0.63	0.06	10.15	0.00
R-Squared	0.83		S.E. of regression	2.71
Adjusted R-Squared	0.82		Sum of squared residual	396.10
F-statistic	87.04		Log Likelihood	-138.01
Prob(F-statistic)	0.00		Durbin-Watson stat	1.78

Source: Own Computation using STATA version 19.0

As presented in Table 6, the estimated short-run coefficient captured by the lead difference of agricultural productivity growth [D ($g_{P_{Agr}}$)=0.63], is positive and statistically significant, confirming the existence of a significant positive short-run relationship between GDP per capita growth and agricultural productivity growth. Specifically, the results suggest that a 1 percentage point increase in agricultural productivity growth is associated with a 0.63 percentage point increase in GDP per capita growth in the short run. The adjusted R-squared value of 0.82 indicates that labor productivity growth in agriculture accounts for about 82 percent of the variation in GDP per capita growth in the short run.

Overall, the empirical results from the ARDL model estimates point to a statistically significant and positive long-run as well as short-run link between GDP per capita growth and agricultural productivity growth.

4.2.7. Toda-Yamamoto Granger Non-Causality Test Result

The final and most critical step in testing the hypothesis that agricultural productivity growth serves as a key driver of economic growth in Ethiopia involves the application of the Granger causality test. This test is employed to ascertain the nature and direction of the causal relationship between the variables specified in the empirical models. While the presence of a cointegrated and statistically significant positive long-run relationship between agricultural productivity growth and GDP per capita growth constitutes a necessary condition for supporting the hypothesis, it is not sufficient. To robustly validate the theoretical proposition, there must also be evidence of a causal relationship running from agricultural productivity growth to GDP per capita growth.

In the current study, therefore, as a sufficient condition for validating the hypothesis, the Granger causality test is conducted using the Toda-Yamamoto approach to Granger causality. To ensure the robustness of the result, we complemented the Toda-Yamamoto Granger causality test with the frequency-domain Granger causality test approach developed by Breitung and Candelon (2006). This technique was developed based on the Toda-Yamamoto Granger causality testing approach; thus, it possesses all the advantages of the Toda-Yamamoto approach. However, the frequency-domain Granger causality testing approach has additional novel advantages. It eliminates seasonal variations since it allows small samples of data. Further, it allows us to scrutinize the short, medium, and long-term causality relationship between the variables of interest.

Table 7 reports the Granger causality test result obtained from both the Toda-Yamamoto and the frequency-domain approach to the Granger causality test.

As shown in Table 7, the results from the Granger causality test indicate that the null hypothesis stating that agricultural productivity growth does not Granger-cause GDP per capita growth is rejected at the 5 percent level of significance (p-value = 0.04).

Table 7: Granger Causality Test Result

Toda-Yamamoto Approach to Granger Causality Test Result			
Null Hypothesis	χ^2	**df**	**Prob.**
$g_{P_{Agr}}$ does not Granger-cause $g_{GDPpercapita}$	10.01	4	0.04
$g_{GDPpercapita}$ does not Granger-cause $g_{P_{Agr}}$	7.80	4	0.09
Frequency Domain Causality Test			
Null Hypothesis	**Long-term ($\omega = 0.05$)**	**Medium-term ($\omega = 1.5$)**	**Short-term ($\omega = 2.5$)**
$g_{P_{Agr}}$ does not Granger-cause $g_{GDPpercapita}$	8.25**	0.93	6.19**
$g_{GDPpercapita}$ does not Granger-cause $g_{P_{Agr}}$	0.09	1.58	1.97

Notes: *, **, and *** denote statistical significance at 10%, 5%, and 1% level of significance, respectively. Source: Own computation, STATA version 19.0.

In contrast, in the case of the reverse causality test, the null hypothesis that GDP per capita growth does not Granger-cause agricultural productivity growth cannot be rejected, as the corresponding p-value exceeds the 5 percent level of significance. The impossibility of rejecting the null hypothesis in the case of the reverse causality test confirms the existence of a unidirectional causality running from agricultural productivity growth to GDP per capita growth, thereby lending empirical support to the "agriculture as an engine of growth" hypothesis. This result is further corroborated by the frequency-domain Granger causality test, reinforcing the robustness and consistency of the inference drawn from the Toda–Yamamoto procedure.

In sum, the empirical results from the ARDL model estimates confirm a statistically significant and positive relationship between agricultural productivity growth and GDP per capita growth, both in the short run and the long run. Complementing this, the Granger causality test confirms a unidirectional causality relationship running from agricultural productivity growth to GDP per capita growth. Taken together, the results from both empirical approaches provide strong and consistent evidence supporting the hypothesis that agricultural productivity growth is a key driver of economic growth in Ethiopia. The result suggests that targeted investment aimed at improving the productivity of smallholder farms significantly promotes long-run economic growth and facilitates structural transformation of the economy. Our result is consistent with similar studies (Diao et al., 2007; Till, 2022; Alemu, 2015).

4.3. Agricultural Export-Led Growth (AELG) Hypothesis

This section presents and discusses the empirical results derived from examining the contribution of agriculture to economic growth within an open-economy framework. Specifically, the analysis aims to test the validity of an Agricultural Export-Led Growth (AELG) hypothesis in the Ethiopian context. To this end, GDP growth (g_{GDP}) is regressed on agricultural export growth ($g_{AgrExport}$), to examine the long-run and short-run causality relationship between the variables.

4.3.1. Lag Length Selection

The first step in the ARDL model bounds testing procedure is selecting the optimum lag length because the result of the bound test for cointegration is sensitive to lag length selection. Accordingly, out of the alternative models evaluated based on the Akaike information criterion (AIC), the automatic selection procedure yielded an ARDL (1, 0) model with one lag for the dependent variable (GDP growth) and zero lag for the distributed lag explanatory variable (agricultural export growth).

4.3.2. Augmented Bounds Test for Cointegration

This section reports and discusses the results obtained from the augmented bounds test for cointegration, as presented below in Table 8.

It is evident from Table 8 that the F-bounds test statistic 5.732 is well beyond the upper critical bound value at a 5 percent level of significance, and a clear rejection of the null hypothesis of no cointegration using the restricted constant and no trend case.

Table 8: Result of the Augmented Bounds Test for Cointegration

Stage	Test Applied	Test Statistics	10%		5%		1%	
			I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
1^{st}	F-bounds	5.732	3.248	3.769	3.986	4.572	5.752	6.469
2^{nd}	t-bounds	-3.722	-2.606	-2.964	-2.945	-3.322	-3.633	-4.043
3^{rd}	Wald-test	9.07	**Df** (1, 32)				**Probability** 0.00	

Source: Own Computation using STATA version 19.0

Once again, it is noted from Table 8 that, the absolute value of t-bounds statistic 3.722, is well above the absolute value of either of the critical bounds values at a 5 percent level of significance, and a clear rejection of the null hypothesis that assumes the speed-of-adjustment coefficient is equal to zero and by extension confirm that the speed of adjustment coefficient is negative and highly significant.

As outlined in Pesaran et al. (2001), the rejection of the t-bounds test in the secondary stage confirms the existence of a cointegrating relationship but does not preclude that it is degenerate. To rule out degenerate cointegration, a joint test of parameter significance on the lagged level of the independent variables ought to be conducted. As shown in Table 8, with a p-value of 0.00, this test rejects the null hypothesis that assumes all tested coefficients are jointly zero, and by extension, confirms that the cointegrating relationship, which emerges, is sensible and not degenerate. To sum up, the augmented bound test for cointegration result confirms the existence of a non-degenerating useful cointegrating relationship between the dependent variable, GDP growth (g_{GDP}) and the explanatory variable, agricultural export growth ($g_{AgrExport}$).

4.3.3. Diagnostics Test

Before estimating the long-run relationship and the short-run dynamics of the ARDL model, it is important to analyze the performance of the ARDL model estimates through the diagnostic tests. Table 9 presents the results obtained from testing the underlying assumption.

Table 9: Model Diagnostic Test

Null Hypothesis	Test Applied	Statistic value	Probability
Error terms are normally distributed	Jarque-Bera	0.79	0.67
No serial correlation of the residual	Breusch-Godfrey LM test for autocorrelation	2.27	0.13
Homoscedasticity	Breusch-Pagan-Godfrey Heteroscedasticity Test	1.13	0.28
The model is correctly specified	Ramsey RESET Test	2.35	0.08

Source: Owen Computation using STATA version 19.0.

As shown in Table 9, the p-value computed for the respective diagnostic tests is greater than 0.05, and thus the null hypothesis cannot be rejected in each case. The impossibility of rejecting the null hypothesis confirms that the model passes all diagnostic tests. Specifically, the results suggest that the error term is normally distributed, no serial correlation of the residual, no problem with heteroscedasticity, and the model is correctly specified.

4.3.4. Stability Test

To test for the stability of the short-run and long-run coefficients estimated by the ARDL model, the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests on the recursive residuals from the estimated ARDL model were performed. Figures 3 and 4 illustrate the results of these tests.

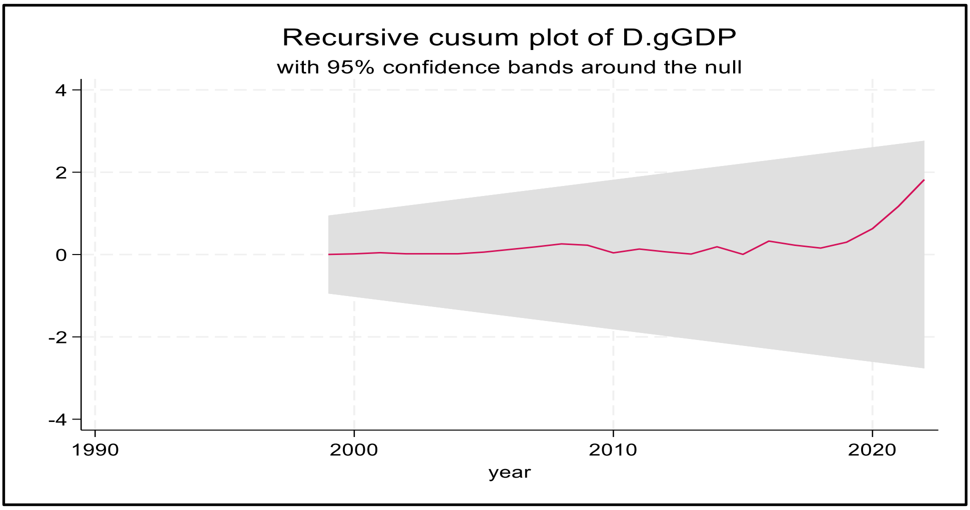

Figure 3: Plots of the cumulative sum of recursive residuals

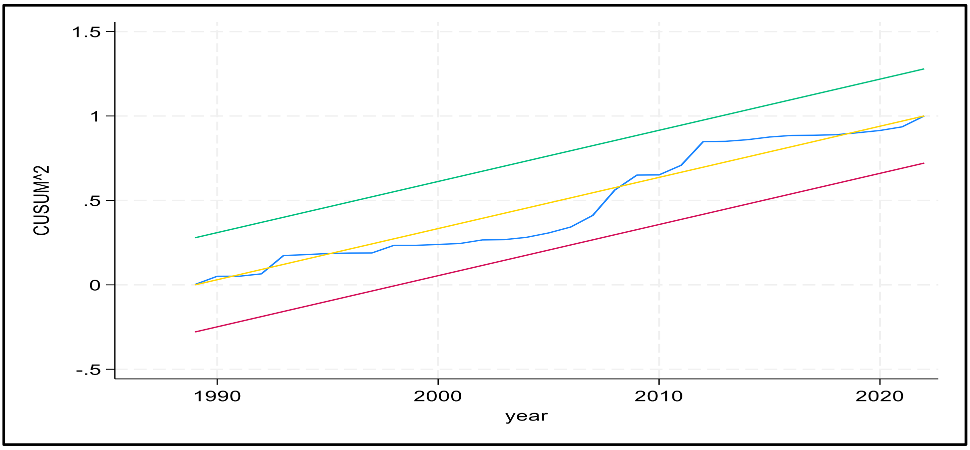

Figure 4: Plots of the cumulative sum of the squared recursive residual

It is evident from Figures 3-4, the plots of CUSUM and CUSUMSQ statistics both lie between the critical bounds at a 5 percent significance level and do not cross the lower and upper critical limits in the estimated model. This indicates that the estimated coefficients have the desired characteristics of parameter stability over the sample period in the estimated model.

4.3.5. Long Run Coefficients Analysis

Having found evidence of cointegration and confirmed that the assumption underlying the ARDL model is not violated, the next step involves analyzing the coefficients of the long-run and short-run dynamics of the ARDL model. Table 10 presents the results of the estimated long-run coefficients alongside their corresponding standard error, t-statistics, and p-values.

Table 10: Long Run Coefficients

Dependent Variable: g_{GDP} **Long Run Coefficients**				
Variables	**Coefficients**	**Std. Error**	**t-Statistic**	**Prob.**
$g_{AgrExport}$	0.18	0.10	1.84	0.08
Constant	15.69	3.06	5.13	0.00
R-square	0.35		Adjusted R-square	0.31

Source: Owen Computation using STATA version 19.0

As shown in Table 10, the estimated long-run coefficient, which measures the elasticity of GDP growth for agricultural export growth ($g_{AgrExport}$=0.18) is positive and statistically significant, as per the expectation. This confirms the existence of a significant positive long-run association between the dependent variable (g_{GDP}) and distributed lag explanatory variable ($g_{AgrExport}$). Specifically, the results suggest that in the long run, a 1 percentage point increase in the growth rate of agricultural exports is associated with a 0.18 percentage point increase in GDP growth. The adjusted R-squared value of 0.31 shows that close to one-third of the difference in the growth rate of GDP is associated with a difference in the rate of agricultural export growth in the long run.

4.3.6. Short Run Dynamic Coefficients Analysis

Once cointegration is established, the error correction model (ECM) is constructed to show the dynamic relationship among variables for the model from the short run to the long run equilibrium position. Table 11 gives the result of short-run dynamics coefficients associated with the ARDL (1, 0) model. As shown in Table 11, the negative and statistically significant estimate ECT_{t-1} support the result of the bound test, which confirmed a long-run equilibrium relationship between GDP growth and agricultural export growth. Further, it reveals the speed of adjustment of the short-run to the long-run equilibrium position of the dependent variable. As shown in Table 11, the value of ECT_{t-1} is -0.56, meaning that over half of any short-term deviation in GDP growth from its long-term path is corrected within a year.

As shown in Table 11, the estimated short-run coefficient represented by the lead difference of agricultural export growth [D ($g_{AgrExport}$)=0.10] is positive and highly statistically significant. This indicates the existence of a significant positive short-run relationship between GDP growth and agricultural export growth. Specifically, a 1 percentage point increase in agricultural export growth is associated with a 0.1 percentage point increase in GDP growth in the short run.

Table 11: Short Run Dynamic Coefficients Result

Dependent Variable: D (g_{GDP}) ARDL(1, 0)				
Short Run Coefficients				
Variables	**Coefficients**	**Std. Error**	**t-Statistic**	**Prob.**
ECT (-1)	-0.56	0.15	-3.72	0.00
D ($g_{AgrExport}$)	0.10	0.05	2.01	0.05
R-Squared	0.29		Adjusted R-Squared	0.25

Source: Own Computation using STATA version 19.0

Overall, the empirical result from the ARDL model estimates reveals the existence of a statistically significant and positive long-run as well as short-run relationship between GDP growth and agricultural export growth.

4.3.7. Toda-Yamamoto Granger Non-Causality Test Result

The final step for validating the agricultural export-led growth hypothesis involves applying the Granger causality test to ascertain whether agricultural export growth Granger causes GDP growth as posited by the AELG hypothesis.

Table 12 reports the Granger causality test result obtained from both the Toda-Yamamoto and the frequency-domain approach to the Granger causality test.

As shown in Table 12, the results from the Granger causality test indicate that the null hypothesis of agricultural export growth does not Granger-cause GDP growth is rejected at the 5 percent level of significance (p-value = 0.04). This result is consistent with the AELG hypothesis.

In contrast, in the case of the reverse causality test, the null hypothesis that GDP growth does not Granger-cause agricultural export growth cannot be rejected, as the corresponding p-value exceeds 0.05. These findings provide evidence of a unidirectional causality running from agricultural export growth ($g_{AgrExport}$), to GDP growth (g_{GDP}), thereby lending empirical support to the agricultural export-led growth (AELG) hypothesis.

In conclusion, the results from the ARDL model indicate a statistically significant and positive link between GDP growth and agricultural export growth in both the short and long run. Additionally, the Granger causality test reveals a unidirectional causal relationship from agricultural export growth to GDP growth, aligning with the AELG hypothesis.

Table 12: Granger Causality Test Result

Toda-Yamamoto Approach to Granger Causality Test Result			
Null Hypothesis	χ^2	**df**	**Prob.**
$g_{AgrExport}$ does not Granger cause g_{GDP}	7.94	3	0.04
g_{GDP} does not Granger cause $g_{AgrExport}$	5.81	3	0.12
Frequency Domain Causality Test			
Null Hypothesis	Long-term ($\omega = 0.05$)	Medium-term ($\omega = 1.5$)	Short-term ($\omega = 2.5$)
$g_{AgrExport}$ does not Granger cause g_{GDP}	2.46*	2.45*	7.61***
g_{GDP} does not Granger cause $g_{AgrExport}$	5.58*	3.01	2.15

Notes: *, **, and *** denote statistical significance at 10%, 5%, and 1% level of significance, respectively. Source: Own computation, STATA version 19.0.

Collectively, the findings from both empirical strategies provide strong supportive evidence validating the Agricultural-Export-Led Growth (AELG) hypothesis in Ethiopia. This implies that, in developing countries like Ethiopia, the agricultural sector exhibits an open-economy engine of growth effect through boosting foreign exchange earnings from exports, thereby easing the balance of payments constraint on import demand. The result suggests the importance of fostering agricultural export growth and diversification as a strategic avenue for promoting long-run economic performance. The findings corroborate previous empirical works (Bleaney, Gemmell, and Greenaway, 1995; Gbetnkom and Khan, 2002; Verter and Bečvářová, 2014; Verter, 2015; Rapsomanikis, 2015).

4.4. Intersectoral Linkage Between Agricultural and Non-agricultural Sectors

This section presents and elaborates on the empirical results derived from examining the intersectoral linkage between the agricultural and non-agricultural sectors (i.e., industry and service sectors). To do this, building on previous studies, we estimated an empirical model where non-agricultural value added is regressed on agricultural value added, after controlling for capital and labor inputs; all variables are log transformed.

4.4.1. Lag Length Selection

To determine the optimal lag structure, the Akaike information criterion (AIC) is employed as it is more efficient in a smaller sample size. Accordingly, out of the alternative models evaluated, the automatic selection procedure yielded an ARDL (1, 0, 0,1) model.

4.4.2. Augmented Bounds Test for Cointegration

This section reports and discusses the results obtained from the augmented bounds test for cointegration. Table 13 reports the results of these tests.

Table 13: Result of the Augmented Bounds Test for Cointegration

Stage	Test Applied	Test Statistics	10%		5%		1%	
			I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
1^{st}	F-bounds	17.403	2.49	3.342	2.955	3.888	4.011	5.105
2^{nd}	t-bounds	-6.608	-2.567	-3.45	-2.889	-3.806	-3.527	-4.497
3^{rd}	Wald-test	5.71	Df (3, 48)		Probability 0.00			

Source: Own Computation using STATA version 19.0

Table 13 indicates that all three augmented ARDL bounds tests (i.e., the F-bounds test of joint significance on all lagged level variables, the t-bound test of significance on the coefficient of the lagged level of the dependent variable, and the Wald test of parametric significance of the lagged levels of the independent variables) are statistically significant at all reasonable significance levels. Accordingly, the significance of all tests or the rejection of the null hypothesis across all three tests confirms the existence of a non-degenerate useful cointegrating relationship between the dependent variable (the natural log of non-agricultural value added) and the explanatory variables (the natural log of agricultural value added, capital stock, and labor force).

4.4.3. Diagnostics Test

Before estimating the long-run relationship and the short-run dynamic coefficients of the ARDL model, it is important to analyze the performance of the ARDL model estimates through the diagnostic tests. Table 14 presents the results obtained from testing the underlying assumptions.

Table 14: Model Diagnostic Test

Null Hypothesis	Test Applied	Statistic value	Probability
Error terms are normally distributed	Jarque-Bera	4.84	0.08
No serial correlation of the residual	Breusch-Godfrey LM test for autocorrelation	3.15	0.07
Homoscedasticity	Breusch-Pagan-Godfrey Heteroscedasticity Test	0.24	0.62
The model is correctly specified	Ramsey RESET Test	1.48	0.23

Source: Owen Computation using STATA version 19.0

It is evident from Table 14, the p-value computed for the respective diagnostic tests is greater than 0.05, and thus the null hypothesis cannot be rejected in each case. The impossibility of rejecting the null hypothesis across all tests confirms that the model passes all diagnostic tests. Specifically, the error term is normally distributed, no serial correlation of the residual, no problem with heteroscedasticity, and the model is correctly specified.

4.4.4. Stability Test

The presence of parameter stability is one of the econometric requirements for a well-specified and performing ARDL model (Murthy and Okunade, 2016). The stability of the regression coefficients evaluated by stability tests shows whether the regression equation is stable over time and suitable for making long-run decisions (Pesaran and Pesaran, 2009). To test for the stability of the short-run and long-run coefficients estimated by the ARDL model, the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests on the recursive residuals from the estimated ARDL model were performed. Figures 5 and 6 illustrate the results of these tests.

As it is seen from Figures 5-6, the plots of CUSUM and CUSUMSQ statistics both lie between the critical bounds at a 5 percent significance level and do not cross the lower and upper critical limits in the estimated model. This indicates that the estimated coefficients have the desired characteristics of parameter stability over the sample period in the estimated model.

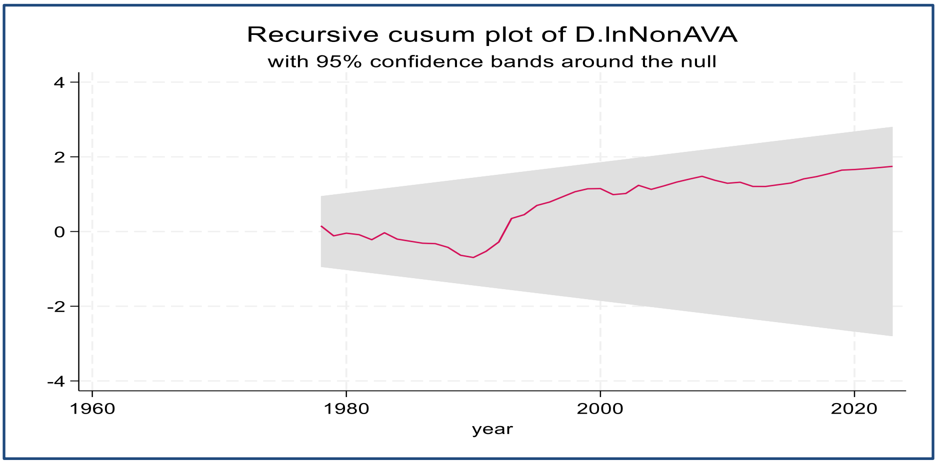

Figure 5: Plots of the cumulative sum of recursive residuals

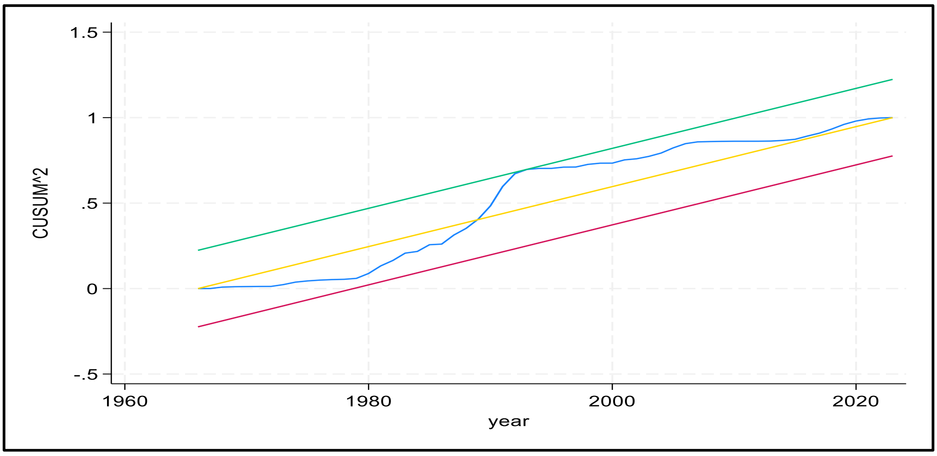

Figure 6: Plots of the cumulative sum of the squared recursive residuals

4.4.5. Long Run Coefficients Analysis

Having found evidence of cointegration and confirmed that the assumption underlying the ARDL model is not violated, the next step involves analyzing the coefficients of the long-run and short-run dynamics of the ARDL model. Table 15 presents the estimated long-run coefficients alongside their corresponding standard error, t-statistics, and p-values.

Table 15: Long Run Coefficients

Dependent Variable: $\ln NonAVA$				
Long Run Coefficients				
Variables	**Coefficients**	**Std. Error**	**t-Statistic**	**Prob.**
$\ln AVA$	0.66	0.21	3.15	0.00
$\ln K$	0.27	0.08	3.43	0.00
$\ln L$	1.19	0.09	13.27	0.00
Constant	-18.73	3.19	-5.87	0.00
R-square	0.55		Adjusted R-square	0.51

Source: Owen Computation using STATA version 19.0

As shown in Table 15, the estimated long-run elasticity coefficients, which measure the elasticity of non-agricultural value added with respect to agricultural value added, capital stock, and labor force, are positive and statistically significant at all conventional significance levels. This indicates a robust positive long-run relationship between the dependent variables, Non-agricultural value added ($\ln NonAVA$) and the explanatory variables: agricultural value added, capital stock, and labor force ($\ln AVA, \ln K, and\ \ln L$). Specifically, the results suggest that a 1 percent increase in agricultural value added is associated with a 0.66 percent increase in non-agricultural value added in the long run, after accounting for the effect of capital and labor inputs. Similarly, a 1 percent increase in capital and labor inputs corresponds to the long-run increases in non-agricultural value added of 0.27 percent and 1.19 percent, respectively. The adjusted R-squared value of 0.51 indicates that the model explains approximately half of the variation in non-agricultural value added over the long run, suggesting a reasonably good fit of the empirical specification.

4.4.6. Short Run Dynamic Coefficients Analysis

Once cointegration is confirmed, the error correction model (ECM) is employed to capture the dynamic adjustment of variables from short-run fluctuations toward long-run equilibrium. Table 16 presents the short-run dynamics derived from the ARDL (1, 0, 0, 1) specification.

The coefficient of the first lag of the error correction term is negative and statistically significant, consistent with the bounds test results and reinforcing the existence of a long-run equilibrium relationship among the variables under study. As it is noted in Table 16, the estimated speed of adjustment coefficient is -0.26, indicating that 26 percent of any short-run disequilibrium in non-agricultural value added is corrected within a year, implying a moderate speed of adjustment toward the long-run path.

Table 16: Short Run Dynamic Coefficients Result

Dependent Variable: D (ln $NonAVA$) ARDL(1, 0, 0, 1)				
Short Run Coefficients				
Variables	**Coefficients**	**Std. Error**	**t-Statistic**	**Prob.**
ECT (-1)	-0.26	0.04	-6.61	0.00
D (ln AVA)	0.17	0.07	2.60	0.01
D (ln K)	0.07	0.02	3.63	0.00
D (ln L)	-2.62	0.98	-2.68	0.01
R-Squared	0.83		S.E. of regression	2.71
Adjusted R-Squared	0.82		Sum of squared residual	396.10
F-statistic	87.04		Log Likelihood	-138.01
Prob(F-statistic)	0.00		Durbin-Watson stat	1.78

Source: Own Computation using STATA version 19.0

Table 16 presents the estimated short-run coefficients, indicating that the lead difference in agricultural value added [D (ln AVA)=0.17] is positive and highly statistically significant. This finding provides strong evidence of a significant short-run relationship between agricultural value added and non-agricultural value added. Specifically, a 1 percent increase in agricultural value added is associated with a 0.17 percent increase in non-agricultural value added in the short run, controlling for capital and labor inputs. In addition, the estimated short-run coefficient for capital stock is positive and statistically significant, suggesting a robust short-run association between increases in capital stock and growth in non-agricultural value added. Conversely, the short-run coefficient for the labor force is negative and statistically significant, indicating a short-run inverse relationship between labor input and non-agricultural value added, contrasting with the positive association observed in the long-run estimates. The adjusted R-squared value of 0.82 demonstrates a strong overall fit of the model, implying that 82 percent of the variation in non-agricultural value added in the short run is explained by the explanatory variables included in the model.

4.4.7. Toda-Yamamoto Granger Non-Causality Test Result

The final step in examining the intersectoral linkages between agriculture and non-agriculture involves conducting the Granger causality test. This test assesses whether agricultural value-added growth precedes and influences output growth in non-agricultural sectors. Table 17 displays the findings from both the Toda–Yamamoto method and the frequency-domain Granger causality test.

Table 17: Granger Causality Test Result

Toda-Yamamoto Approach to Granger Causality Test Result			
Null Hypothesis	χ^2	**df**	**Prob.**
$\ln AVA$ does not Granger cause $\ln NonAVA$	31.37	8	0.00
$\ln NonAVA$ does not Granger cause $\ln AVA$	12.37	8	0.13
Frequency Domain Causality Test			
Null Hypothesis	Long-term ($\omega = 0.05$)	Medium-term ($\omega = 1.5$)	Short-term ($\omega = 2.5$)
$\ln AVA$ does not Granger cause $\ln NonAVA$	7.25**	6.02**	0.09
$\ln NonAVA$ does not Granger cause $\ln AVA$	0.01	1.01	0.22

Notes: *, **, and *** denote statistical significance at 10%, 5%, and 1% level of significance, respectively. Source: Own computation, STATA version 19.0.

According to Table 17, the null hypothesis that agricultural value added does not Granger-cause non-agricultural value added is rejected at all reasonable significance levels (p-value = 0.00). Conversely, the null hypothesis that non-agricultural value added does not Granger-cause agricultural value added cannot be rejected, as the corresponding p-value is greater than 0.05. These results reveal a unidirectional causal relationship from agriculture to non-agricultural sectors, offering strong empirical evidence that agricultural expansion causes output growth in non-agricultural sectors (i.e., industry and service sectors).

In summary, the results from the ARDL model estimates indicate a statistically significant and positive link between nonagricultural value added and agricultural value added in both the short and long run. Additionally, the Granger causality test reveals a unidirectional causal relationship from agricultural value added to nonagricultural value added.

Taken together, these findings demonstrate a strong intersectoral linkage, indicating that agricultural output growth generates positive spillover effects, thereby fostering growth in nonagricultural sectors. The finding underscores the importance of establishing robust intersectoral linkage for accelerating sustained economic growth and economic transformation.

4.5. Agricultural Productivity and Structural Transformation

This section presents and discusses the empirical findings examining the role of agricultural productivity in driving structural change. To explore this relationship, we estimate an empirical model in which employment growth in the nonagricultural sector as a proxy variable for structural transformation is regressed on agricultural labor productivity growth.

4.5.1. Lag Length Selection

To determine the optimal lag structure, the Akaike information criterion (AIC) is employed as it is more efficient in a smaller sample size. Accordingly, out of the alternative models evaluated, the automatic selection procedure yielded an ARDL (1, 0) model with one lag for the dependent variable, nonagricultural employment growth ($g_{NonAgrEmp}$) and zero lag for the distributed lag explanatory variable, agricultural labor productivity growth ($g_{P_{Agr}}$).

4.5.2. Augmented Bounds Test for Cointegration

This section presents and discusses the results of the augmented bounds test for cointegration, as shown in Table 18 below.

Table 18: Result of the Augmented Bounds Test for Cointegration

Stage	Test Applied	Test Statistics	10%		5%		1%	
			I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
1^{st}	F-bounds	11.091	3.128	3.616	3.784	4.319	5.288	5.902
2^{nd}	t-bounds	9.922	-2.586	-2.949	-2.901	-3.279	-3.523	-3.922
3^{rd}	Wald-test	14.99	Df (1, 50)				Probability 0.00	

Source: Own Computation using STATA version 19.0

It is evident from Table 18 that all three augment ARDL bounds tests (i.e., the overall F-bound test on all lagged level variables, the t-bound test of significance of the coefficient of the lagged level of the dependent variable, and the Wald test of parametric significance of the lagged levels of the independent variable) are statistically significant at all conventional significance levels. The significance of all three tests implies that the null hypothesis is rejected in each case, thereby confirming the existence of a non-degenerate useful cointegrating long-run relationship between the dependent variable (nonagricultural employment growth) and the explanatory variable (agricultural productivity growth).

4.5.3. Diagnostics Test

Before estimating the long-run relationship and the short-run dynamics of the ARDL model, it is important to analyze the performance of the ARDL model estimates through the diagnostic tests. Table 19 presents the results obtained from testing the underlying assumptions.

Table 19: Model Diagnostic Test

Null Hypothesis	Test Applied	Statistic value	Probability
Error terms are normally distributed	Jarque-Bera	1.15	0.56
No serial correlation of the residual	Breusch-Godfrey LM test for autocorrelation	1.98	0.15
Homoscedasticity	Breusch-Pagan-Godfrey Heteroscedasticity Test	0.28	0.59
The model is correctly specified	Ramsey RESET Test	1.14	0.29

Source: Owen Computation using STATA version 19.0

As shown in Table 19, the p-value computed for the respective diagnostic tests is greater than 0.05, and thus the null hypothesis cannot be rejected in each case. The impossibility of rejecting the null hypothesis indicates that the model passes all diagnostic tests. Specifically, the error term is normally distributed, no serial correlation of the residual, no problem with heteroscedasticity, and the model is correctly specified.

4.5.4. Stability Test

To test for the stability of the short-run and long-run coefficients estimated by the ARDL model, the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests on the recursive residuals from the estimated ARDL model were performed.

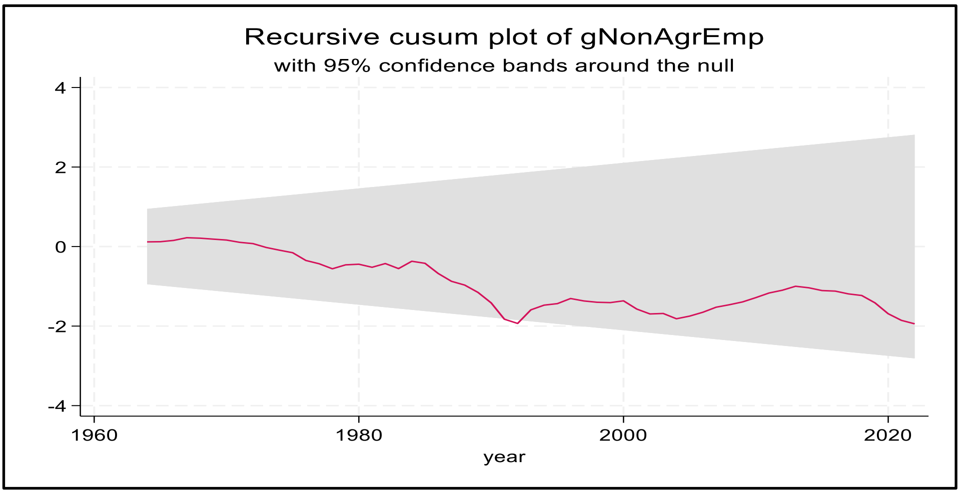

Figure 7: Plots of the cumulative sum of recursive residuals

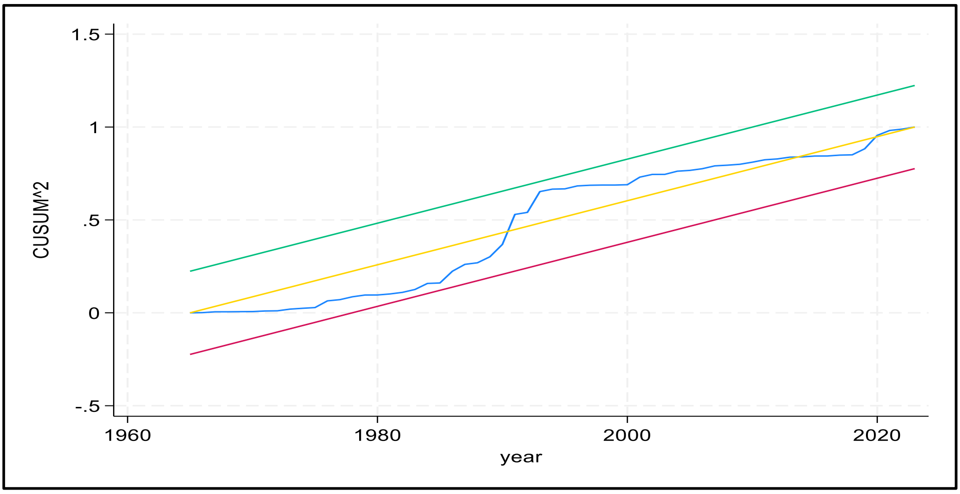

Figure 8: Plots of the cumulative sum of the squared recursive residual

Figures 7 and 8 illustrate the results of these tests. The plots of CUSUM and CUSUMSQ statistics both lie between the critical bounds at a 5 percent significance level and do not cross the lower and upper critical limits in the estimated model. This indicates that the estimated coefficients have the desired characteristics of parameter stability over the sample period in the estimated model.

4.5.5. Long Run Coefficients Analysis

Having found evidence of cointegration and confirmed that the assumption underlying the ARDL model is not violated, the next step involves analyzing the coefficients of the long-run and short-run dynamics of the ARDL model. Table 20 presents the result of the estimated long-run coefficients alongside their corresponding standard error, t-statistics, and p-values.

Table 20: Long Run Coefficients

Dependent Variable: $g_{NonAgrEmp}$				
Long Run Coefficients				
Variables	**Coefficients**	**Std. Error**	**t-Statistic**	**Prob.**
$g_{P_{Agr}}$	0.50	0.16	3.07	0.00
Constant	5.81	0.88	6.62	0.00
R-square	0.37		Adjusted R-square	0.35

Source: Owen Computation using STATA version 19.0

Table 20 reveals that the estimated long-run coefficient, which captures the elasticity of nonagricultural employment growth for agricultural productivity growth ($g_{P_{Agr}} = 0.5$), is positive and highly statistically significant. This provides strong evidence of a significant positive long-run relationship between nonagricultural employment growth and agricultural productivity growth. Specifically, the result implies that a 1 percentage point increase in the growth rate of agricultural productivity is associated with a 0.5 percentage point increase in nonagricultural employment growth in the long run. The adjusted R-squared value of 0.35 indicates a moderate explanatory power of the model, suggesting that approximately one-third of the variation in nonagricultural employment growth can be attributed to changes in agricultural productivity growth. Overall, the findings underscore the significant role of agricultural productivity growth in driving employment expansion in nonagricultural sectors.

4.5.6. Short Run Dynamic Coefficients Analysis

Once cointegration is established, the error correction model (ECM) is constructed to show the dynamic relationship among variables for the model from the short run to the long run equilibrium position. Table 21 gives the result of short-run dynamics associated with the ARDL (1, 0) model. As shown in Table 20, the negative and statistically significant estimate of ECT_{t-1} support the result of the bound test, which confirmed a long-run equilibrium relationship between nonagricultural employment growth and agricultural productivity growth. Further, it reveals the speed of adjustment of the short-run to the long-run equilibrium position of the dependent variable. As shown in Table 21, the speed of adjustment coefficient is -0.50, meaning that half of any short-term deviation in nonagricultural employment growth from its long-term path is corrected within a year. This implies a moderate speed of adjustment toward the equilibrium after a shock.

Table 21: Short Run Dynamic Coefficients Result

Dependent Variable: D ($g_{NonAgrEmp}$) ARDL(1, 0)				
Short Run Coefficients				
Variables	**Coefficients**	**Std. Error**	**t-Statistic**	**Prob.**
ECT (-1)	-0.50	0.16	3.07	0.00
D ($g_{P_{Agr}}$)	0.25	0.07	3.57	0.00
R-Squared	0.36		Adjusted R-Squared	0.36

Source: Own Computation using STATA version 19.0

As shown in Table 21, the estimated short-run coefficient captured by the lead difference of agricultural productivity growth [D ($g_{P_{Agr}}$)=0.25] is positive and statistically significant at all conventional significance levels. This confirms a strong positive short-run relationship between employment growth in nonagricultural sectors and agricultural productivity growth. Specifically, a 1 percentage point increase in agricultural productivity growth is associated with a 0.25 percentage point increase in the growth rate of nonagricultural employment in the short run. Overall, the findings point to a statistically significant and positive long-run as well as short-run relationship between nonagricultural employment growth and agricultural productivity growth.

4.5.7. Toda-Yamamoto Granger Non-Causality Test Result

The final step in assessing the impact of agricultural productivity growth on structural transformation involves conducting a Granger causality test to determine whether agricultural productivity growth Granger-causes employment growth in non-agricultural sectors. Table 21 presents the results of the Granger causality tests, using both the Toda-Yamamoto approach and the frequency-domain method.

Table 22: Granger Causality Test Result

Toda-Yamamoto Approach to Granger Causality Test Result			
Null Hypothesis	χ^2	**df**	**Prob.**
$g_{P_{Agr}}$ does not Granger cause $g_{NonAgrEmp}$	17.46	6	0.00
$g_{NonAgrEmp}$ does not Granger cause $g_{P_{Agr}}$	4.31	6	0.63
Frequency Domain Causality Test			
Null Hypothesis	Long-term ($\omega = 0.05$)	Medium-term ($\omega = 1.5$)	Short-term ($\omega = 2.5$)
$g_{P_{Agr}}$ does not Granger cause $g_{NonAgrEmp}$	13.46***	2.51	5.71**
$g_{NonAgrEmp}$ does not Granger cause $g_{P_{Agr}}$	0.51	0.49	2.38

Notes: *, **, and *** denote statistical significance at 10%, 5%, and 1% level of significance, respectively. Source: Own computation, STATA version 19.0.

As shown in Table 22, the null hypothesis stating agricultural productivity growth does not Granger-cause employment growth in the nonagricultural sector is decisively rejected at all reasonable levels of significance (p-value = 0.00). However, in the case of the reverse causality test, the null hypothesis that employment growth in nonagricultural sectors does not Granger-cause agricultural labor productivity growth cannot be rejected, as the corresponding p-value (0.63) exceeds 0.05. The impossibility of rejecting the null in the case of the reverse causality test confirms the existence of unidirectional causality running from agricultural productivity growth to nonagricultural employment growth. Therefore, the results from both empirical approaches provide robust empirical support for the critical role of agricultural productivity improvements in facilitating structural transformation by releasing surplus labor to the industrial and service sectors.

4.6. The Relative Contribution of Agricultural Productivity in Driving Overall Productivity

This section presents and explains the results of the empirical analysis on the relative contribution of agricultural and non-agricultural productivity growth to overall economic productivity growth. To assess this, economy-wide labor productivity growth is regressed on labor productivity growth in the agricultural and non-agricultural sectors.

4.6.1. Lag Length Selection

To determine the optimal lag structure, the Akaike Information Criterion (AIC) is employed, as it is more efficient in smaller sample sizes. Accordingly, out of the alternative models evaluated, the automatic selection procedure yielded an ARDL (1, 1, 1) model with one lag for both the dependent variable and the distributed lag explanatory variables.

4.6.2. Augmented Bounds Test for Cointegration

This section reports and discusses the results obtained from the augmented bounds test for cointegration, which are presented in Table 23 below.

Table 23: Result of the Augmented Bounds Test for Cointegration

Stage	Test Applied	Test Statistics	10%		5%		1%	
			I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
1^{st}	F-bounds	6.362	2.721	3.465	3.262	4.081	4.497	5.463
2^{nd}	t-bounds	-4.914	-2.565	-3.226	-2.887	-3.576	-3.526	-4.256
3^{rd}	Wald-test	557.687	Df				Probability	
			(2, 48)				0.00	

Source: Own Computation using STATA version 19.0

It is seen from Table 23 that all three ARDL bounds tests (the overall F-bound test on all lagged level variables, the t-test on the lagged level of the dependent variable, and the Wald test on the lagged levels of the independent variables) are statistically significant at all conventional significance levels. This indicates that the null hypothesis is rejected in each case, providing strong evidence of a cointegrating long-run relationship between the dependent variable (aggregate labor productivity growth) and the independent variables (agricultural and nonagricultural labor productivity growth).

4.6.3. Diagnostics Test

Before estimating the long-run relationship and the short-run dynamics of the ARDL model, it is important to analyze the performance of the ARDL model estimates through the diagnostic tests. Table 24 presents the results obtained from testing the underlying assumption.

Table 24: Model Diagnostic Test

Null Hypothesis	Test Applied	Statistic value	Probability
Error terms are normally distributed	Jarque-Bera	6.96	0.06
No serial correlation of the residual	Breusch-Godfrey LM test for autocorrelation	0.14	0.71
Homoscedasticity	Breusch-Pagan-Godfrey Heteroscedasticity Test	1.38	0.24
The model is correctly specified	Ramsey RESET Test	2.27	0.09

Source: Owen Computation using STATA version 19.0

As shown in Table 24, the p- p-value computed for the respective diagnostic tests is greater than 0.05, and thus the null hypothesis cannot be rejected in each case. This implies the fact that the model passes all diagnostic tests (i.e., the error term is normally distributed, no serial correlation of the residual, no problem with heteroscedasticity, and the model is correctly specified).

4.6.4. Stability Test

To test for the stability of the short-run and long-run coefficients estimated by the ARDL model, the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests on the recursive residuals from the estimated ARDL model were performed.

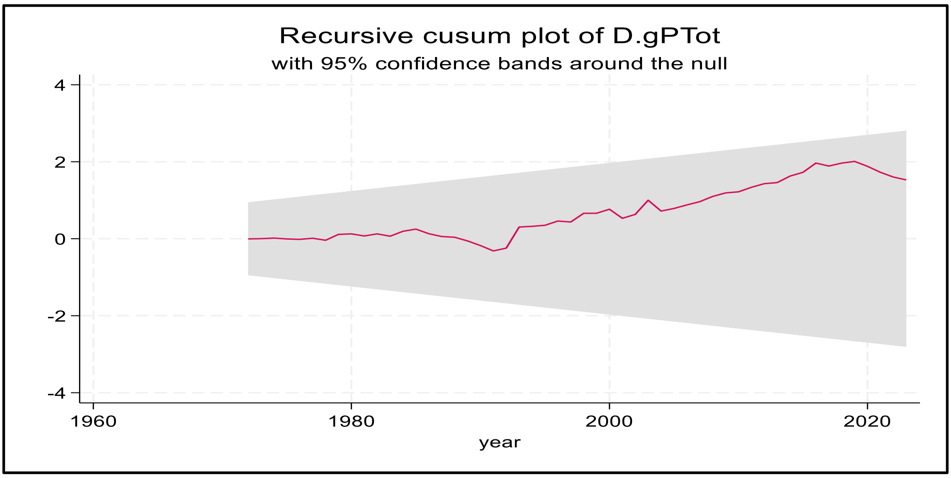

Figure 9: Plots of the cumulative sum of recursive residuals

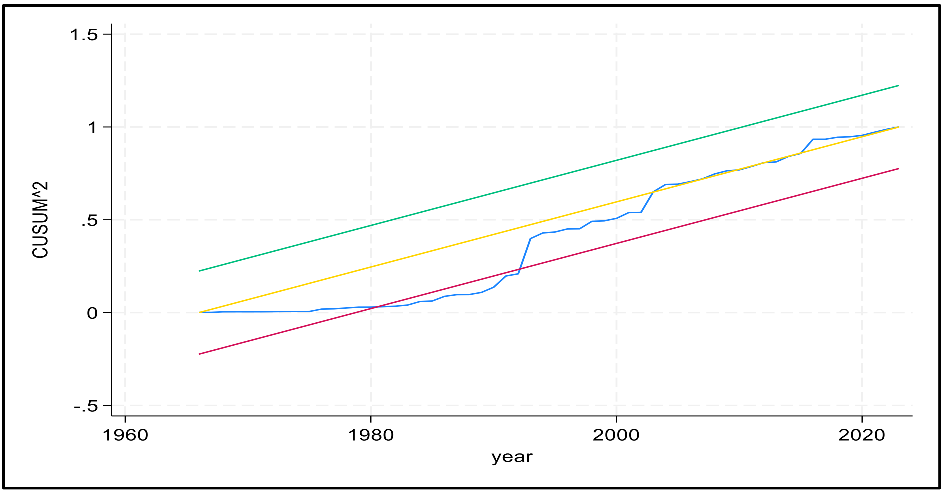

Figure 10: Plots of the cumulative sum square of the recursive residual

Figures 9 and 10 illustrate the results of these tests. As it is seen from Figures 9-10 below, the plots of CUSUM and CUSUMSQ statistics both lie between the critical bounds at a 5 percent significance level and do not cross the lower and upper critical limits in the estimated model. This indicates that the estimated coefficients have the desired characteristics of parameter stability over the sample period in the estimated model.

4.6.5. Long Run Coefficients Analysis

Having found evidence of cointegration and confirmed that the assumption underlying the ARDL model is not violated, the next step involves analyzing the coefficients of the long-run and short-run dynamics of the ARDL model. Table 25 presents the result of the estimated long-run coefficients alongside their corresponding standard error, t-statistics, and p-values.

Table 25: Long Run Coefficients

Dependent Variable: $g_{P_{Total}}$				
Long Run Coefficients				
Variables	**Coefficients**	**Std. Error**	**t-Statistic**	**Prob.**
$g_{P_{Agr}}$	0.76	0.04	17.07	0.00
$g_{P_{NonAgr}}$	0.34	0.07	4.55	0.00
Constant	0.86	0.20	4.22	0.00
R-square	0.96		Adjusted R-square	0.96

Source: Owen Computation using STATA version 19.0

As shown in Table 25, the estimated long-run elasticity coefficients for agricultural (0.76) and non-agricultural (0.34) productivity growth are both positive and highly statistically significant. This indicates a strong positive long-run relationship between aggregate labor productivity growth and its sectoral components. Specifically, after controlling for other factors, a one percentage point increase in agricultural productivity growth is associated with a 0.76 percentage point increase in economy-wide labor productivity growth, while a similar increase in non-agricultural productivity leads to a 0.34 percentage point rise. These results suggest that agricultural productivity growth has a stronger impact on overall productivity than non-agricultural productivity growth. The result suggests that investments aimed at improving the productivity of smallholder farmers can significantly boost the overall performance of the economy.

4.6.6. Short Run Dynamic Coefficients Analysis

Once cointegration is established, the error correction model (ECM) is constructed to show the dynamic relationship among variables for the model from the short run to the long run equilibrium position. Table 26 gives the result of short-run dynamics associated with the ARDL (1, 1, 1) model.

The coefficient of the first lag of the error correction term (ECT_{t-1}) should be negative and statistically significant if the model can correct any of the shocks in the short run to the long-run equilibrium. As shown in Table 26, the negative and statistically significant estimate of ECT_{t-1} support the result of the bound test, which confirmed a long-run equilibrium relationship between the variables under study. According to Table 26, the value of ECT_{t-1} is -0.67, meaning that two-thirds of short-term deviation in aggregate productivity growth from its long-term path is corrected within a year. This implies the speed of adjustment toward the equilibrium after a shock is too fast.

Table 26: Short Run Dynamic Coefficients Result

Dependent Variable: D ($g_{P_{Total}}$) ARDL(1, 1, 1)				
Short Run Coefficients				
Variables	**Coefficients**	**Std. Error**	**t-Statistic**	**Prob.**
ECT (-1)	-0.67	0.14	-4.91	0.00
D ($g_{P_{Agr}}$)	0.71	0.02	30.59	0.00
D ($g_{P_{NonAr}}$)	0.31	0.04	7.13	0.00
R-Squared	0.97		Adjusted R-Squared	0.96

Source: Own Computation using STATA version 19.0

As shown in Table 26, the estimated short-run coefficient captured by the lead difference of agricultural productivity growth [D ($g_{P_{Agr}}$)=0.71] and nonagricultural productivity growth [D ($g_{P_{NonAgr}}$)=0.31] are positive and statistically significant at all conventional significance levels. This confirms a strong and significant short-run positive relationship between overall productivity growth and agricultural and non-agricultural productivity growth.

In short, the findings demonstrate the existence of a significant positive relationship between the dependent variable (the economic-wide productivity growth) and the independent variables (agricultural productivity growth and nonagricultural productivity growth), both in the long run as well as in the short run. In addition, the result suggests that productivity growth originating from agriculture has a substantial impact on the overall productivity of the economy relative to non-agricultural productivity growth.

5. Conclusion and Policy Implications

This study was motivated by the persistent duality characterizing Ethiopia's agricultural sector. On the one hand, agriculture is the cornerstone of the economy, contributing significantly to growth, poverty alleviation, food security, and export earnings, while also serving as a major source of labor and capital. On the other hand, it continues to exhibit persistent underdevelopment, characterized by low productivity, a dominance of smallholder farmers who rely on subsistence rain-fed farming, and traditional technology. Despite multiple policy interventions aimed at transforming the sector, the hope for an agricultural revolution has yet to materialize, and poverty and food insecurity remain pressing developmental challenges of the nation.

Against this backdrop of seemingly paradoxical agricultural dynamics, this paper comprehensively investigated the potential contribution of the agricultural sector as a driving force of long-run economic growth and structural transformation in Ethiopia. It addressed two research questions: Does Ethiopian agriculture maintain unique capacities to act as an engine of growth and a catalyst for structural transformation? Is an Agriculture-Led-Development strategy the most viable pathway for Ethiopia’s development? To this end, the study employed a robust empirical strategy, combining the augmented ARDL bounds testing approach for the cointegration modeling framework with the Toda-Yamamoto Granger non-causality and Frequency-Domain Granger causality tests, using time series data spanning from 1962 to 2023.

More specifically, the study pursued five interrelated objectives, each executed independently to address the central research questions. First, it investigated the contribution of agricultural productivity to economic growth. The findings reveal a significant positive long-run causal relationship from agricultural productivity growth to GDP per capita growth, affirming agriculture's potential to act as a powerful growth escalator in Ethiopia. This result highlights the strategic importance of targeted investments in improving smallholder productivity as a means of enhancing overall economic performance. Second, the paper tested the agricultural export-led growth (AELG) hypothesis. The empirical results support the validity of the AELG hypothesis in the Ethiopian context, underscoring the importance of agricultural exports in driving overall economic performance. The result suggests the importance of fostering agricultural export growth and diversification for promoting sustained economic growth and easing the balance of payment constraints on import demand. Third, the study examined the linkage of agriculture with nonagricultural sectors. The findings demonstrate significant linkages from agriculture to non-agricultural sectors, indicating that growth in agricultural output generates positive spillover effects, stimulating non-agricultural activity. The finding underscores the importance of establishing robust intersectoral linkage for accelerating sustained economic growth and economic structural transformation. Fourth, the paper explored the role of agricultural productivity in driving structural transformation. The empirical results provide strong evidence that improvements in agricultural productivity are instrumental in facilitating structural transformation, primarily by releasing surplus labor into the industrial and service sectors. The empirical evidence suggests that policy efforts aimed at accelerating economic transformation should place greater emphasis on the agricultural sector, particularly through targeted investment and comprehensive reforms that improve the productivity of smallholder farms. Finally, the study examined the relative contribution of sectoral productivity in the agricultural and nonagricultural sectors to overall productivity growth. The results suggest that agricultural productivity growth exerts a stronger impact on the economy-wide productivity growth compared to non-agricultural productivity growth.

In sum, the empirical findings across all five objectives provide strong support for the notion that agriculture holds a special capacity to act as a powerful engine of growth and a vehicle for structural transformation in Ethiopia. The overarching conclusion emerging from this empirical analysis is that the agricultural sector is the best engine of growth and structural change, at least during the early stage of development, characterizing Ethiopia's economy. The results strongly support the viability of an agriculture-led development strategy in Ethiopia, thereby endorsing the "agriculture-first for development" hypothesis. This implies that for Ethiopia, where the manufacturing sector has yet to fulfill a leading growth role, agricultural growth emerges as the primary viable route for achieving sustained economic growth and catalyzing growth-enhancing structural transformation.

The policy implication is that fostering agricultural development and transformation in such a way that boosts agricultural productivity, transforms smallholder farmers, diversifies agricultural export, and creates strong backward and forward linkage with other sectors of the economy, particularly with the manufacturing sector, is a panacea for an inclusive growth trajectory, industrial development, and structural transformation. Without it, the latter is hardly achievable. Putting it differently, agriculture-centered industrialization and structural transformation are the only or at least the most viable and efficient pathway for achieving sustained catch-up growth and development that leaves no one behind. The converse meant that any development strategy that relegates and marginalizes agriculture in the early stage of transformation would hinder overall progress.

The findings of the study, despite lending support for agriculture as the main engine of growth at an early stage of development, also recognize that agriculture cannot be the sole engine of growth for successful long-term growth and economic transformation, since agriculture is subject to diminishing returns to scale and for many other reasons. Economic history also shows that no country has diversified its economic complexity and climbed the ladder of prosperity by specializing in agriculture. Growth based on agriculture would peter out if not accompanied by nonagricultural growth (manufacturing and service). This implies that there is growth complementarity among economic sectors, especially between the agriculture and manufacturing sectors, over the course of development. For materializing structural transformation, fostering the growth of the nonagricultural sector and enhancing intersectoral linkage among economic sectors is determinant. The implication is instead of excessively emphasizing a single sector, adopting a multi-sectoral approach to development may better help developing countries like Ethiopia to achieve growth-enhancing economic transformation and development. However, in the context of resource scarcity characterizing developing economies like Ethiopia, the top priority should be given to agriculture first.

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Appendix I: Results Output Generated from STATA version 19.0

Agricultural Productivity and Economic Growth
Long-run and Short-run Coefficients
Time variable: year, 1962 to 2023
Delta: 1 unit
ardl gGDPpercapita gPAgr, ec1 aic constant restricted
ARDL(4,0) regression
Sample: 1966 thru 2023 Number of obs = 58
R-squared = 0.8286
Adj R-squared = 0.8122
Log likelihood = -138.01372 Root MSE = 2.7599

D. gGDPpercapita|	Coefficient	Std. err.	t	P>|t|	[95% conf. interval]	
ADJ |						
gGDPpercapita| L1.	-.7045799	.1047573	-6.73	0.000	-.9147909	-.494369
LR |						
gPAgr | L1.	.9011016	.1455454	6.19	0.000	.6090435	1.19316
_cons	1.542236	.5211712	2.96	0.005	.4964294	2.588042
SR |						
gGDPpercapita LD.	.0185264	.1076743	0.17	0.864	-.1975379	.2345908
L2D.	-.1204732	.087414	-1.38	0.174	-.2958824	.0549359
L3D	.1605538	.0788791	2.04	0.047	.0022713	.3188363
gPAgr | D1.	.6348981	.0625626	10.15	0.000	.5093571	.7604392

Bound test for cointegration result
estat ectest

Pesaran, Shin, and Smith (2001) bounds test

H0: no level relationship F = 42.125
Case 2 t = -6.726

Finite sample (1 variables, 58 observations, 3 short-run coefficients)
Kripfganz and Schneider (2020) critical values and approximate p-values

	10%		5%		1%		p-value	
	I(0)	**I(1)**	**I(0)**	**I(1)**	**I(0)**	**I(1)**	**I(0)**	**I(1)**
F	3.095	3.619	3.751	4.330	5.265	5.946	0.000	0.000
t	-2.565	-2.924	-2.884	-3.259	-3.516	-3.913	0.000	0.000

do not reject H0 if

either F or t are closer to zero than critical values for I(0) variables

(if either p-value > desired level for I(0) variables)

reject H0 if

both F and t are more extreme than critical values for I(1) variables

(if both p-values < desired level for I(1) variables)

decision: no rejection (.a), inconclusive (.), or rejection (.r) at levels:

	10%	5%	1%
decision	.r	.r	.r

Wald Test Coefficient Restriction on lagged level of the independent variable

Wald Test:

Equation: Untitled

Test Statistic	Value	df	Probability
t-statistic	2.597462	45	0.0126
F-statistic	6.746808	(1, 45)	0.0126
Chi-square	6.746808	1	0.0094

Null Hypothesis: C(2)=0

Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(2)	0.346207	0.133287

Normality Test

jb gGDPpercapita

Jarque-Bera normality test: 3.944 Chi(2) .1392

Jarque-Bera test for Ho: normality:

. estat imtest

Cameron & Trivedi's decomposition of IM-test

Source	chi2	df	p
Heteroskedasticity	40.78	27	0.0432
Skewness	6.84	6	0.3359
Kurtosis	1.46	1	0.2268
Total	49.08	34	0.0455

Autocorrelation Test

. estat bgodfrey

Breusch–Godfrey LM test for autocorrelation

lags(p)	chi2	df	Prob > chi2
1	0.301	1	0.5835

H0: no serial correlation

Heteroskedasticity Test

. estat hettest

Breusch–Pagan/Cook–Weisberg test for heteroskedasticity
Assumption: Normal error terms
Variable: Fitted values of D.gGDPpercapita

H0: Constant variance

chi2(1) = 2.34
Prob > chi2 = 0.1261

Model Misspecification Ramsey reset Test

. estat ovtest

Ramsey RESET test for omitted variables
Omitted: Powers of fitted values of D.gGDPpercapita

H0: Model has no omitted variables

F(3, 48) = 1.72
Prob > F = 0.1751

Model Stability Test

. estat sbcusum

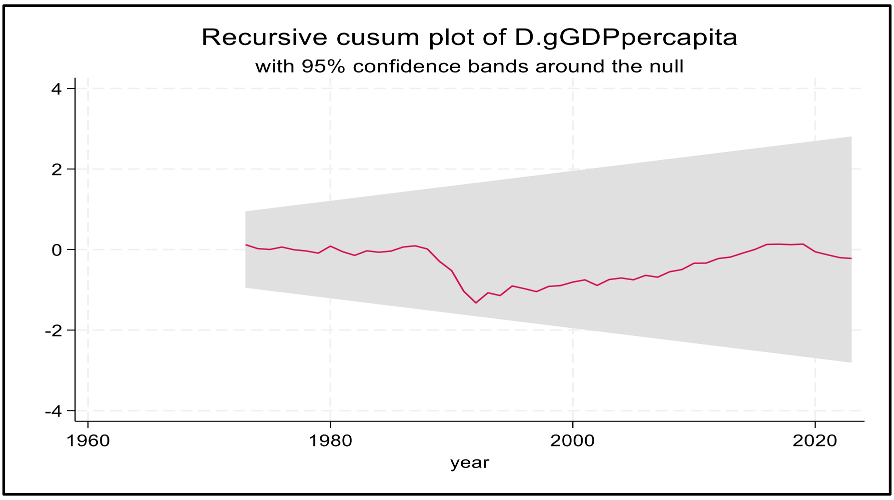
Cumulative sum test for parameter stability

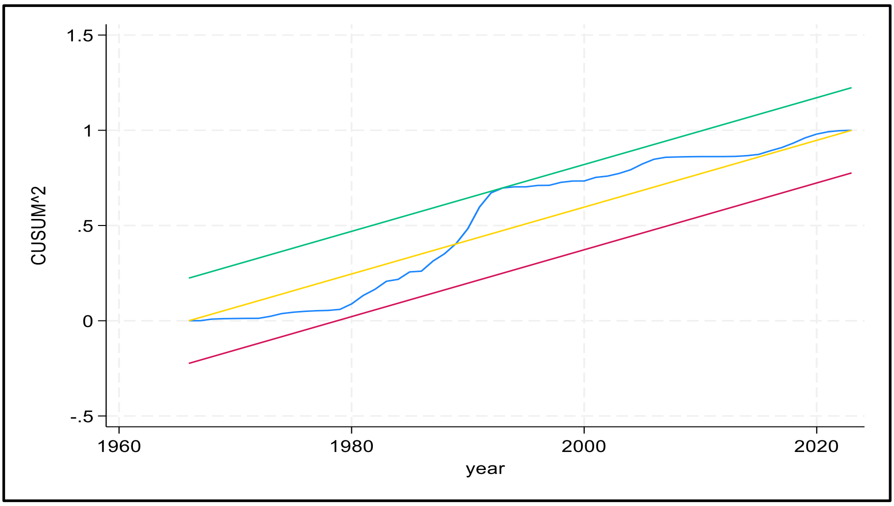
Sample: 1966 thru 2023 Number of obs = 58

H0: No structural break

	Test		Critical value	
Type	**statistic**	**1%**	**5%**	**10%**
Recursive	0.7423	1.1430	0.9479	0.8499

. cusum9 gGDPpercapita gPAgr, cs2(cusum2) lw(lower) uw(upper)





Toda-Yamamoto Granger Non-causality test

VAR Granger Causality/Block Exogeneity Wald Tests
Date: 06/02/25   Time: 18:53
Sample: 1 63
Included observations: 58

Dependent variable: GGDPPERCAPITA			
Excluded	**Chi-sq**	**df**	**Prob.**
GPAGR	10.01590	4	0.0402
All	10.01590	4	0.0402
Dependent variable: GPAGR			
Excluded	**Chi-sq**	**df**	**Prob.**
GGDPPERCAPITA	7.800387	4	0.0992
All	7.800387	4	0.0992

Frequency-Domain Granger causality test

```
bcgcausality gGDPpercapita gPAgr, frequency (0.05) varlag (4)
----------------------------------------------------------------------
Granger-causality from  gPAgr to  gGDPpercapita
----------------------------------------------------------------------
H0: No Granger-causality from gPAgr to gGDPpercapita at frequency w =  0.05
Wald test statistic = 8.2569
pvalue = 0.0161
----------------------------------------------------------------------
No graphical output
----------------------------------------------------------------------
. bcgcausality gGDPpercapita gPAgr, frequency (1.5) varlag (4)
----------------------------------------------------------------------
Granger-causality from  gPAgr to  gGDPpercapita
----------------------------------------------------------------------
H0: No Granger-causality from gPAgr to gGDPpercapita at frequency w =  1.50
Wald test statistic = 0.9354
pvalue = 0.6265
----------------------------------------------------------------------
No graphical output
----------------------------------------------------------------------
. bcgcausality gGDPpercapita gPAgr, frequency (2.5) varlag (4)
----------------------------------------------------------------------
Granger-causality from  gPAgr to  gGDPpercapita
----------------------------------------------------------------------
```

H0: No Granger-causality from gPAgr to gGDPpercapita at frequency w = 2.50
Wald test statistic = 6.1943
pvalue = 0.0452

No graphical output

. bcgcausality gPAgr gGDPpercapita, frequency (0.05) varlag (4)

Granger-causality from gGDPpercapita to gPAgr

H0: No Granger-causality from gGDPpercapita to gPAgr at frequency w = 0.05
Wald test statistic = 0.0928
pvalue = 0.9547

No graphical output

. bcgcausality gPAgr gGDPpercapita, frequency (1.5) varlag (4)

Granger-causality from gGDPpercapita to gPAgr

H0: No Granger-causality from gGDPpercapita to gPAgr at frequency w = 1.50
Wald test statistic = 1.5805
pvalue = 0.4537

No graphical output

. bcgcausality gPAgr gGDPpercapita, frequency (2.5) varlag (4)

Granger-causality from gGDPpercapita to gPAgr

H0: No Granger-causality from gGDPpercapita to gPAgr at frequency w = 2.50
Wald test statistic = 1.9733
pvalue = 0.3728

Agricultural Export Led-Growth (AELG) Hypothesis

Long-run and Short-run Coefficients

ardl gGDP gAgrExport, ec1 aic constant restricted

ARDL(1,0) regression

Sample: 1990 thru 2022 | Number of obs = 33

R-squared = 0.3568

Adj R-squared = 0.3139

Log likelihood = -116.95692 | Root MSE = 8.7834

D. gGDP	Coefficient	Std. err.	t	P>|t|	[95% conf. interval]	
ADJ |						
gGDP L1.	-.559505	.1503121	-3.72	0.001	-.8664833	-.2525267
LR |						
gAgrExport | L1.	.1755355	.0952646	1.84	0.075	-.0190207	.3700918
_cons	15.69076	3.056181	5.13	0.000	9.44921	21.93232
gAgrExport D1.	.098213	.0488504	2.01	0.053	-.0015529	.1979789

Bound Test for Cointegration Result

. estat ectest

Pesaran, Shin, and Smith (2001) bounds test

H0: no level relationship F = 5.732

Case 2 t = -3.722

Finite sample (1 variables, 33 observations, 0 short-run coefficients)

Kripfganz and Schneider (2020) critical values and approximate p-values

	10%		5%		1%		p-value	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
F	3.248	3.769	3.986	4.572	5.752	6.469	0.010	0.019
t	-2.606	-2.964	-2.945	-3.322	-3.633	-4.043	0.008	0.021

do not reject H0 if

either F or t are closer to zero than critical values for I(0) variables

(if either p-value > desired level for I(0) variables)

reject H0 if
both F and t are more extreme than critical values for I(1) variables
(if both p-values < desired level for I(1) variables)

decision: no rejection (.a), inconclusive (.), or rejection (.r) at levels:

	10%	5%	1%
decision	.r	.r	.a

Wald Test Coefficient Restriction on lagged level of the independent variable

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
t-statistic	-3.011662	32	0.0050
F-statistic	9.070109	(1, 32)	0.0050
Chi-square	9.070109	1	0.0026

Null Hypothesis: C(2)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(2)	-0.441816	0.146702

Restrictions are linear in coefficients.

Normality Test

jb gGDP
Jarque-Bera normality test: .7927 Chi(2) .6728
Jarque-Bera test for Ho: normality:

Autocorrelation Test
estat bgodfrey

Breusch–Godfrey LM test for autocorrelation

lags(p)	chi2	df	Prob > chi2
1	2.273	1	0.1316

H0: no serial correlation

Heteroskedasticity Test

estat hettest

Breusch–Pagan/Cook–Weisberg test for heteroskedasticity
Assumption: Normal error terms
Variable: Fitted values of D.gGDP

H0: Constant variance

chi2(1) = 1.13
Prob > chi2 = 0.2888

Model Misspecification Ramsey reset Test

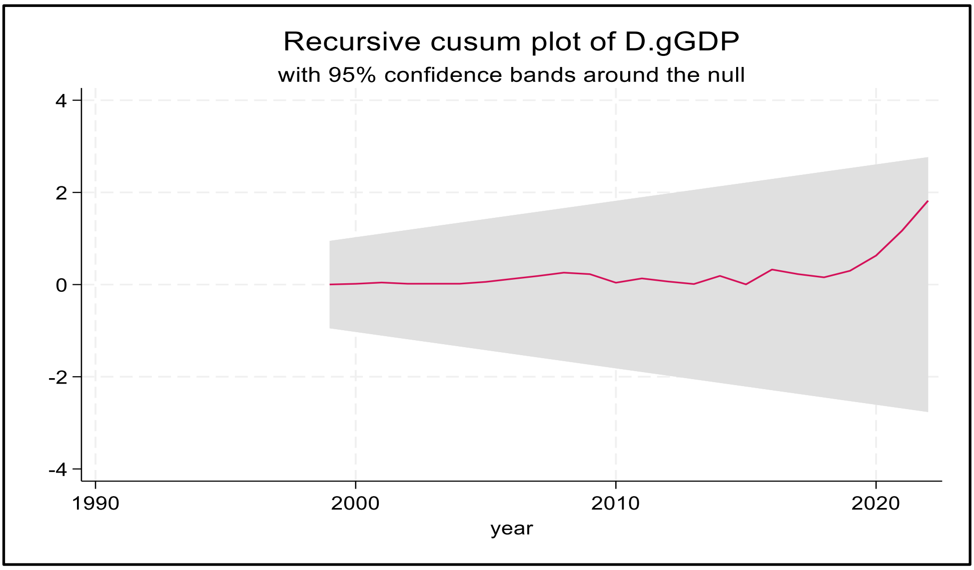
. estat ovtest

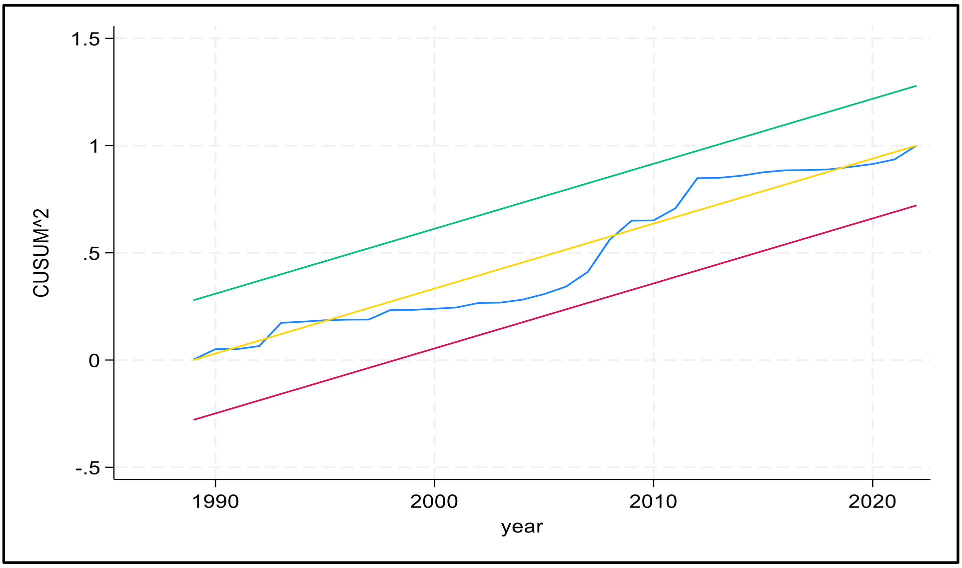
Ramsey RESET test for omitted variables
Omitted: Powers of fitted values of D.gGDP

H0: Model has no omitted variables

F(3, 40) = 2.35
Prob > F = 0.0866

Model Stability Test





Toda-Yamamoto Granger Non-causality test

VAR Granger Causality/Block Exogeneity Wald Tests
Date: 06/05/25 Time: 19:01
Sample: 1986 2022
Included observations: 34

Dependent variable: GGDP

Excluded	Chi-sq	df	Prob.
GAGREXPORT	7.948447	3	0.0471
All	7.948447	3	0.0471

Dependent variable: GAGREXPORT

Excluded	Chi-sq	df	Prob.
GGDP	5.810895	3	0.1212
All	5.810895	3	0.1212

Frequency-Domain Granger causality test

bcgcausality gGDP gAgrExport, frequency (0.05) varlag (3)

Granger-causality from gAgrExport to gGDP

H0: No Granger-causality from gAgrExport to gGDP at frequency w = 0.05

```
Wald test statistic = 2.4564
pvalue = 0.2928
-----------------------------------------------------------------------
 bcgcausality gGDP gAgrExport, frequency (1.5) varlag (3)
-----------------------------------------------------------------------
Granger-causality from  gAgrExport to  gGDP
-----------------------------------------------------------------------
H0: No Granger-causality from gAgrExport to gGDP at frequency w =  1.50
Wald test statistic = 2.4546
pvalue = 0.2931
-----------------------------------------------------------------------
. bcgcausality gGDP gAgrExport, frequency (2.5) varlag (3)
-----------------------------------------------------------------------
Granger-causality from  gAgrExport to  gGDP
-----------------------------------------------------------------------
H0: No Granger-causality from gAgrExport to gGDP at frequency w =  2.50
Wald test statistic = 7.6124
pvalue = 0.0222
-----------------------------------------------------------------------
. bcgcausality gAgrExport gGDP, frequency (0.05) varlag (3)
-----------------------------------------------------------------------
Granger-causality from  gGDP to  gAgrExport
-----------------------------------------------------------------------
H0: No Granger-causality from gGDP to gAgrExport at frequency w =  0.05
Wald test statistic = 5.5891
pvalue = 0.0611
-----------------------------------------------------------------------
. bcgcausality gAgrExport gGDP, frequency (1.5) varlag (3)
-----------------------------------------------------------------------
Granger-causality from  gGDP to  gAgrExport
-----------------------------------------------------------------------
H0: No Granger-causality from gGDP to gAgrExport at frequency w =  1.50
Wald test statistic = 3.0036
pvalue = 0.2227
. bcgcausality gAgrExport gGDP, frequency (2.5) varlag (3)
-----------------------------------------------------------------------
Granger-causality from  gGDP to  gAgrExport
-----------------------------------------------------------------------
H0: No Granger-causality from gGDP to gAgrExport at frequency w =  2.50
Wald test statistic = 2.1507
pvalue = 0.3412
```

Intersectoral Linkage between agriculture and nonagricultural sectors
Long-run and Short-run Coefficients

ardl lnNonAVA lnAVA lnK lnL, ec1 aic constant restricted

ARDL(1,0,0,1) regression

Sample: 1962 thru 2023	Number of obs = 62
	R-squared = 0.5528
	Adj R-squared = 0.5129
Log likelihood = 117.61589	Root MSE = 0.0382

D.lnNonAVA	**Coefficient**	**Std. err.**	**t**	**P>|t|**	**[95% conf. interval]**	
ADJ |						
lnNonAVA L1.	-.2592815	.0392367	-6.61	0.000	-.3378819	-.180681
LR |						
lnAVA | L1.	.6551023	.2082147	3.15	0.003	.2379982	1.072206
lnK L1	.2685504	.0782955	3.43	0.001	.1117057	.4253952
lnL L1	1.187408	.0895114	13.27	0.000	1.008095	1.366721
_cons	-18.73242	3.191048	-5.87	0.000	-25.12486	-12.33999
SR						
lnAVA D1.	.1698559	.0652556	2.60	0.012	.0391331	.3005787
lnK D1.	.0696301	.0191854	3.63	0.001	.0311971	.1080632
lnL D1.	-2.615725	.9768928	-2.68	0.010	-4.572676	-.6587732

Bound Test for Cointegration Result
. estat ectest

Pesaran, Shin, and Smith (2001) bounds test

H0: no level relationship	F = 17.403
Case 2	t = -6.608

Finite sample (3 variables, 62 observations, 1 short-run coefficients)

Kripfganz and Schneider (2020) critical values and approximate p-values

	10%		**5%**		**1%**		**p-value**	
	I(0)	**I(1)**	**I(0)**	**I(1)**	**I(0)**	**I(1)**	**I(0)**	**I(1)**
F	2.490	3.342	2.955	3.888	4.011	5.105	0.000	0.000
t	-2.567	-3.450	-2.889	-3.806	-3.527	-4.497	0.000	0.000

do not reject H0 if

either F or t are closer to zero than critical values for I(0) variables

(if either p-value > desired level for I(0) variables)

reject H0 if

both F and t are more extreme than critical values for I(1) variables

(if both p-values < desired level for I(1) variables)

decision: no rejection (.a), inconclusive (.), or rejection (.r) at levels:

	10%	5%	1%
decision	.r	.r	.r

Wald Test Coefficient Restriction on lagged level of the independent variable

Wald Test:

Equation: Untitled

Test Statistic	**Value**	**df**	**Probability**
F-statistic	5.713798	(3, 48)	0.0020
Chi-square	17.14139	3	0.0007

Null Hypothesis: C(2)=C(3)=C(4)=0

Null Hypothesis Summary:

Normalized Restriction (= 0)	**Value**	**Std. Err.**
C(2)	0.243606	0.085665
C(3)	0.045772	0.029220
C(4)	0.328674	0.089600

Restrictions are linear in coefficients.

Normality Test
jb lnNonAVA
Jarque-Bera normality test: 4.843 Chi(2) .0888
Jarque-Bera test for Ho: normality:
estat imtest

Cameron & Trivedi's decomposition of IM-test

Source	chi2	df	P
Heteroskedasticity	15.97	14	0.3153
Skewness	8.47	4	0.0758
Kurtosis	2.51	1	0.1128
Total	26.95	19	0.1057

Autocorrelation Test

estat bgodfrey

Breusch–Godfrey LM test for autocorrelation

lags(p)	chi2	df	Prob > chi2
1	3.150	1	0.0759

H0: no serial correlation

Heteroskedasticity Test
estat hettest

Breusch–Pagan/Cook–Weisberg test for heteroskedasticity
Assumption: Normal error terms
Variable: Fitted values of D.lnNonAVA

H0: Constant variance

chi2(1) =   0.24
Prob > chi2 = 0.6273

Model Misspecification Ramsey reset Test

estat ovtest

Ramsey RESET test for omitted variables

Omitted: Powers of fitted values of D.lnNonAVA

H0: Model has no omitted variables

F(3, 43) = 1.48

Prob > F = 0.2340

Model Stability Test

. estat sbcusum

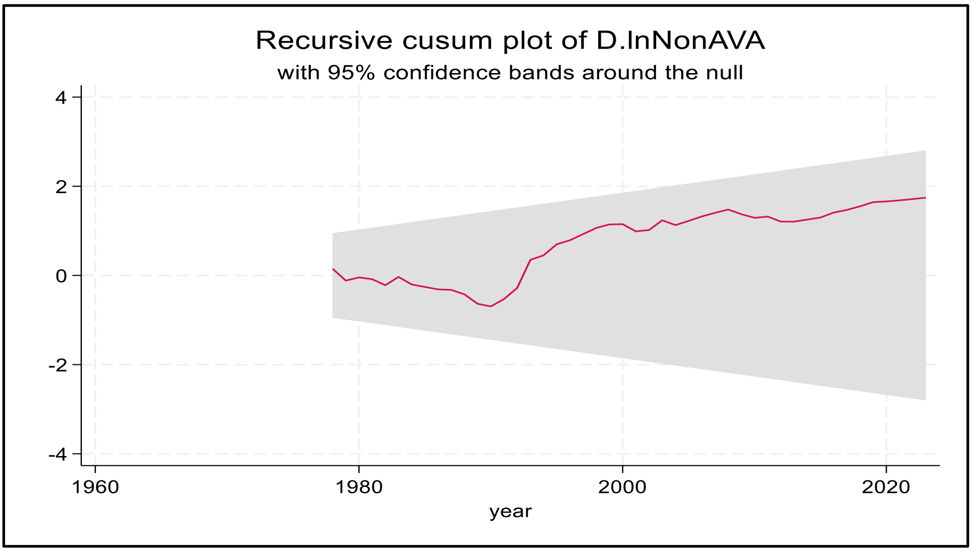
Cumulative sum test for parameter stability

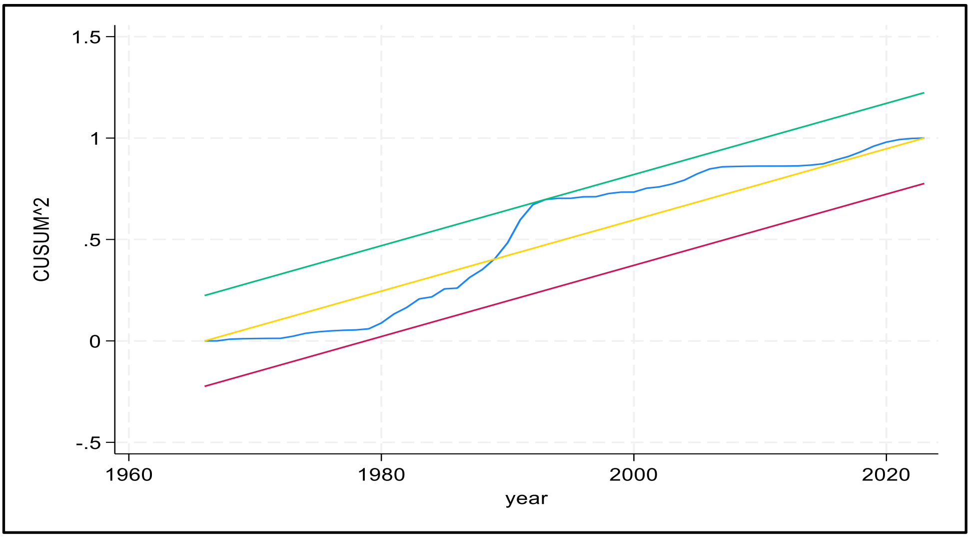
Sample: 1965 thru 2023 Number of obs = 59

H0: No structural break

Type	Test statistic	Critical value		
		1%	5%	10%
Recursive	0.9694	1.1430	0.9479	0.8499

cusum9 lnNonAVA lnAVA, cs2(cusum2) lw(lower) uw(upper)





Toda-Yamamoto Granger Non-causality test

VAR Granger Causality/Block Exogeneity Wald Tests
Date: 06/03/25 Time: 15:54
Sample: 1961 2023
Included observations: 55

Dependent variable: LNNONAVA

Excluded	Chi-sq	df	Prob.
LNAVA	22.21952	8	0.0045
LNK	15.39503	8	0.0519
LNL	12.95639	8	0.1134
All	60.47705	24	0.0001

Dependent variable: LNAVA

Excluded	Chi-sq	df	Prob.
LNNONAVA	1.399397	8	0.9943
LNK	9.326457	8	0.3155
LNL	32.64264	8	0.0001
All	60.09302	24	0.0001

Dependent variable: LNK

Excluded	Chi-sq	df	Prob.
LNNONAVA	9.476048	8	0.3037
LNAVA	12.65308	8	0.1244
LNL	5.857684	8	0.6632
All	66.66782	24	0.0000

Dependent variable: LNL

Excluded	Chi-sq	df	Prob.
LNNONAVA	1.923761	8	0.9833
LNAVA	6.317761	8	0.6117
LNK	3.847565	8	0.8706
All	13.98275	24	0.9470

Pairwise Granger causality test

VAR Granger Causality/Block Exogeneity Wald Tests
Date: 06/08/25 Time: 16:18
Sample: 1961 2023
Included observations: 55
Dependent variable: LNNONAVA

Excluded	Chi-sq	df	Prob.
LNAVA	31.49636	8	0.0001
All	31.49636	8	0.0001

Dependent variable: LNAVA

Excluded	Chi-sq	df	Prob.
LNNONAVA	12.37415	8	0.1353
All	12.37415	8	0.1353

Frequency-Domain Granger causality test

bcgcausality lnNonAVA lnAVA lnK lnL, frequency (0.05) varlag (8)

Conditioning type is = geweke
Granger-causality from lnAVA to lnNonAVA conditional on lnK lnL

H0: No Granger-causality from lnAVA to lnNonAVA at frequency w = 0.05
Wald test statistic = 7.2494
pvalue = 0.0267

No graphical output

. bcgcausality lnNonAVA lnAVA lnK lnL, frequency (1.5) varlag (8)

Conditioning type is = geweke
Granger-causality from lnAVA to lnNonAVA conditional on lnK lnL

H0: No Granger-causality from lnAVA to lnNonAVA at frequency w = 1.50
Wald test statistic = 6.0291
pvalue = 0.0491

No graphical output

. bcgcausality lnNonAVA lnAVA lnK lnL, frequency (2.5) varlag (8)

Conditioning type is = geweke
Granger-causality from lnAVA to lnNonAVA conditional on lnK lnL

H0: No Granger-causality from lnAVA to lnNonAVA at frequency w = 2.50
Wald test statistic = 0.0953
pvalue = 0.9535

No graphical output

. bcgcausality lnAVA lnNonAVA lnK lnL, frequency (0.05) varlag (8)

Conditioning type is = geweke
Granger-causality from lnNonAVA to lnAVA conditional on lnK lnL

H0: No Granger-causality from lnNonAVA to lnAVA at frequency w = 0.05
Wald test statistic = 0.0060
pvalue = 0.9970

No graphical output

. bcgcausality lnAVA lnNonAVA lnK lnL, frequency (1.5) varlag (8)

Conditioning type is = geweke
Granger-causality from lnNonAVA to lnAVA conditional on lnK lnL

H0: No Granger-causality from lnNonAVA to lnAVA at frequency w = 1.50
Wald test statistic = 1.0091
pvalue = 0.6038

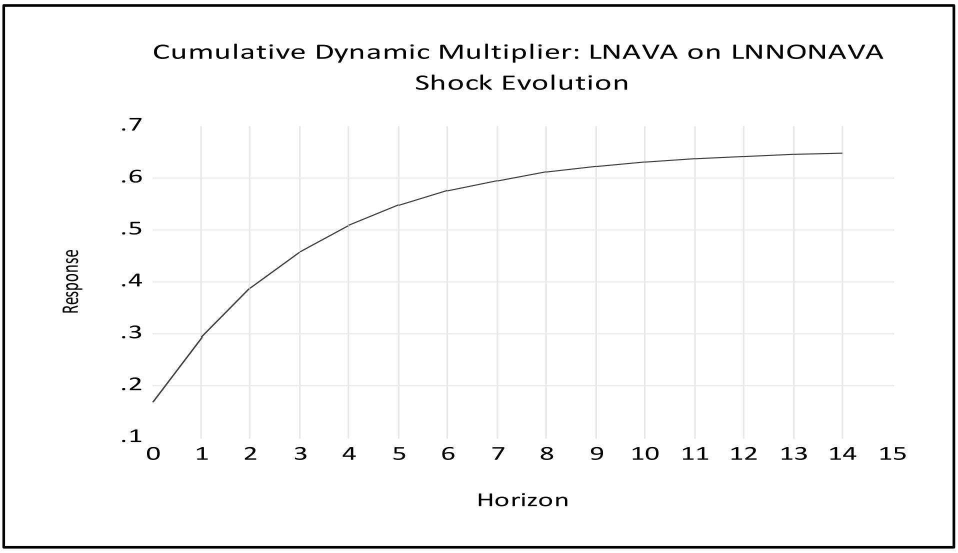
No graphical output

. bcgcausality lnAVA lnNonAVA lnK lnL, frequency (2.5) varlag (8)

Conditioning type is = geweke
Granger-causality from lnNonAVA to lnAVA conditional on lnK lnL

H0: No Granger-causality from lnNonAVA to lnAVA at frequency w = 2.50
Wald test statistic = 0.2275
pvalue = 0.8925

Cumulative Dynamic Multiplier and Shock Evolution



Agricultural Productivity and Structural Transformation

Long-run and Short-run Coefficients
ardl gNonAgrEmp gPAgr, ec1 aic constant restricted

ARDL(1,0) regression

Sample: 1966 thru 2023 | Number of obs = 58
R-squared = 0.3764
Adj R-squared = 0.3537
Log likelihood = -149.60965 | Root MSE = 3.2775

D.gNonAgrEmp	Coefficient	Std. err.	t	P>|t|	[95% conf. interval]	
ADJ						
D.gNonAgrEmp L1	-.4967762	.100927	-4.92	0.000	-.6990383	-.294514
LR |						
gPAgr | L1.	.5048645	.1642521	3.07	0.003	.1756958	.8340331
_cons	. 5.805935	.8764744	6.62	0.000	4.049441	7.562429
SR						
gPAgr D1.	.2508046	.0702312	3.57	0.001	.1100581	.3915512

Bound Test for Cointegration Result

. estat ectest

Pesaran, Shin, and Smith (2001) bounds test
H0: no level relationship F = 11.091
Case 2 t = -4.922

Finite sample (1 variables, 58 observations, 0 short-run coefficients)

Kripfganz and Schneider (2020) critical values and approximate p-values

	10%		5%		1%		p-value	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
F	3.128	3.616	3.784	4.319	5.288	5.902	0.000	0.000
t	-2.586	-2.949	-2.901	-3.279	-3.523	-3.922	0.000	0.000

do not reject H0 if
either F or t are closer to zero than critical values for I(0) variables
(if either p-value > desired level for I(0) variables)

reject H0 if
both F and t are more extreme than critical values for I(1) variables
(if both p-values < desired level for I(1) variables)

decision: no rejection (.a), inconclusive (.), or rejection (.r) at levels:

	10%	5%	1%
decision	.r	.r	.r

Wald Test Coefficient Restriction on lagged level of the independent variable

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
t-statistic	3.872586	50	0.0003
F-statistic	14.99692	(1, 50)	0.0003
Chi-square	14.99692	1	0.0001

Null Hypothesis: C(2)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(2)	0.295964	0.076425

Restrictions are linear in coefficients.

Normality Test

Jarque-Bera normality test: 1.147 Chi(2) .5635
Jarque-Bera test for Ho: normality:
Autocorrelation test
Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 2 lags

F-statistic	1.938552	Prob. F(2,48)	0.1550
Obs*R-squared	3.961025	Prob. Chi-Square(2)	0.1380

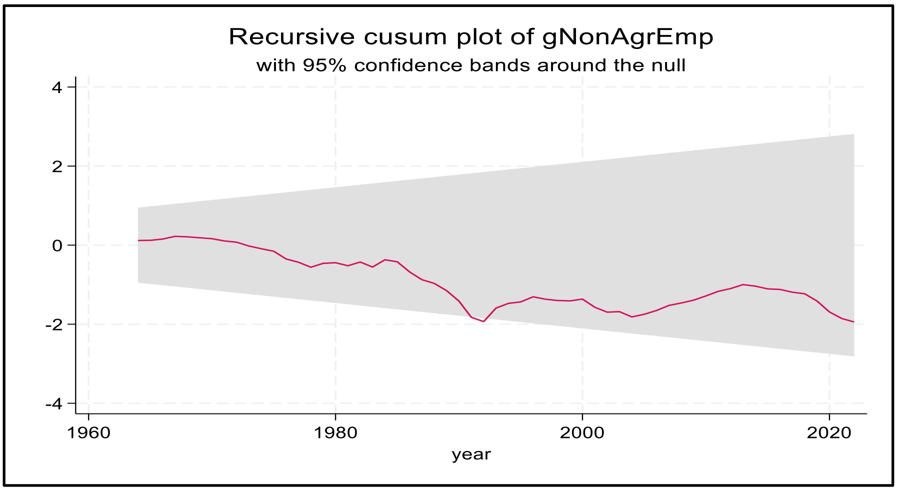
Heteroscedastic test
Heteroskedasticity Test: ARCH

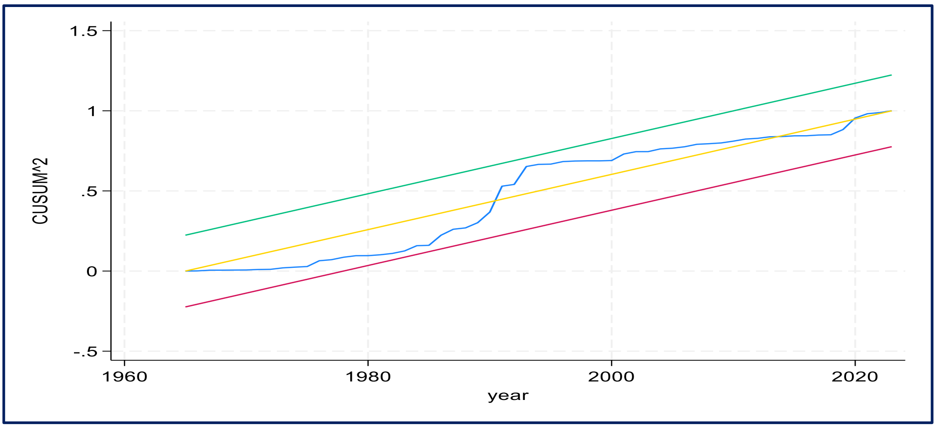
F-statistic	0.289101	Prob. F(1,50)	0.5932
Obs*R-squared	0.298937	Prob. Chi-Square(1)	0.5845

Model misspecification test
Ramsey RESET Test
Equation: UNTITLED
Omitted Variables: Squares of fitted values
Specification: GNAGREMP GNAGREMP(-1) GPAGR C

	Value	df	Probability
t-statistic	1.068346	49	0.2906
F-statistic	1.141363	(1, 49)	0.2906
Likelihood ratio	1.220377	1	0.2693

Model Stability Test





Toda-Yamamoto Granger Non-causality test

VAR Granger Causality/Block Exogeneity Wald Tests
Date: 05/06/24 Time: 04:04
Sample: 1962 2015
Included observations: 48

Dependent variable: GNAGREMP			
Excluded	**Chi-sq**	**df**	**Prob.**
GPAGR	17.46597	6	0.0077
All	17.46597	6	0.0077
Dependent variable: GPAGR			
Excluded	**Chi-sq**	**df**	**Prob.**
GNAGREMP	4.312522	6	0.6345
All	4.312522	6	0.6345

Frequency-Domain Granger causality test

Frequency Domain Granger Causality test
cgcausality gNAgremp gPAgr, frequency (0.05) varlag (6)

Granger-causality from gPAgr to gNAgremp

H0: No Granger-causality from gPAgr to gNAgremp at frequency w = 0.05
Wald test statistic = 13.4605
pvalue = 0.0012

No graphical output

. bcgcausality gNAgremp gPAgr, frequency (1.5) varlag (6)

```
Granger-causality from  gPAgr to  gNAgremp
----------------------------------------------------------------------
H0: No Granger-causality from gPAgr to gNAgremp at frequency w =  1.50
Wald test statistic = 2.5128
pvalue = 0.2847
----------------------------------------------------------------------
No graphical output
----------------------------------------------------------------------
. bcgcausality gNAgremp gPAgr, frequency (2.5) varlag (6)
----------------------------------------------------------------------
Granger-causality from  gPAgr to  gNAgremp
----------------------------------------------------------------------
H0: No Granger-causality from gPAgr to gNAgremp at frequency w =  2.50
Wald test statistic = 5.7102
pvalue = 0.0576
----------------------------------------------------------------------
No graphical output
----------------------------------------------------------------------
. bcgcausality gPAgr gNAgremp, frequency (0.05) varlag (6)
----------------------------------------------------------------------
Granger-causality from  gNAgremp to  gPAgr
----------------------------------------------------------------------
H0: No Granger-causality from gNAgremp to gPAgr at frequency w =  0.05
Wald test statistic = 0.5180
pvalue = 0.7718
----------------------------------------------------------------------
No graphical output
----------------------------------------------------------------------
. bcgcausality gPAgr gNAgremp, frequency (1.5) varlag (6)
----------------------------------------------------------------------
Granger-causality from  gNAgremp to  gPAgr
----------------------------------------------------------------------
H0: No Granger-causality from gNAgremp to gPAgr at frequency w =  1.50
Wald test statistic = 0.4900
pvalue = 0.7827
----------------------------------------------------------------------
No graphical output
----------------------------------------------------------------------
. bcgcausality gPAgr gNAgremp, frequency (2.5) varlag (6)
----------------------------------------------------------------------
Granger-causality from  gNAgremp to  gPAgr
----------------------------------------------------------------------
H0: No Granger-causality from gNAgremp to gPAgr at frequency w =  2.50
Wald test statistic = 2.3854
pvalue = 0.3034
----------------------------------------------------------------------
No graphical output
```

The contribution of agricultural productivity in driving aggregate productivity growth relative to nonagricultural productivity growth

Long-run and Short-run Coefficients

ardl gPTot gPAgr gPNonAgr, ec1 aic constant restricted

ARDL(1,1,1) regression

Sample: 1966 thru 2023	Number of obs = 58
	R-squared = 0.9698
	Adj R-squared = 0.9669
Log likelihood = -80.131761	Root MSE = 1.0174

D.gPTot	Coefficient	Std. err.	t	P>|t|	[95% conf. interval]	
ADJ |						
gPTot | L1.	-.6727732	.1369051	-4.91	0.000	-.9474934	-.3980529
LR |						
gPAgr | L1.	.7580275	.0444035	17.07	0.000	.6689253	.8471298
gPNonAgr | L1	.3388659	.0745248	4.55	0.000	.189321	.4884107
_cons	.8637357	.2047347	4.22	0.000	.4529054	1.274566
SR						
gPAgr | D1.	.7058019	.023075	30.59	0.000	.6594985	.7521054
gPNonAgr | D1.	.3107769	.0191854	3.63	0.001	.0311971	.1080632

Bound Test for Cointegration Result

. estat ectest

Pesaran, Shin, and Smith (2001) bounds test

H0: no level relationship F = 6.362

Case 2 t = -4.914

Finite sample (2 variables, 58 observations, 2 short-run coefficients)

Kripfganz and Schneider (2020) critical values and approximate p-values

	10%		5%		1%		p-value	
	I(0)	**I(1)**	**I(0)**	**I(1)**	**I(0)**	**I(1)**	**I(0)**	**I(1)**
F	2.721	3.465	3.262	4.081	4.497	5.463	0.001	0.003
t	-2.565	-3.226	-2.887	-3.576	-3.526	-4.256	0.000	0.002

do not reject H0 if

either F or t are closer to zero than critical values for I(0) variables

(if either p-value > desired level for I(0) variables)

reject H0 if

both F and t are more extreme than critical values for I(1) variables

(if both p-values < desired level for I(1) variables)

decision: no rejection (.a), inconclusive (.), or rejection (.r) at levels:

	10%	5%	1%
decision	.r	.r	.r

Wald Test Coefficient Restriction on lagged level of the independent variable

Wald Test:

Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	557.6873	(2, 48)	0.0000
Chi-square	1115.375	2	0.0000

Null Hypothesis: C(4)=C(5)=0

Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(4)	0.713689	0.023005
C(5)	0.314010	0.042857

Restrictions are linear in coefficients.

Normality test

jb gPTot

Jarque-Bera normality test: 6.962 Chi(2) .0308

Jarque-Bera test for Ho: normality:

estat imtest

Cameron & Trivedi's decomposition of IM-test

Source	chi2	df	p
Heteroskedasticity	46.35	35	0.0950
Skewness |	7.83	7	0.3480
Kurtosis	1.50	1	0.2205
Total	55.68	43	0.0930

Autocorrelation test
estat bgodfrey

Breusch–Godfrey LM test for autocorrelation

lags(p)	chi2	df	Prob > chi2
1	0.140	1	0.7084

H0: no serial correlation

Heteroskedasticity Test

Breusch–Pagan/Cook–Weisberg test for heteroskedasticity
Assumption: Normal error terms
Variable: Fitted values of D.gPTot
H0: Constant variance

chi2(1) = 1.38
Prob > chi2 = 0.2403

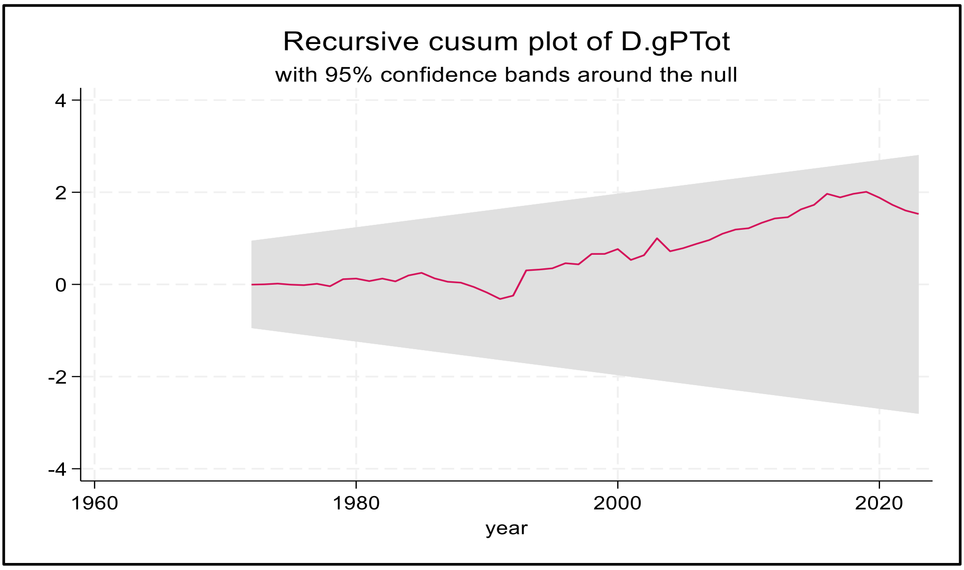
Model Misspecification Ramsey reset Test
estat ovtest

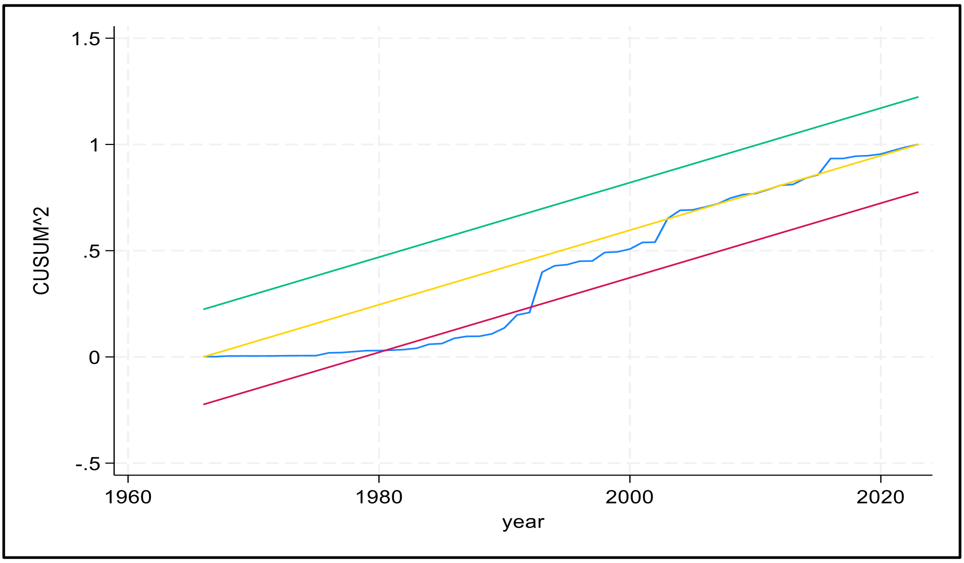
Ramsey RESET test for omitted variables
Omitted: Powers of fitted values of D.gPTot

H0: Model has no omitted variables

F(3, 49) = 2.27
Prob > F = 0.0918

Model Stability Test





AfCFTA Agreement and Ethiopia's Engagement in Intra-Africa Trade Integration: The Challenges and Prospects with Suggested Strategies

Addis Kassahun Mulat[1] , Rahel Belete Balkew

Acronyms

AfCFTA	African Continental Free Trade Area
AfDB	African Development Bank
AGOA	African Growth Opportunity Act
ARS	African Standards
ARSO	Africa Regional Standard Organization
AU	African Union
CAD	Cash Against Document
CAGR	Compound Annual Growth Rate
CES	Compulsory Ethiopian Standards
CET	Common External Tariffs
CODEX	Codex Alimentarius
COMESA	Common Market for Eastern and Southern Africa
ECCSA	Ethiopian Chamber of Commerce and Sectoral Associations
ECX	Ethiopian Commodity Exchange
EHDA	Ethiopian Horticulture Development Agency
EHPEA	Ethiopian Horticulture Producers and Exporters Association
ESI	Ethiopian Standard Institute
EU	European Union
FTA	Free Trade Area
FGD	Focus Group Discussion

[1] Contact Addresses:
Email: addiskassahun@gmail.com; etgrace@gmail.com
Tel: mobile: +251 911 214321; +251920331128
Office: +251 114701774
P.O. Box 341 Code 1110, Addis Ababa
Co-Authors: Addis Kassahun Mulat (PhD) and Rahel Belete Balkew (PhD)
Affiliations: Kilimanjaro Global Consulting Training and Innovation Hub; Ethiopian Chamber of Commerce and Sectoral Association (EECSA); & Ethiopian Economics Association (EEA)

GDP	Gross Domestic Product
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GoE	Government of Ethiopia
GTI	Guided Trade Initiative
GTP	Growth and Transformation Plan
HGER	Homegrown Economic Reform Agenda
IGAD	Intergovernmental Authority on Development
IMF	International Monetary Fund
MFN	Most Favored Nation
MOT	Ministry of Trade
MOTRI	Ministry of Trade and Regional Integration
NBE	National Bank of Ethiopia
NSB	National Standards Body
NTBs	Non-Tariff Barriers
RECs	Regional Economic Communities
SMEs	Small and Medium Enterprises
SPS	Sanitary and Phyto-Sanitary
TBT	Technical Barriers to Trade
TR	Technical Regulations
UNCTAD	United Nations Conference on Trade and Development
UNECA	United Nations Economic Commission for Africa
USD	Unites States Dollar
WB	World Bank
WTO	World Trade Organization

Abstract

Introduction and Background: After a five-and-a-half-year period of negotiations, which was launched on 15 June 2015, the Africa Continental Free Trade Area (AfCFTA) was signed by the 44 African Union Heads of State and Governments on 21 March 2018, in Kigali, Rwanda. Ethiopia is among the 39 African countries that have ratified the African Continental Free Trade Area (AfCFTA) agreement as of January 2021. Trading under AfCFTA has already started since 1st of Jan. 2021. There are some key and most important AfCFTA's domestication requirements that a country should fulfil to benefit from AfCFTA such as

The country should take a deliberate step to produce/develop a National AfCFTA Implementation Strategy which show its competitiveness areas that demonstrate its comparative advantages.

Ethiopia should put prioritization of the sectors, sub-sectors in its AfCFTA National Strategy

Domestication of AfCFTA (alignment and harmonization) in its national regulatory mechanism

Now, Ethiopia is developing its AfCFTA National Implementation Strategy after more than 32 African countries have already developed their own AfCFTA National Implementation strategies. More than eight countries have started the Guided Trade Initiative (GTI) voluntarily since 2022.

Kilimanjaro Global Consulting team, led by Addis Kassahun and Rahel Belete (PhDs), has commissioned through the financial resource from GIZ and conducted assessment covering the Trade in Goods especially focusing on agricultural commodities value chains in Avocado, Soybean and Onion with the objective of examining the challenges and barriers including exploring the potential opportunities and use the evidences to develop the AfCFTA Trade Strategy and Trade Guide for the Ethiopian business actors and state party under AfCFTA National Implementation and compliance of the agreement. AfCFTA is an opportunity for Ethiopia because it has been a closed economy for a long period starting from 1974-1991 and a very limited liberalization from 1991-2010, and it is opening now under the new reformist government. However, implementing the trade deal continues to pose serious challenges to Ethiopia as the country has yet to deal with several issues preventing it from taking advantage of what would be a transformative economic

arrangement. As a voice of the private sector and its business communities in Ethiopia, ECCSA is responsible in making the private sector ready to trade under the AfCFTA. To support and facilitate the Ethiopian's companies' active engagement in the Intra-Africa Trade and provide support for the government to enhance its role in addressing the pressing challenges of the private sector and seize the opportunities created in the effective implementation of AfCFTA, an assessment conducted to generate data and evidences to develop a separate trade strategy and trade guide for AfCFTA implementation considering the private sector contexts. To be successful under AfCFTA the state party and private sector are expected to do a lot which has been investigated in this study.

Methodology: A mixed methods study design has been employed using both quantitative and qualitative data collection approaches. It is developed based on the various literature reviews and primary data collected using face-to-face, telephone and virtual interviews and focus group discussions with diverse stakeholders from the private sector, government and non-governmental organizations and AfCFTA Secretariate which based in Accra, Ghana. Quantitative data have been collected from key Federal government ministries, authorities, commissions and institutes, including the private sector main actors in the agricultural goods producers, processors and exporters, including national and regional chambers; women owned businesses and exporters: 140 respondents have participated in the study.

Key Findings: The Ethiopian Government has developed the AfCFTA National Implementation Strategy and officially lunched the strategy document at the end of June 2025. As a voice of the private sector and its business communities in Ethiopia, ECCSA is responsible in making the private sector ready to trade under the AfCFTA but this is not a sufficient condition for success for Intra-Africa Trade under AfCFTA. The findings shows that not only MOTRI but also other government authorities should play a critical role in alignment and harmonizations of the regulatory requirements and standards as stipulated in the AfCFTA agreement for Trade in Goods and its instruments/protocols including annexes. SMEs play an important role in creating jobs and can be important drivers of economic activities in the Ethiopian business landscape as well.

Agricultural commodities value chain actors wise, almost all the value chain actors emphasized that challenges like lack of peace and security due to internal conflicts and deteriorating rule of laws in Ethiopia, infrastructures (like warehouse, storage, market place, logistics and transportation facilities, constant Air flight and Air Cargo space availability, knowledge gap and lack of expertise in the fields of international and regional business, government office bureaucracy and corruption in the government services, government monopoly and lack of government attention to the private sector initiatives, absence of packaging and labeling materials and high customs related prices are the critical challenges to do business. At higher level, macroeconomic imbalances, inflation and the recent macroeconomic policy reforms including the change in the foreign exchange rate regimes and above all the weak productive capacities have been cited as challenges for the country to become competitive in the regional and continental markets at least in the short-term. Based on the through situational analysis using SLOT, Enablers and Barriers analysis, key strategies have been forwarded in the following six major strategic themes and options:

- Institutionalization and Domestication of AfCFTA,
- Provision of Trade Intelligence,
- Enhancing Human and Institutional Capacities,
- Trade Promotion and Diversifying Exports,
- Empowering Women and Youth in MSMEs,
- Collaboration and Partnership in AfCFTA

Conclusion and Recommendation: Finally, ECCSA and the respective government authorities are expected to work closely to find solutions to the challenges and seize the opportunities identified in the agricultural value chain on the basis of their mandates by changing the business-as-usual mindsets.

Key Words: AfCFTA Agreement, Trade and Regional Integration; Private Sector and State party in the AfCFTA Implementation

1. Introduction and Background

1.1. Introduction

The landmark African Continental Free Trade Area (AfCFTA) came into force in January 2021, opening up new opportunities for an inclusive post-COVID-19 pandemic recovery for Africa. The AfCFTA is the largest trading bloc in the world, with a membership of 54 African countries and has the potential to establish Africa as the world's largest free trade area, with a combined GDP of $3.4 trillion and a market of more than 1 billion consumers. Today, African's more than 250 million youth between 15-34 make up more than 60% of Africa's population. SMEs account for more than 90% of businesses. Informal trade constitutes more than 30% of intra-African cross-border trade, and 60-70% of informal traders are women. An important part of the AfCFTA's secretariat mandate is therefore to ensure the active participation of women, youth and SMEs in Africa's trade story2. The African Continental Free Trade Area is expected to be a game changer for Africa and a key engine of economic growth and industrialization for sustainable development, in line with the 2030 Agenda for Sustainable Development, adopted by the General Assembly, and Agenda 2063: The Africa We Want, of the African Union.

Under the African Continental Free Trade Area (AfCFTA), the agriculture sector is inevitably seen as a key sector to ensure, enhance, and contribute to sustainable development, economic growth, improved livelihoods, and poverty reduction. It is also seen as a catalyst for increased value addition, processing, and eventual industrialization. Recent reports show that Ethiopia's trade with Africa is currently largely based on agri-food (major exports of vegetables, fruit, nuts and livestock; some imports of processed food); Agri-food is still expected to dominate Ethiopia's trade with Africa following AfCFTA, but the share of industry will become sizeable. In the short-term, Ethiopia's major destination markets will be its neighboring Eastern African countries and progress step by step to the other RECs by building institutional capacities, increasing agricultural productivity, quality production and addressing the multifaceted technical, Non-Tarriff Barriers (NTBs) and other associated challenges.

[2] AfCFTA Secretariat (2021): AfCFTA Private Sector Engagement Strategy 2022-2032 DRAFT - Full version; AfCFTA, AU and Mastercard Foundation

1.2. Background and Historical Perspective

According to Benedict (2021)[3] the establishment of the African Continental Free Trade Area (AfCFTA) is one of the 15-flagship projects identified by the African Union (AU) and adopted by the Assembly of Heads of State and Government as an endeavor that would contribute towards the realization of the AU Agenda 2063. The idea and the discussion of continental economic integration started in 1980, the Organization of African Unity (the predecessor to the African Union) adopted the Lagos Plan of Action for the Economic Development of Africa 1980-2000, which contained a regional development plan for Africa, including the formation of an African Common Market. These ideas and discussions were further elaborated through the 1991 Organization of African Unity Treaty establishing the African Economic Community, the so-called Abuja Treaty. It was not until the adoption of Agenda 2063, however, and the identification of the flagship programs, that the ambitions were concretized[4]. Pan-African negotiations for an AfCFTA were launched in June 2015 with the "indicative" target date for conclusion set for 2017, consistent with the African Union's Action Plan for "Boosting Intra-African Trade (BIAT) and the Establishment of a Continental Free Trade Area (CFTA) as endorsed by the 18th African Union Summit of African Heads of States and Governments (January 2012)[5].

The targeted date of 2017 for the AfCFTA represented fast-tracking by 2 years the completion of stage 4 in respect of free trade area as envisaged by the Abuja Treaty of 19916. The "CFTA roadmap" provided that the first phase of the negotiations would address the core issues of trade in goods and services, followed by the second phase that would address the broader trade-related issues of intellectual property rights, competition policy and investment. The signing of the Agreement Establishing the African Continental Free Trade Area in Kigali on 21 March 2018 is

[3] Benedict Musengele (2021). AfCFTA: A Stimulant to Intra- COMESA Trade. Common Market for Eastern and Southern Africa, Special Report.
[4] Unpublished Report prepared and submitted by African Union 6 December 2019 to Danish support on the African Continental Free Trade Area. Retrieved from https://um.dk.
[5] African Union (2015), Decision on the launch of Continental Free Trade Area negotiations (Assembly/AU/Dec.569(XXV)), adopted at the 25th ordinary session of the Assembly of the Union, 14–15 June 2015, Johannesburg, South Africa
[6] For a discussion of boosting intra-African trade by fast-tracking AfCFTA, see UNCTAD and African Union (2012), Trade liberalization, investment and economic integration in African Regional Economic Communities towards the African Common Market (UNCTAD/DITC/TNCD/2011/2)

a key milestone for the African behind the border Agenda 2063. To sum-up, the evolution of African Continental Economic Integration is summarized in Figure 1. Below.

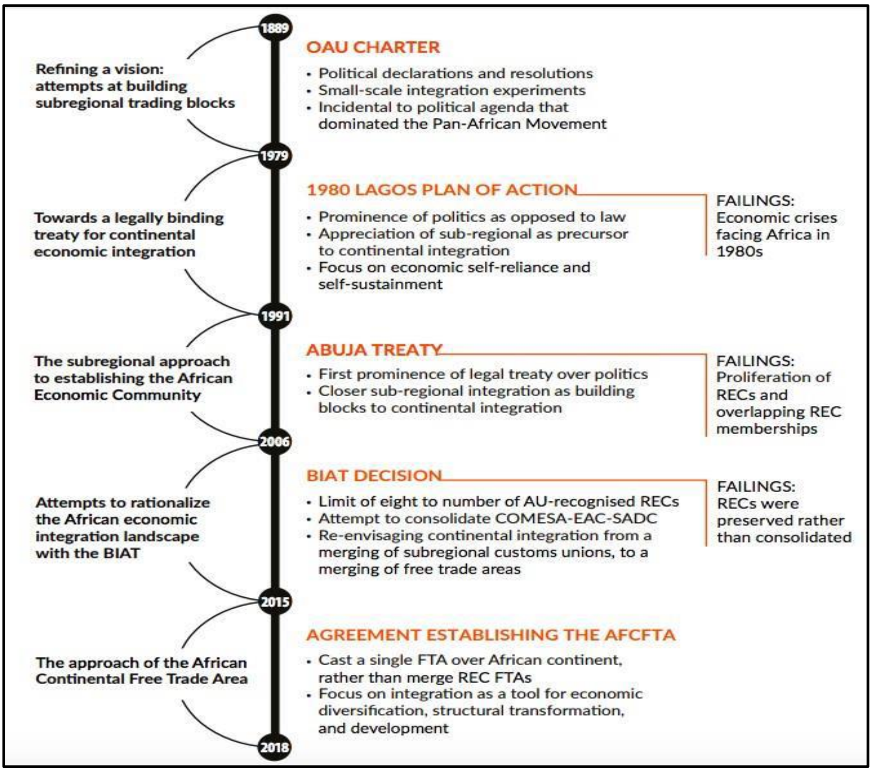


Figure 1: Evolution of African Continental Economic Integration

Source: A Study Report on The Export Coordination Challenges to the AfCFTA Market:

Empirical Evidence from Ethiopia- Lead Plus 2022. In this regard, May 2020 marked a year since the AfCFTA Agreement legally entered into force, having surpassed the necessary 22 ratifications. Though trade is due to begin under the agreement in January 2021, a number of key aspects are still being finalized.

1.3. Major Guiding Principles and Definitions

Regional Integration (RI): is an arrangement between two or more countries to cooperate, through formal, regional rules and institutions, to overcome barriers to the flow of goods, services, capital, and people across borders, which passes through four stages/ types of regional integration to reach ultimate integration:

Free Trade Area (FTA): - countries agree to reduce or eliminate barriers to trade between them. Traditionally, this was focused on goods trade by removing customs duties, but FTAs now also include services as well as non-tariff barriers.

Customs Unions: – where countries remove customs duties between themselves and adopt a uniform customs duty regime towards third countries.

Common Market: – in addition to free movement of goods and a customs union, a common market also includes free movement of services, capital and labor (persons).

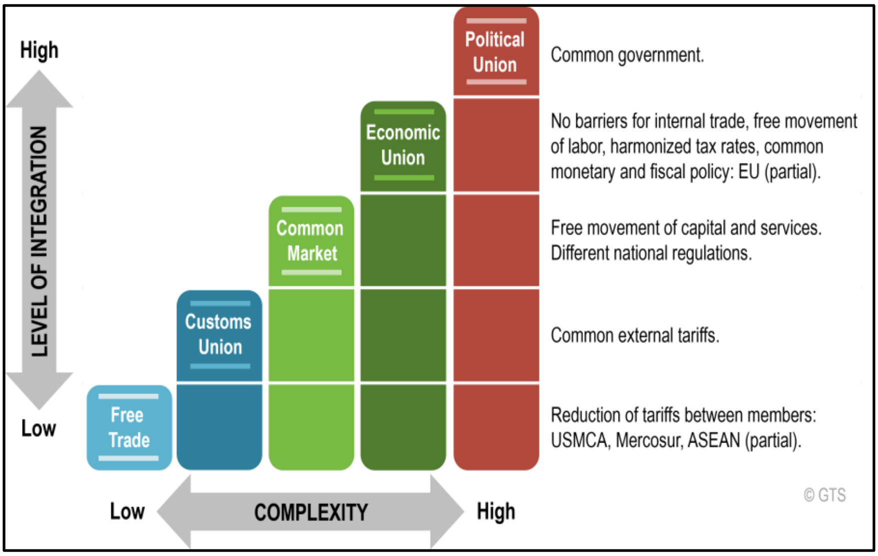


Figure 2: Stage of Regional Integration in Africa

Economic Union: – is where in addition to having a common market, country adopt common economic policies, and often trade relations with third countries are handled centrally.

The overall goal of AfCFTA is to create a single market for goods and services, facilitated by the movement of persons and also to achieve the Pan-African Vision of "an integrated, prosperous and peaceful Africa" enshrined in Agenda 2063. The agreement compels countries to remove tariffs on 90% of goods and the African countries expect to lay the foundation for the establishment of a Continental Customs Union (CCU)[7].

[7] Théophile Albert (2019). The African Continental Free Trade Agreement: Opportunities and Challenges. Published by: CUTS INTERNATIONAL, GENEV Rue de Vermont 37-39 1202 Geneva, Switzerland www.cuts-geneva.org

1.4. Rationale for National AfCFTA Strategies

Harnessing the benefits of the AfCFTA begins with putting the Agreement into a national perspective, including ratification by member States, which is a prerequisite. The benefits of the AfCFTA Agreement will not be realized overnight. Countries need to identify capacity gaps to be addressed, as well as their comparative and competitive advantages for diversification and the ability to develop or integrate value chains under the Agreement. This requires the design and implementation of new policy interventions or revisiting existing policy frameworks, to make the most of AfCFTA. They also need to identify means to deal with cost adjustments, including any foreseen adverse fiscal impact resulting from the implementation of the Agreement. These are some of the elements that countries must consider in developing their AfCFTA-tailored strategies at the national levels. The objective of the AfCFTA National Strategy for each African country is to complement their broader development framework, especially in relation to the trade policy environment of each State Party to the Agreement. A country's AfCFTA National strategy will facilitate the identification of key value addition and trade opportunities and constraints, measures, and capacities required for it to take full advantage of national, regional and global markets within the context of AfCFTA. The Federal Democratic Government of Ethiopia in close collaboration with the UNECA's Trade Policy Center and Policy Studies Institute (PSI) has taken the initiative to develop its National AfCFTA Implementation Strategy for Ethiopia. PSI was commissioned to develop the National Implementation Strategy and launched in June 2024 in close collaboration with the MOTRI, with the broader scope covering Macro (Aggregate) level diagnostics assessment of all the sectors of the economy. The current assessment conducted by the Kilimanjaro Global team on AfCFTA targeting the private sector that operates in the agricultural commodities with special emphasis to selected agricultural commodities value chains: Avocado, Soybean and Onion. It helps the main actors in the agricultural goods to get a better understanding and alignment with the government regulatory requirements and standards to trade under AfCFTA.

1.5. Objectives and Methods of the Assessment

The specific objectives include the following

- Examine the challenges and barriers that the opening of the regional market would have to those agricultural goods in general and under onion, avocado, and soybean value chains in particular;

- Explore potential opportunities in trading Ethiopian agricultural products under the AfCFTA and specifically to those under avocado, soybean and onion value chains;
- Provide inputs for the development of an AfCFTA Trade Guide and strategy document that helps to harmonize the regional agreement (AFCFTA) with national standards and requirements.

A mixed methods study design has been employed using both quantitative and qualitative data collection approaches. **Desk review** of various continental, regional and national strategy and policy documents, assessment reports and publications, existing AfCFTA agreement, AfCFTA private sector strategy and national development strategy and policy instruments; regulatory procedures and manuals have been reviewed, analyzed and summarized to provide the right contexts for the development of a Trade Strategy and Guide in order to provide strategic directions for the private sector under AfCFTA implementation. In addition to the secondary sources literature reviews, face to face, ZOOM and Telephone- based interviews and discussions with respective internal and external stakeholders: Producers, Processors and Exporters in the agricultural value chains have been consulted. Donor's communities, AfCFTA Secretariat based in Accra, Ghana, African Union (AU) and UN system's relevant divisions (UNECA) and the government of Ethiopia's relevant ministries and authorities have also been interviewed and consulted. Experiences gained from various consultative high-level workshops, private-public dialogue forums have been utilized. **Overall, more than 150 respondents have been interviewed.**

2. The Intra-Africa Trade in Goods

Trade within Africa is low compared to other global regions, with 18% of exports remaining on the continent, compared to 50-60% or more in Europe, North America, and Asia. African countries primarily export unprocessed commodities to Western markets and import processed products that could be manufactured on the continent. Intra-African regional trade in goods accounted for 18% ($87 billion) of Africa's exports in 2018, compared with 66% in Europe and 58% in Asia, and 22% in Latin America. Within Africa, geographical regions mostly trade among themselves. The exception is Central Africa, which trades mostly with Southern Africa. If the AfCFTA focuses on developing value chains that can increase value addition in Africa, it has the ability to boost intra-African trade, boost production, and create jobs.

The AfCFTA, AU and Mastercard Foundation conducted African trade in good value chains and prioritized an initial list of four value chains for the first set of interventions, based on high potential for meeting demand locally and the ability to produce the goods locally. These sectors are agriculture and agro-processing, automotive, pharmaceuticals, and transportation and logistics. The Trade in goods is concentrated in a few countries and a small set of goods: Africa's top 15 exporters deliver 83% of the continent's global exports, and the 15 top importers attract 77%. In terms of Exports –Intra-African, in total, 64% of intra-African goods exports by value is driven by six countries (South Africa, DRC, Nigeria, Egypt, Côte d'Ivoire, Zimbabwe)[8]. 35% of intra-African exports is driven by three goods: mineral fuels, chemicals, and copper. According to the AFCFTA Secretariat, AU and Mastercard Foundation study on African Goods Value Chains, the highest-priority value chains include those with a high value of imports from outside Africa, and high production within Africa. This indicates potential for demand to be met through local production (e.g., automotive, agro-processing).

2.1. Ethiopia in Regional and Intra-Africa Trade

Ethiopia's integration in the African and global economy comes through its membership of the Common Market for Eastern and Southern Africa (COMESA), the Intergovernmental Authority on Development (IGAD) and, most recently, the AfCFTA. However, as per the Africa Regional Integration Index Report (2019), Ethiopia is considered a low performer, being ranked 40th out of 54 African countries (AU, AFDB, UNECA, 2020). Recent reports show that Ethiopia's trade with Africa is currently largely based on agri-food (major exports of vegetables, fruit, nuts and livestock; some imports of processed food); Agri-food is still expected to dominate Ethiopia's trade with Africa following AfCFTA, but the share of industry will become sizeable. The Government now intends to leverage its ratification of the AfCFTA to improve its current trade profile. African economies in general, and Ethiopia in particular, have strived to participate in global trade opportunities and integrate into global value chains, along with a growing and stiff international competition among different markets. Despite this, Ethiopia's share of trade to GDP declined from 48.2% in 2011 to 24% in 2020 and 20.59% in 2023. Given that numerous non-tariff barriers exist between Ethiopia and many other African countries, trade liberalization under the AfCFTA itself will not be sufficient for increasing Ethiopia's volume of intra-African exports. As per quantitative analysis,

[8] HS2 classification of all products, including mineral and natural resources HS Codes: 26, 27, 71, 74, 81

and aligned to the study's scope, the market opportunities arising from the AfCFTA are in the following sectors: vegetables, coffee, oilseeds, textiles and garments and machinery. Ethiopia possesses a comparative advantage in the production of horticultural commodities given its advantages of a favorable climate, proximity and connections with European and Middle Eastern markets, the size of its domestic market, amongst others[9].

Ethiopia has a unique and diverse climate that enables producers to offer a range of opportunities for both the domestic and export markets. The horticulture industry is not only one of the country's youngest sectors, but it is also of the very fast-growing industries in Ethiopia.

3. National Strategies, Trade Policy & Performance

3.1. Ethiopia's National Development Strategies and Trade Policy Orientation

The Government of Ethiopia, through the Ten-Year Perspective Development Plan, has launched a homegrown economic reform. The plan has, as its national vision, for Ethiopia to become Africa's prosperity icon by 2030. To this end, the Government has enacted six strategic pillars[10] with one of these centered on ensuring the private sector's leadership in the Ethiopian economy. In this context, the AfCFTA is expected to contribute to realizing Ethiopia's path to becoming a middle-income country by 2030. Therefore, it is important to see that Ethiopia's trade policy objectives are laid out in the Homegrown Economic Reform Agenda of 2020 and the Ten-Year Development Plan 2021-2030. The HGER is structured around three key pillars at the macro-financial, structural, and sectoral levels. The Ten-Year Development Plan supplements the HGER and has 6 key objectives, structured around 10 strategic pillars and 6 priority focus areas. One of the key areas is increasing export earnings.

Trade policy refers to the management of international exchanges of goods and services between national and regional economies. It involves regulating imports and managing exports, including export promotion and export controls. The government

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[9] International Economics (2024)" Study on "How the Private Sector in Ethiopia Can Benefit from AfCFTA", Final Report; August 5, 2024 Submitted by International Economics: Strategic Analysis for Growth & Development

[10] The strategic pillars are (1) Ensure quality Growth, (2) Improve productivity and competitiveness, (3) Undertake institutional transformation, (4) Ensure private sector's leadership in the economy, (5) Ensure equitable participation of women and children, and (6) build a climate resilient green economy.

of Ethiopia has taken important policy changes since 1993. By the early 2000s, Ethiopia was moving away from the conventional market-oriented policy reforms and instead pursuing a developmental state approach. In addition, Ethiopia has taken concrete steps with regard to its accession to the WTO and submitted its application in 2003 and is a member of a number of continental and regional integration efforts. Since 2010, it has announced a Trade Policy, which was a step toward more liberalization of the market, considering regional integration in the Intra-Africa Trade and Ethiopia balances its goal of pursuing a trade policy that supports its long-term development objective with the goal of regional and global integration. The instruments of trade policy, such as tariffs, quotas, export subsidies, and voluntary export restraints, are tools put into practice by countries on a daily basis. Ethiopia's trade with Africa has also changed over time. Ethiopia's exports to Africa showed a slight increase from US$180 million in 2011 to US$184.7 million in 2015 and back to US$180 million in 2016. The ratio of exports to imports declined from 42% to 26%, indicating a deteriorating trade balance[11].

3.2. General Ethiopia's Export and Import Performance and Potentials in Africa

The share of Ethiopia's agricultural sector contribution to GDP continues to decline from its share of 45.7% in 2010 to 32.7% in 2020, largely because of the unprecedented expansion of the construction sector, which boosted the share of industry contribution from 14.8% to 29% in the same time period (The 10-year Development Plan document, 2021). The share of crops to GDP is close to 21%, of which oilseeds and pulses constitute 11.5% of crop value (NBE report, 2020. It was observed that, while Ethiopia's economy grew exponentially over the past 10 years, trade in goods did not grow at the same rate, remaining sluggish throughout the period, thus declining its share in GDP[12]. For the last 10 years, it consistently contributed to a lion's share of 74% of foreign currency. Regarding the agricultural commodities (Avocado, Soybean, and onion) production in Africa, the following table provides a summary that shows sparkling differences among the African peers. On Onion production, Ethiopia is not out of the ten top producers in Africa; 7th level for Soybean, and the 2nd in Avocado, next to Egypt, but the difference between them is enormous. Ethiopia produces less than 37% of what Egypt produces!

[11] AAU (2029): The African Continental Free Trade Area (AfCFTA): Opportunities and challenges for the Ethiopian private sector; Prepared by Addis Ababa University (AAU) Business Enterprises; submitted to: Ethiopian Chamber of Commerce and Sectoral Associations, May 2019

[12] Source: World Bank's World Development Indicators

Table 1: Top 10 countries that produce onion, Soybean, & Avocado in Africa

No	ONION	Quantity in Tones	No	SOYBEAN	Quantity in Metric Tones	No	AVOCADO	Quantity in Tones
1	Egypt	3,663,943	1	South Africa	2,755,000	1	Kenya	416,803
2	Algeria	1,763,118	2	Nigeria	1,180,000	2	Ethiopia	152,505
3	Sudan	1,591,709	3	Zambia	475,000	3	Malawi	93,872
4	Nigeria	1,554,966	4	Benin	295,000	4	South Africa	82,677
5	Niger	1,496,545	5	Ghana	215,000	5	Morocco	82,369
6	Morocco	802,389	6	Uganda	200,000	6	Cameroon	75,116
7	South Africa	678,544	7	Ethiopia	150,000	7	DRC	63,372
8	Senegal	420,000	8	Zimbabwe	75,000	8	Ivory Coast	35,993
9	Mozambique	409,742	9	Egypt	56,000	9	Madagascar	27,310
10	Cameroon	386,766	10	Tanzania	25,900	10		

Source: Onion, FAO, 2022; Soybean: ISSUE 7 of Milling Middle East & Africa Magazine Avocado: FAO, 2021

Ethiopia's exports are dominated by agricultural products with low value addition, whilst imports are dominated by capital, high-value-added goods necessary for domestic production. The structure of exports in 2020 is dominated by coffee (31.4%), sesamum seeds (14.3%), vegetables (10.2%), roses (6.6%), kidney beans (3.4%), and goat meat (2.4%)[46]. Reviewing the Ethiopian Exports in two of the quarters in 2023 and 2024 reveals some shifts in some of the export products. In 2023, total export proceeds declined by about 7.5% from $833.1 million in the first quarter (July-September 2023) to $770.7 million in the second quarter (October-December 2023). The following Table 1 shows the major export values, shares, and growth in the second quarter of 2023 relative to the first quarter of 2023.

Table 2: Ethiopia's Major Export Values, Share, and Growth (Q1 and Q2 in 2023) in Agricultural

S/N	Commodities	June-September 2023			October-December 2023		
		Value	Share	Percentage	Value	Share	Percentage
		USD	%	Change (%	USD	%	Change (%)
1	Coffee	355.1	42.62	(19.5)	218.4	28.3	(38.5)
2	Flower	112.1	13.46	(9.5)	113.5	14.7	1.2
3	Pulses	85.5	10.26	(8.4)	88.4	11.5	3.3
4	Gold	78.8	9.46	68.4	85.3	11.1	8.2
5	Chat	43.3	5.20	(0.7)	46.3	6	7
6	Oilseeds	31.6	3.79	(56.7)	78.4	10.2	148.1
7	Textile & T. Products	31.5	3.78	12.6	28.6	3.7	(9.3)
8	Fruit & Vegetables	17.6	2.11	5.0	18.7	2.4	5.9
9	Meat & Meet Products	13.6	1.63	(12.7)	15.3	2	12.4
10	Live Animals	8	0.96	85.2	10.5	1.4	31.8
11	Leather & L. Products	6.6	0.79	31.2	5.2	0.7	(20.6)
12	Others	19.9	2.39	(74.1)	26.7	3.46	46.2
	Total Exports	833.1		(15.8)	770.7		(7.5)

[46] Study on "How the Private Sector in Ethiopia Can Benefit from AfCFTA" Final Report by International Economics-Strategic Analysis for Growth & Development, August 5, 2024

Source: Macroeconomic Report of EEA, 2023

In 2024, the data on Ethiopia's top ten export products provides a valuable snapshot of the country's export. The data suggests that Ethiopia has a strong presence in the global market for coffee, oilseeds, and flowers.

Table 3: Top 10 Export Products (January-March 2024)

Rank	Commodities	Value (Million USD)	Share (%)
1	Coffee	245.6	31.5
2	Oilseeds	164.9	21.1
3	Flower	126.2	16.2
4	Pulses	79.4	10.2
5	Chat	49.3	6.4
6	Textile & Textile Products	31.3	4.0
7	Meat & Meet Products	19.9	2.5
8	Leather & Leather Products	16.2	2.1
9	Fruit & Vegetables	15.7	2.0
10	Live Animals	11.4	1.5

Source: Computed based on data in MOTRI (2024)

In summary, looking at the quarterly trend, there has been a shifting trend in the share of commodities. Though coffee remains the leading export commodity, its share declined during the review quarter. On the other hand, the share of several commodities has increased slightly. The share of total exports for oil seeds, chat, gold, and cut flowers increased in the review quarter.

Oil seeds witnessed the largest increment in the share of exports from 3.8% in the first quarter to 10.2% during the review quarter. Structurally, the composition of Ethiopian exports more or less remains unchanged, dominated by coffee, cut flowers, pulses, gold, oil seeds, and chat, accounting for about 82% of total exports in the review quarter. This demonstrates its heavy reliance on agriculture and primary commodities.

AfCFTA: Long- term Impact on Ethiopian GDP, Exports and Imports

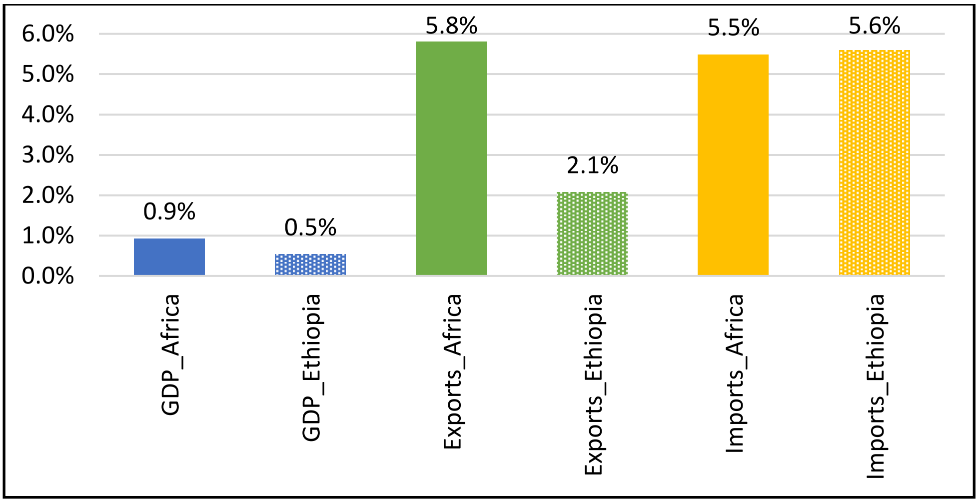

Figure 3: Change in GDP, Exports & Imports with AfCFTA (without AfCFTA) in % – 2045

Source: MOTRi (2024)

- % increases in GDP in all African countries, including Ethiopia;
- current Ethiopia's overall trade balance is largely negative,
- it is expected to substantially increase in 2045; even as Ethiopia's imports increase relatively more than Ethiopia's exports.

The AfCFTA represents an opportunity to transform the Ethiopian trade landscape. It is estimated that intra-African trade will increase by around USD 737 million in the East African region upon the full implementation of the AfCFTA, equivalent to a 13% rise in exports from the 2014 baseline. Ethiopia for its part can expect a 10% rise from the base year, representing more than USD 10.7 million in absolute terms. However, given that numerous non-tariff barriers exist between Ethiopia and many other African countries, trade liberalization under the AfCFTA itself may not be sufficient for increasing Ethiopia's volume of intra-African exports.

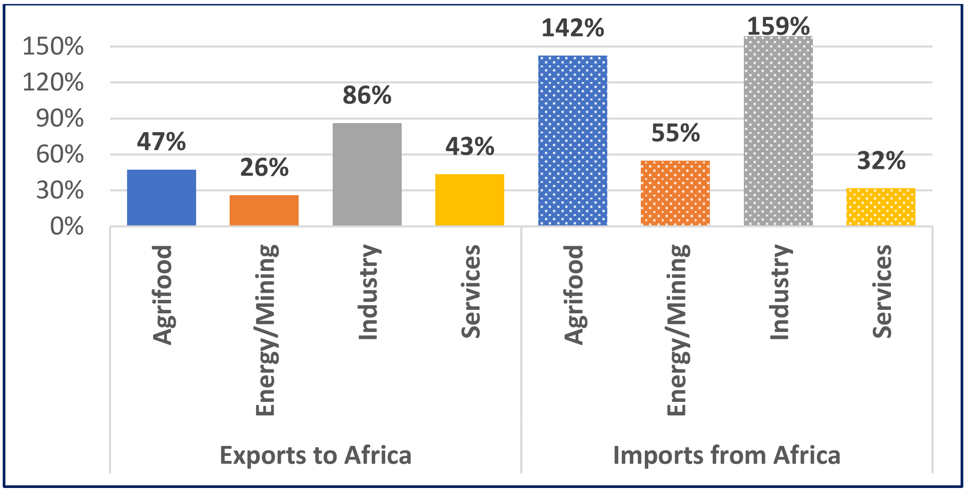

Figure 4: Change by main sectors, with AfCFTA (without AfCFTA) – % – 2045)

Source: MOTRi (2024)

- ➢ All sectors in Ethiopia will considerably benefit,
- ➢ Industry to benefit the most in relative terms (in energy/mining: exports driven by electricity and mining products)
- ➢ Ethiopia's exports to & imports from the rest of Africa in "Textile, clothing and leather" (combined) will increase by 111% and 271%, respectively.

Opportunities and Benefits from AfCFTA: Ethiopia's Engagement in its Comparative Advantages in Agricultural Products

Distribution of absolute gains in Ethiopia's trade with Africa following

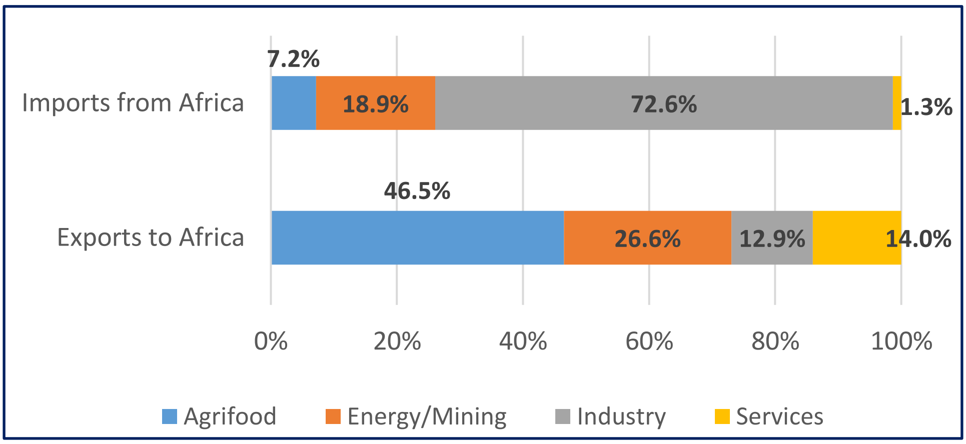

Figure 5: AfCFTA implementation as compared to baseline (i.e. without AfCFTA) – By main sectors – % – 2045

- In absolute terms, most of Ethiopia's gains in exports would be in agriculture and gains in imports would be in industry;
- Ethiopia's trade with Africa is currently largely based on agrifood (major exports of vegetables, fruit, nuts and livestock; some imports of processed food); Agrifood is still expected to dominate Ethiopia's trade with Africa following AfCFTA, but the share of industry will become sizeable.

4. Challenges Facing the AfCFTA and Ethiopian Traders

4.1. Macro Level Challenges

One of the major hurdles facing the AfCFTA is the issue of distrust, which has deep historical roots stemming from colonialism and the subsequent exploitation of African economies. The legacy of disrupted trade networks and imposed economic systems has led to a pervasive lack of trust amongst African nations.

Another challenge lies in the non-innovative nature of Africa's private sector, particularly its Micro, Small, and Medium Enterprises (MSMEs). Hindered by limited access to finance and a focus on survival rather than innovation, African businesses struggle to compete on a global scale. To address this, there must be a shift towards fostering innovation and value addition within the private sector, drawing inspiration from successful models such as Germany's MSME-driven economy.

Furthermore, the overlapping memberships across African Regional Economic Communities (RECs) create inconsistencies and hinder the integration process. Resolving these conflicts and streamlining regional cooperation is essential for the success of the AfCFTA. Additionally, informal trade, characterized by undocumented cross-border transactions, poses a challenge to formalizing intra-Africa trade and realizing its full potential.

Infrastructure deficiencies, inadequate transportation networks, and border facilities further impede the implementation of the AfCFTA. Addressing these shortcomings requires significant investment in infrastructure development, which remains a critical priority for the continent. Moreover, the over-reliance on external partners for support and funding raises concerns about sustainability and the alignment of interests.

Labor standards and climate change present additional challenges, highlighting the need for comprehensive policies that address social inequalities and environmental sustainability. Fragility within Africa's RECs further complicates the integration process, requiring concerted efforts to foster stability and cooperation amongst member states.

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Regarding the challenges/obstacles with the Trade in Good Protocol, a recent assessment report of AfCFTA to intra-African trade as reported by businesses trade obstacles linked to NTMs imposed by partner countries in Africa mostly related to SPS/TBT as well as Rules of Origin shows that:

- ➢ Export-related measures: Regulations imposed by the home country (of exporters) on exports (56%)
- ➢ Import-related measures: Regulations of importing African countries that businesses find burdensome (44%)
- ➢ Access to Information: One 3rd of trade costs comes from lack of information and regulation divergence

Ethiopia's exports are dominated by agricultural products with low-value addition, whilst imports are dominated by capital, high value-added goods necessary for domestic production, with Asia and Europe as the main destinations for Ethiopian exports. Ethiopia's trade profile bears certain similarities to that of its African peers, especially when it comes to intra-regional trade, which is considerably low, with Ethiopia's trading partners in Africa being quite limited.

4.2. Business Level Challenges

On Developing Trade Guide and Strategy for recent Trade Agreement of AfCFTA for exporting agricultural Products, particularly Avocado, Soybeans and Onion, Kilimanjaro Global Consulting, Training and Innovation team has consulted more than 150 individuals selected from producers, processors, exporters and other ECCSA'S internal and external stakeholders directly and indirectly operating in the business ecosystem. In order to implement the AfCFTA agreement effectively, it has become critical to assess the agricultural commodities producers, processors and exporters' value chain and identify their practical challenges, opportunities and look into their potential. The detailed challenges and potential suggestions are summarized in matrix form (See Annex 1 for more details). Based on the assessment made, the major problems of producers to produce at large scale and increase productivities include: shortage of inputs such as fertilizer, quality selected seeds, pesticide, and forced to buy at inflated price, lack of training and close supervision by agricultural experts, farming land for those willing to expand their farm, credit facility through banking system, and market chain related problems.

Nevertheless, there are some peculiarities or differences observed in the challenges for Avocado, Soybean, and Onion value chains faced as well. Comparatively speaking, the majority of Avocado and Onion producers mentioned that they have faced challenges in terms of being unable to produce and meet the quality of products and a sustainable supply to the market. Lack of proper packaging and labeling materials, poor logistics and transportation in supply chains, and infrastructure problems are highly affected in these areas. On the other hand, the majority of respondents Soybean products are mainly challenging in unfair product price and illegally fixed the price, quality and quantity of the products by the trade unions or associations.

The Ethiopian government's primary responsibility and fundamental role is to make a sustainable peace for the country as a whole and ensuring the rule of law and secure the peace and create a conducive business environment for smooth -effective business operation in the country. Thus, the Ethiopian Government should focus on the current peace and security-related problems and come up with peaceful solutions to the political problems.

Majority of Avocado and Onion producers are challenging differently from Soybean producers, processors, and exporters. Avocado and Onion producers are struggling to produce quality products and a sustainable supply. Selecting quality seeds and preparing land to produce quality products are one of the major challenges in this specific value chain. On side of exporters the major problems identified from their feedback include, among others include shortage of exportable quality product, tedious bureaucratic chain to pass and export, credit facility (financial problem), limited exposure and experience sharing from other countries, inadequate information on AfCFTA, exporters are not sure on harmonization of Customs and Standards to participate and fetch the benefit available from AfCFTA agreement.

Nevertheless, there is a peculiar suggested solution in Avocado Processors and Exporters, who stated that certified and standardized packaging and labeling materials should be free from customs and provide incentives for potential investors to invest in packaging and labeling products to be produced locally. In light of the limitations identified and the suggested solutions, the following are recommended as future policy makers and research subjects.

- The association and the private sector actors along the development partners should factors in relation to Ethiopian current peace and security problems and associated challenges to the agriculture and related business communities;
- The association needs to closely work the government authorities to address the critical challenges the business communities have faced in the areas of Ethiopia's poor market supply and shortages of the agricultural and industrial inputs;
- Both the ECCSA and the government should plan for extensive internal and external capacity building and institutional alignment and harmonization interventions;
- ECCSA needs to advocate for the establishment of large agglomeration enterprise that could solve or minimize logistics and operations, the need of large warehousing and shipping related challenges for large scale export in the Intra-Africa-Trade.

4.3. Overall Summary Results from Women-Owned Business Groups

The Participation of the private sector actors: Regional Chambers, Logistics and other Associations, Women Business Owners Coalition, and SMEs Groups have provided their perspectives on AfCFTA agreement, its challenges and prospects:

The Center for Accelerated Women's Economic Empowerment (CAWEE) has been a trailblazer in promoting women exporters involved in Small & Medium Enterprises (SMEs) since its inception in 2004. It has been actively engaged in the awareness creation, sensitization and providing international trade training, Business Development Services (BDS), market linkages, and advocacy. CAWEE plays a crucial role in empowering women entrepreneurs in Ethiopia and beyond, expanding their businesses in Africa's growing market. The small and medium-sized enterprises (SMEs) form the backbone of the African economy, representing more than 90% of businesses and employing about 60% of workers, many of whom are women and youth (International Trade Centre 2018, p ix). Considering the opportunities presented by the African Continental Free Trade Area (AfCFTA), CAWEE participated in the last three Inter-Africa Trade Fairs, which were held twice in Cairo, Egypt and Durban, South Africa and took part with quite a number of women Exporters from Ethiopia, which is a practical inter-Africa trade experience worth mentioning. The Assessment on the Women-led business and their challenges in the Intra-Africa Trade include:

- Information and Networks: Limited access to market information and business networks restricts women's ability to compete in larger markets.
- Access to Finance: Women entrepreneurs face significant barriers in accessing credit and financial services due to lack of collateral and discriminatory lending practices.
- Operational Costs: Higher operational costs for women-owned businesses due to smaller scale operations and less access to economies of scale.
- Informal Sector Dominance: Around 70% of women in Africa are engaged in the informal sector, which is often characterized by low pay, poor working conditions, and limited growth opportunities.
- Legal and Regulatory Barriers: Gender-biased laws and practices that limit women's ability to own property, enter into contracts, and enforce rights.

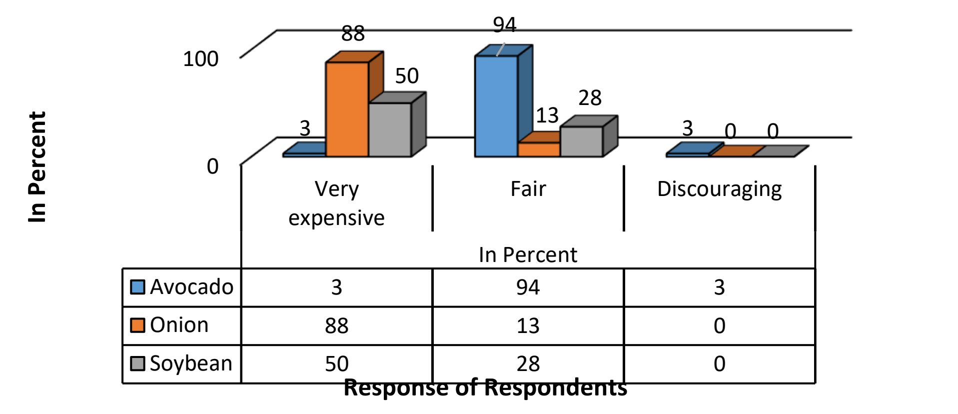
5. Quantitative Data Analysis and Survey Results

The survey conducted on 61 producers or farmers who are willing to participate on this research focusing on Onion, Soybeans and Avocado Producers. Out of this small in number who participated were Onion producers which account only eight (13.1%). On the second level were Soybean producers which account 18 (29.5%) and the largest share taken by Avocado producers which accounts 35 (57.4%).

5.1. The price of inputs in relation to the price of product

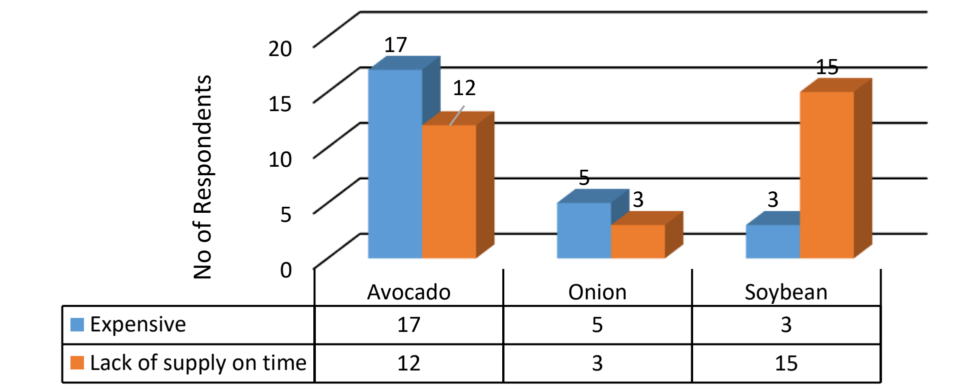
Out of 61 Respondents, 57 of them have responded to this query. From the total respondents, 35 of them are Avocado producers and 94% of them responded that the price of the inputs relative to the product price is fair. 88% and 50% of onion and soybeans producers responded that the price of inputs are very high, respectively. Their responses are closer to reality since one Avocado tree planted the need of inputs such as fertilizer, pesticide, and the like are limited relative to seasonal products such as Onion & Soybeans.

Chart 2: Price of Inputs relative to Product Price



5.2. Farming Problems

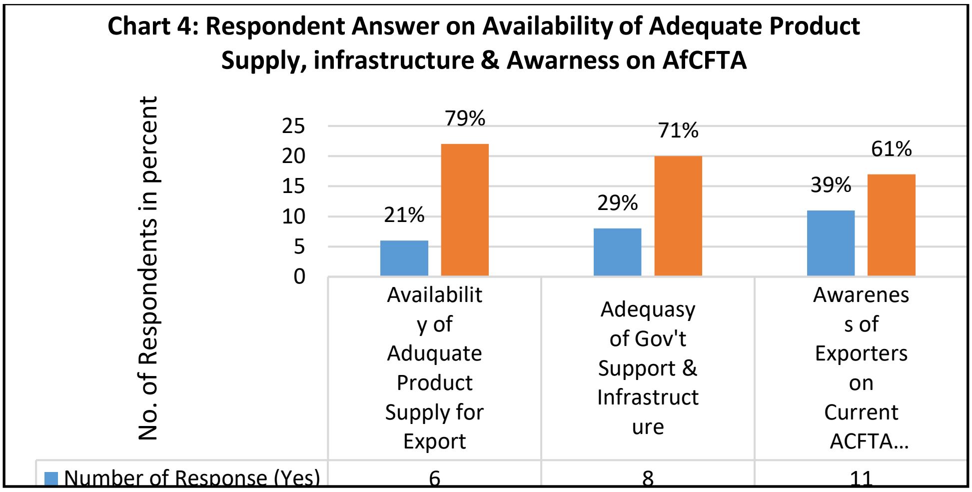
Chart 3: Reasons if you didn't use sufficient amount of pesticides or fertilizer or selected seeds



Out of 61 Respondent 57 of them responded for this question. These respondent for not using sufficient number of inputs such as quality selected seeds, fertilizer, pesticides, chemicals, etc., 30 (52%) of them says because of lack of supply on time. Specially, it is true that seasonal products such as Soybeans need input on time. The response for securing inputs such as selected seeds, pesticides and fertilizer on time, 90% of the respondents not affirmative.

5.3. Product Supply, Adequate Government Support & Awareness

On the Exporters' side, there is a willingness to expand their export business. However, the respondents' results show that 79% of them are not sure of the availability of adequate product supply. 71% of them also complain on the Government having support and facilitating infrastructure. Even 61% of the respondents were not aware of the current agreement ratified by the government to join AfCFTA (Chart 4).



6. National Standards and Regulatory Requirement-Procedures

In order to export and Import products or exchange products with each other, harmonization of standards or having governing standards that all African countries implement are inevitable. It is clear that any exporter has minimum requirements that need to fulfil. In order to know whether all respondents have common basic requirements for export, this question raised for all 28 exporters and responded as stated below missed mentioning capital except one respondent.

Exporters Response for basic requirements needed to Export Agricultural Products stated below.

Table 4: Exporters Responses on Basic Minimum Requirements for Exporters from Ethiopia

No	Regulatory Requirements	Number of Respondents
1	Business License	28
2	TIN Number	28
3	Capital	27
4	Standard Certificate	28
5	Rule of Origin Certificate	28

6	Ethiopian Customs clearance certificate	28

It is important to include the pertinent government regulatory authorities that will be expected to engage in the AfCFTA implementation (see Annex 1 for the details).

6.1. General Standards and Specific Regulatory Requirements-Procedures

This section provides the general regulatory and other business requirements that the agricultural producers, processors and exporters should fulfill when they decide to engage in the Intra-Africa Trade include the following:

- Since most exporters are corporate business companies, they are expected to secure export business licenses and taxpayer identification number (TIN) certificate from the Federal Ministry of Trade and Regional Integration (MOTRI), while individual exporters to secure these from regional;
- To ensure their business is sustained, all business actors are required to settle their income taxes and/or dividend taxes at the end of each year and comply with other regulatory requirements like timely clearance and renewal;
- The exporters are expected to ensure compliance with product standards, specifications and certifications, including Sanitary and Phytosanitary certification and quality standards set for export, following harmonized AfCFTA requirements like branding, packaging, and labeling;
- Obtain certificates of origin from ECCSA for COMESA, which is non-preferential while other certificates of origin from the Ethiopian Customs Commission (NB: for AfCFTA there should be a competent designated authority as per the AfCFTA requirements but not yet determined by the Ethiopian law. It is not yet finalized);
- Obtain customs declarations and commercial invoices, or any other documentation; customs clearance and products have HS codes; Establish trade logistics and payment mechanisms.

In a nutshell, the procedural process that exporters and importers are required to complete includes:

- Bill of Loading; Commercial Invoices for the buying/purchasing and Airway Bills for Air transport
- Packing lists/ standard packaging based on the product type requirements
- Products in the security & safety categories, INSA & related Security

Certifications are needed

- For Medicine categories, Certification from the Ethiopian Pharmaceutical Authority is required
- Some Narcotic agricultural commodities, like GESHO, require Sanitary and Phytosanitary (SPS) Certification from the Agricultural Regulatory Authority
- Letter of Credit used to be applied before the Macroeconomic Reform. The change to Market-based Floating Exchange Rate allowed Franco Valutta, whereby importers and exporters can use their own foreign currency without a banking channel. However, the MoF has recently announced the suspension of Franco Valuta for importing goods, effective from early November 2024.

6.2. Specific National Regulatory Requirements and Standards

A) Ethiopia Standard Institute (EST) Regulatory Requirements & Standards for alignment under the AfCFTA

(Selected Potential Destination Country Markets for the Ethiopian Agricultural Commodities: Avocado, Soybean and Onion)

Table 5: Information on Harmonization of Ethiopian Regulatory Standards for Avocado, Soybean and Onions with the Regional and Sub-regional NSBs

Agricultural Products	Standard Requirements					Technical Regulations (TR)
	Ethiopia Standard Institute (ESI)	African Standards (ARS)	East African Standards (EAS)	National Standards Body Other NSB	Codex Alimentarius (CODEX)	
Avocado	Compulsory Ethiopian standards (CES) 193	Type of Avocado, General and specific requirements, provision on concerning quality, classification, food safety concerns, and Harvest issues are addressed.	Refer Draft Ugandan Standards (DUS) Draft East African Standards (DEAS) 19	South Africa Bureau of Standards (SABS) Grading, packing and marking of avocados intended for sale, sizing, tolerance, and sample of the consignment, inspection methods, offence and penalties, permissible deviations by number, permissible cultivars, mass range and size code, quality factors maximum defects allowed. DUS/ DEAS 19 Adopted from EAS	Minimum requirements, classification, size, tolerance, provisions concerning presentation, marking or labeling, identification, contaminants, hygiene	SABS
Soyabean	CES 244	General and specific requirements, Contaminants (heavy metals and pesticides	DEAS 824: 2024 Soybean seed Requirements for certification.	SABS act No. R. 478		

		limits), hygiene, packaging, labeling and sampling requirements are included in the standards.	DEAS 762:2024 Standard specifies requirements, sampling and test methods for dry soybeans of varieties (cultivars) grown from Glycine max (L.) Merr. Intended for human consumption. The sampling techniques are based on EAS 900. The contents are similar with the ARS.		
Onions	CES 93				Minimum requirements, Classification, Provisions, concerning size, tolerance, presentation, Marking and labeling, additives contaminates and hygiene requirements are included.
Important links,					
1	African Trade Web portal		https://trade.arso-oran.org/search-results/RW/00804.4		
2	Eping		https://www.epingalert.org/		
3	Ethiopian Standards Institute (ESI)		https://www.ethiostandards.org/home		
4	WTO TBT agreement series		tbttotrade_e.pdf (wto.org)		

B) The Ethiopian Customs Commission Regulatory Requirements Guide

The guide provides practical guidance on Ethiopia's experiences, Customs and Tax, among others.

Ethiopia – Customs and Tax: Ethiopia applies customs duties and two taxes on imports.

1. **Customs duties – range** from 0 to 35% under six bands - 0, 5, 10, 20, 30, 35. There are currently no export duties.
2. **Sur-tax – uniform 10%** applied on most commercial imports. fertilizers, petroleum and lubricants; motor vehicles for freight and passengers, and special purpose motor vehicles; aircraft, spacecraft, and parts, Capital (Investment) goods.

Social welfare levy – is levied at 3% on products exempt from Sur-tax. This tax was introduced in August 2022

Ethiopia – Domestic Taxes: Three domestic taxes applied

1. **Value Added Tax (VAT)** – is charged on the supply of goods (and services), including imports, at a rate of 15%.
2. **Excise Tax** – ranging from 5 to 500%. Rates of more than 100% are applied to used vehicle imports.
3. **Withholding Tax** – advance payment of 3% on business income tax. This amount is to be deducted from the importer's business income tax.
4. Ethiopia provides a 10% reduction on applied tariff rates to COMESA imports.

The then Ethiopian Revenues and Customs Authority/ ERCA, March 2017 Ethiopian Customs Commission's Customs Guide, Step by Step Procedures on Export from Ethiopia, are summarized below:

How to Export Goods from Ethiopia

The procedure for exporting commercial goods from Ethiopia mirrors the one for importing, and this section provides an overview (a summary of the steps in Figure 2 as per the ERCA 2017 Ethiopia Customs Guideline). In line with the AfCFTA agreement and requirements, alignment and harmonization should be considered.

How to export goods from Ethiopia - summary of steps

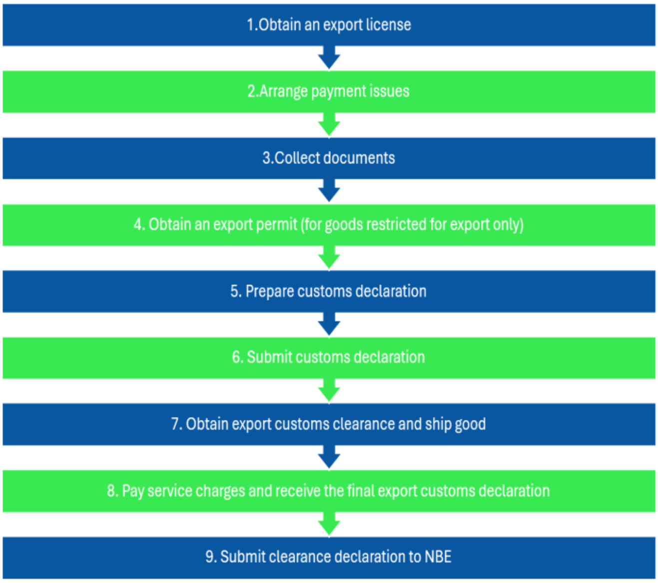


Figure 6: EXPORT Customs Guide

Source: Ethiopian Customs Commission (ECC)

How to import goods into Ethiopia – summary of steps

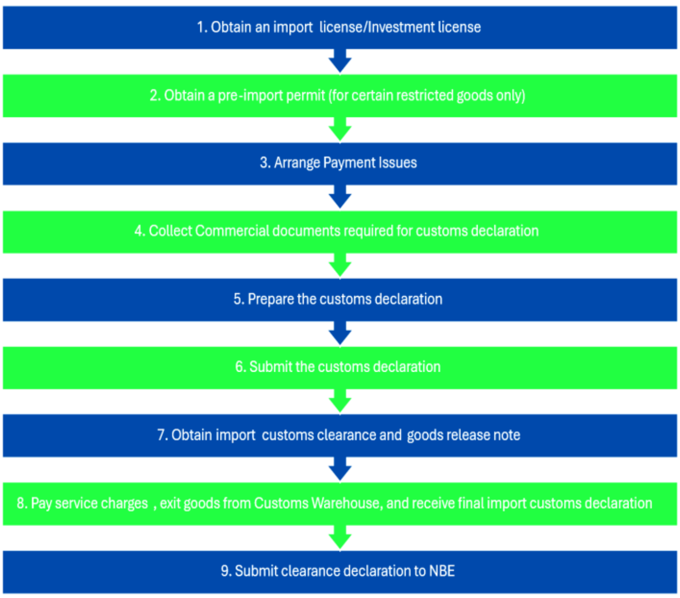


Figure 7: Import Customs Guide:

Source: Ethiopian Customs Commission

C) CBE Financial Payment Procedures and Mechanism

The summarized requirements for export business under CBE financial payment procedures and Mechanisms are:

Box 1: CBE Financial Payment Procedures and Mechanism

1. The exporter shall get an export permit before export of the good.
2. The acceptable Mode of Payments for export of goods shall include LC at sight and on acceptance; Cash Against Document (CAD) at sight and on acceptance; Advance payments (via bank transfers, debit/credit cards, or cash notes declared at customs) valid only for one year; and consignment sales.
3. Banks bear the responsibility for ensuring that export proceeds for all export permits approved are repatriated into the country within 90 days.
4. Exports of chat, livestock, and injera are only permitted with L/C and Advance mode of payments.
5. Exports to Sudan and to Somalia are only permitted with L/C or Advance mode of payments.
6. Exports to Somalia and Djibouti can be affected through advance payments via a money transfer service company authorized by NBE. In cases of such advance payments for exports, this should mention the purpose of the advance as being for future export payment and the type of commodity

D) Certificate of Origin

BOX 2: Issuance of Certificate of Origin for Intra-Africa Trade

Overall, in Ethiopia there are two kinds of certificate of origin: preferential and non – preferential. These two types of certificates of origins given by the governmental organization and ECCSA:

1. **Preferential Certificate of Origin:** This certificate is used to claim reduced or zero tariffs under free trade agreements. It certifies that the goods meet specific criteria to qualify for preferential treatment. Currently this is issued by ECC.
2. **Non-Preferential Certificate of Origin:** This type certifies shows the origin of goods but does not provide any special tariff benefits. It is often required for customs purposes to prove the country of origin. Currently ECCSA issues Non-Preferential Certificate of Origin under COMESA.

E) ECCSA's requirements and procedures in issuing Certificate of Origin for Agricultural and/or Manufacturing products originated from Ethiopia under COMESA

1. *Providing Information and Guidance*
   - Offers application forms and explains the process for obtaining the certificate
   - Provide guidance on the COMESA Rules of Origin for different types of goods.
2. *Application and Document Review:*
   - Receive the completed application form and all supporting documents.
   - Meticulously review the application for completeness and accuracy.
   - Thoroughly examine the documents to verify the claimed origin of goods. This might involve contacting the exporter for further clarification or additional information if needed.
3. *Verification and Compliance Check:* Trade Facilitation Division verifies that the goods comply with the COMESA Rules of Origin. This may involve checking minimum processing requirements or the percentage of regional content.
4. *Issuing the Certificate:* Once everything is verified and meets COMESA requirements, the trade facilitation expert will issue the official COMESA Certificate of Origin.

Box 3: Exporter Requirements: To obtain the manual COMESA Certificate of Origin, the exporter, need to fulfill:

1. **Eligibility Confirmation:** Ensure the export involves goods moving between COMESA member states
2. **Understanding COMESA Rules of Origin:** Familiarize themself with the criteria that define whether their goods qualify as originating from a COMESA member state.
3. **Application and Documentation Preparation:**
   - 3.1. Obtain the application form from ECCSA.
   - 3.2. Pay service fee
   - 3.3. Complete the application accurately, including details about the exporter, the importer, the goods being exported (description, quantity, value), and relevant HS codes.
4. Gather supporting documents that demonstrate the origin of the exporting goods. This may include invoices, bills of lading, production records, or any other documents specified by the designated authority.

5. Submission of Application and Documents: Submit the completed application form and all supporting documents to trade facilitation division for review.
6. Awaiting Issuance: Trade facilitation division will assess the application and documents. If everything is in order and the goods comply with COMESA origin rules, issue the manual COMESA Certificate of Origin

6.3. Expectations from the Government and Private Sector's Umbrella Organizations

All exporters participating in this assessment mentioned 16 problem areas Government and the private sector umbrella organizations, like ECCSA to solve in order to have a successful export business.

Table 6: Major Areas of Problems Repeatedly Cited by The Respondents that Need Attention

No	Major Problem Areas	Percentage of respondents mentioned each point
1	Inability to solve corruption and bureaucracy	75
2	Long stretched documentation process	89.3
3	Inflated custom prices	85.7
4	Unaligned standards with other African countries	67.9
5	Lack of awareness and sensitization on AfCFTA	92.9
6	Inability of fulfilling the standards/ customer demand	89.3
7	Lack of sustainable Supply of Exportable Products	89.3
8	Access to adequate land size (Farm Land Problem)	60.7
9	Inadequate infrastructures including capacity problems	89.3
10	Slow domestication of the Trade Agreement to local contexts	96.4
11	Poor Market linkages	89.3
12	Lacks Foreign Exchange	64.3
13	Facilitate Access to Finance	28.6
14	Continued instability and security challenges	82.1
15	Inadequate supports to the exporters from the government and ECCSA	92.9
16	Information sharing gaps	96.4

7. Major Discussions from Qualitative assessment

The various stakeholders' discussions, information and data collected and analyzed above and the key informants and online discussion findings show that:

With respect to the regulatory requirements that exporters are expected to fulfill some special requirements to actively engage in the African Intra-AFRIC-Trade, some of the government ministries, authorities and commission representatives clearly stated that

> *"…. there is no special requirement that the exporters will be expected to fulfill in engaging in the intra-Africa trade, which is different from the existing requirements. …but it is crucial here that they have to fulfil the AfCFTA Rule of Origin and a Certificate of Origin in the AfCFTA, which is issued by a mandated and/or designated authority in Ethiopia. The government is working on this process aspect to designate the appropriate authority for the same..." (KII)*

"….Generally, exporters are required to have

- *Export licenses*
- *Trade documentation such as Bank permit, Invoices, Packaging lists, Insurance document, Transport document, Quality and product standard documents, and*
- *AfCFTA Certificate of Origin issued by the designated competent authority…However, honestly speaking, there is no legally designated competent authority to handle the AfCFTA Rule of Origin in Ethiopia. As a result, origin verification will be a serious problem…" (KII)*

"….Exporters from Ethiopia are expected to have a Certificate of Origin for each product that they are planning to export. To get a Certificate of Origin. Potential exporters from Ethiopia are expected to complete the following:

- *Submit the application by completing the AfCFTA Certificate of Origin Form*
- *Proof of production process (including the content of and composition of each material used in the production process)*
- *Products covered under the AfCFTA Trade in Goods Protocol - The Origin Rules in the Annex document …." (KII)*

"…there is no special requirement that the exporters will be expected to fulfill in engaging in the intra-Africa trade, which is different from the existing requirements. …but it is crucial here that they have to fulfil the AfCFTA Rule of Origin and a Certificate of Origin in the AfCFTA, which is issued by a mandated and/or designated authority in Ethiopia. The government is working on this process aspect to designate the appropriate authority for the same..." (KII)

Most government representatives interviewed have concerns and fears over:

- The potential loss of revenue due to the tariff exemptions as a result of the AfCFTA
- Since most Ethiopian companies have not exposed to strong competition so far, they may lose growth to other African companies in the sort run period
- The lack of technical skill in the implementation of AfCFTA, which will be an area that both the state parties and ECCSA should focus to work together
- damping of used and counterfeit commodities into the country if we are not prepared well
- importation of non-African origin goods by forged certificate of origin

On the areas of awareness and sensitization of the AfCFTA: The ECCSA has conducted a very limited orientation to the business communities which is inadequate compared to the magnitude of the tasks involved to bring the private sector actors and business communities on board on the AfCFTA Implementation. The actual agricultural commodities producers, processors and exporters interviewed mentioned that they are not aware of the AfCFTA, its benefits and what are required from them to effectively engage in the AfCFTA implementation. Some of the ECCSA and regional Chambers team members clearly mentioned the challenges they are in, among others;

> *".... Let alone to provide adequate information to the business communities about AfCFTA implementation and the required details supports, we are not clearly understood what the stake are, what we are required for, what we should do..." (KII)*
>
> *"... the Ethiopian Chamber has provided orientation and/or training not more than 200 participants so far…With such very limited engagement of the business communities and their representatives in the ECCSA's limited interventions, how could we bring inclusivity of the direct beneficiaries to know their obligations and rights?" (KII)*

Despite some efforts made by the MOTRi to provide an initial discussion and orientation training to the selected regional government representatives in selected regions, the representatives from the regional chapters have not received no other major continued awareness-raising training, sessions, and experience-sharing participation on the required alignment-harmonization of government regulatory requirements, along with the changes that have been made so far. These need to be communicated down from the top level with full transparency.

Coordination and Partnership with the pertinent government bodies: Almost all the respondents mentioned that there is weak coordination and communication with the ECCSA and its regional Chambers, ECCSA and its members, ECCSA and the other pertinent government ministries, and also the coordination within the government ministries and authorities dealing with the AfCFTA related issues needs to be institutionalized. There is no adequate mechanism and system to share the existing current information on the AfCFTA, the possible changes that the government regulatory authorities have made so far. It looks there is fragmentation that requires a strong National AfCFTA Coordination Office for Ethiopia that can handle the day-to-day issues of AFCFTA. Most respondents cited that the realization of the AfCFTA agreement is not something that can be handled by the National Technical Committee mechanism alone, given inadequate inter-governmental as well as private-public closely working practices. We need to get a lesson from the other African countries. There is also a need to establish the National Inquiry Point (NIP) in Ethiopia.

> *"... there is a need to establish a legal framework that ECCSA to push for the establishment of the National Inquiry Point under the AfCFTA agreement..." (KII)*

ECCSA's Internal Capacity to provide the required Technical Support to the Business Communities in diverse areas: Most respondents have the view that ECCSA lacks the required human resources both in quality and quantity; and technological infrastructure to provide adequate technical and trade facilitation supports to the business communities and also to the government.

> *"... Although the Ethiopian Chamber has its own multistory building that the other African countries Chambers do not have, we have more than 50 permanent staff at ECCSA. But it is true we should have good numbers of experts/specialists in trade and regional integration, E-Commerce etc. to provide adequate required supports to the business communities and to the government in the AFCFTA implementation..." (KII)*

> *"... the Ethiopian Chamber need to work closely with the Institute of Ethiopian Standard (IES) that is working closely with the African Regional Standard Organization (ARSO) which has been integrating the national agricultural products standards requirements from each African country. This collaboration will help for the ECCSA to organize valuable trainings for the stakeholders in the agricultural value chains…and also make close monitoring on the portal..." (KII)*

ECCSA Policy Advocacy and Engagement with the Government: Almost all the interviewed regional chamber respondents mentioned that there is weak coordination and communication between the ECCSA and its regional Chambers, ECCSA and its member companies

> *"... the Ethiopian Chamber has provided orientation and/or training to not more than 200 participants so far...and there should be a continuous and more organized all-inclusive training, capacity building, and experience sharing events…." (KII)*

ECCSA's Membership should be mandatory like the other African countries: Most respondents mentioned that the Ethiopian Chamber's experience during the Imperial Haileselassie Regime was the "Golden Age of the Chamber", among others, for its high support from Emperor and its independence from government interventions and its mandatory membership approach. Some of the respondents stated that making a mandatory ECCSA's membership starting from the issuance of a business license will make the Chamber more powerful and able to enhance its capacity not only with financial resources but also with its constituents.

> *"... the ECCSA and MOTRI database need to be integrated so that the Chamber will have a broader reach of the business communities and better share information and provide the required technical assistance and capacity building activities, including training on the AfCFTA and other diverse business areas…. After all, ECCSA is under MOTRI in its structure..." (KII).*

ECCSA's Collaboration and Partnership with the Pertinent Government Ministries: The close working relationship ECCSA has with the MOTRI and MOI has to be further strengthened. Moreover, following the Ethiopian Foreign Affairs Economic Diplomacy principle, the Ethiopian Embassies in African countries should be one of the key areas the ECCSA should leverage to enhance the Ethiopian export destination markets for its products. For example, the Economic experts (attached in the respective embassy) should actively engage and plan milestones to be accomplished annually to effectively implement AfCFTA. The contact addresses of all the Ethiopian Embassies in Africa should be in the ECCSA Trade Strategy and Guide document, which might need signing an MOU with the Ethiopian Ministry of Foreign Affairs (MOFA).

ECCSA needs to closely work with other platforms like Women and Youth-led businesses, SMEs, existing producers' associations/unions, and help farmers, for example, to be organized in different forms: Associations and Unions, and get a business license, which is a requirement to be a member of the Chamber and get adequate attentions and supports in the implementation of AfCFTA. ECCSA needs to address the weak coordination and communication problems that exist between the ECCSA and its regional Chambers, ECCSA and its members, ECCSA.

Despite the challenges, the Ethiopian exporters will have immense opportunities to leverage from the bigger market created, increasing productivity and production with additional investment and diversifying new technologies to cope with and win the new level of competition, resort to large-scale commercial farming and utilize the new subsequent agricultural policy supports from the government.

8. Major Challenges, Opportunities and Strategic Options

8.1. Major Challenges related to Ethiopia's Structural Problems in Trade in Goods

The main challenges that the Ethiopian chambers, the private sector actors in general and the agricultural goods value chain actors: Producers, Processors and Exporters are facing in the opening of the regional market in Africa are provided in a summary matrix Annex VI. When we examine the challenges and barriers that the opening of the regional market would have to those agricultural goods in general and under onion, avocado, and soybean value chains in particular, it is important to look into these challenges at different levels:

Table 7: Major Challenges for the Ethiopian Agricultural Products Value Chains (Macro Level)

S/N	Higher Macro-Level Main Challenges	Suggested Actions & Solutions
1	The issue of distrust, which has deep historical roots stemming from colonialism and the subsequent exploitation of African economies	A Concerted effort to rebuild trust through collaborative initiatives and shared economic benefits
2	The non-innovative nature of Africa's private sector, particularly its Micro, Small, and Medium Enterprises (MSMEs)	A Shift towards fostering innovation and value addition within the private sector, drawing inspiration from successful models
3	The overlapping memberships across African Regional Economic Communities (RECs) create inconsistencies and hinder the Africa's integration process	Resolving the conflicts within the RECs and streamlining regional cooperation is essential for the success of the AfCFTA
4	Fragility within Africa's RECs further complicates the integration process,	Requiring concerted efforts to foster stability and cooperation amongst member states
5	Informal trade, characterized by undocumented cross-border transactions	Formalizing intra-Africa trade and realizing its full potential
6	Labor standards and climate change present additional challenges	Highlighting the need for comprehensive policies that address social inequalities and environmental sustainability

Table 8: Major Challenges for the Ethiopian Agricultural Products Value Chains at Meso-Micro levels, including MSMEs

S/N	Meso-Micro Level Main Challenges	Suggested Actions & Solutions
1	Primary goods with low-value addition of export and import dominated by high -value products	Make value -addition through processing products and diversification of agricultural export commodities
2	Information and Networks: Lack of updated & accurate information, awareness and exposure gaps in AfCFTA to meet quality standards There is little discussion and preparation on market access conditions that the country will observe when exporting to the rest of Africa Limited access to market information and business networks restricts women's and youth's ability to compete in larger markets	ECCA should invest in business intelligence and evidence-informed decision making, The private sector (as well as the public sector) needs to have a solid understanding of the details of the AfCFTA and its potential impact – both positive and adverse. ECCSA make information available and accessible to the agricultural commodities value chain actors in Avocado, Soybean & Onion Create experience sharing opportunities for the main actors in the value chains The agricultural commodities value chain actors in Avocado, Soybean & Onion need to develop their skills and experience to enhance quality of their products for exports by branding, packaging and leveling etc.
3	Access to Finance: MSMEs including women entrepreneurs face significant barriers in accessing credit and financial services due to lack of collateral and discriminatory lending practices. Limited access to financial resources/FOREX Challenge in accessing to working premises	Organize, link and engage the value chain actors with the available microfinance institutions The government authorities in the respective regions and localities to facilitate access to BDS including working premises The recent macroeconomic policy reform is expected to address some of the FOREX challenges in the future with additional policy measures

4	Potential revenue loss – Trade diversion - Increased foreign competition & Weak capacity of regulators can affect ability to regulate foreign businesses and competitiveness -strict foreign exchange regulations could make liberalization ineffectual	The agricultural commodities value chain actors in Avocado, Soybean & Onion need to be aware and prepared for the potential increase in competitions with the foreign traders in prices, quality and meeting other standards
5	Lack of institutional regulatory alignment-harmonization: Complex and costly formal trade procedures	Government institutions need to speed up the alignment and harmonization of their regulatory requirements, standard procedures and further fine tune to facilitate the Ethiopian value addition processing & export trade. For example, it requires to address Legal and Regulatory Barriers: Gender-biased laws and practices that limit women's ability to own property, enter contracts, and enforce rights Informal Sector Dominance: Around 70% of women in Africa are engaged in the informal sector, which is often characterized by low pay, poor working conditions, and limited growth opportunities Operational Costs: Higher operational costs for women-owned businesses due to smaller scale operations and less access to economies of scale which requires attentions from the government, development partners& ECCSA
6	Spread of corruption; Hostility towards small traders Physical & verbal harassment at cross-border points	Government should take its responsibilities seriously to bring and maintain peace and security; to solve political problems via dialogues
7	Access to ICT, Technical education and skills development Training	The government, ECCSA & other development partners to create access to digital technology Support the business communities to build ITC

		and other technical skills and experience Entrepreneurs and value chain actors need to adapt, ensuring that they have up to date knowledge, skills and practical experience with current issues including AfCFTA
8	Limited networking and establishing contacts with the Ethiopian Embassies-consular offices in African Lack of leveraging the Ethiopia's Economic Diplomacy at its embassies in African countries	ECCSA should enhance its trade promotion and market access potentials ECCSA to make formal agreement with the Ministry of Foreign Affairs (MOFA) to effectively utilize the Ethiopian Embassies in Africa Ethiopian agricultural commodities exporters to make efforts to access foreign markets through divers' channels including Ethiopian embassies abroad
9	Lack of genuine Public-Private Dialogues (PPD); Lack of clear mechanism for AfCFTA National Coordination Office to be responsible for day-to-day AfCFTA matters	ECCSA to enhance and create access for the companies to participate in continuous Public-Private Dialogues (PPDs) forums

8.2. Major Prospects-Opportunities for the Ethiopian Agricultural Value Chain Actors

When we explore potential opportunities in trading Ethiopian agricultural products under the AfCFTA in general and specifically to those under avocado, soybean and onion value chains, the African Continental Free Trade Area (AfCFTA) aims to create a single continental market for goods and services, with free movement of business persons and investments. It has immense opportunities and potential

Table 9: Major Prospects and Opportunities for the Ethiopian Agricultural Products Value Chains

S/ N	Opportunities and Potential Impacts of FCFTA	Opportunities for Ethiopian Agricultural Value Chain Actors: Avocado, Soybean and Onion
1	Expected to boost Intra-African trade by 52.3%.	Ethiopian agricultural commodities value chain actors shall have larger market size which encourage to boos agricultural productions and productivities to be competitive in the larger Africa markets
2	Potential to lift 30 million people out of extreme poverty by 2035	Ethiopian agricultural commodities value chain actors shall have larger market size which encourage to boos agricultural productions and productivities to be competitive in the larger Africa markets,
3	Projected to increase Africa's income by $450 billion by 2035	Ethiopian agricultural commodities value chain actors shall get the opportunity to trade more volumes of Avocado, Soybean and Onions within the Eastern Africa Communities and beyond which increase their business and income levels
4	Increase the continent's exports by $560 billion, with manufacturing accounting for $230 billion	Ethiopian agricultural commodities value chain actors shall transform their business with more value addition potentials vis diversification of products and processing technologies and technology transfers in the larger Africa markets
5	Increase labor, capital and goods mobilities within African countries	Ethiopian agricultural commodities value chain actors shall leverage the opportunities to acquire external exposures to the broader Africa markets with free movement of people, capital and goods under AfCFTA

In short, **the opportunities** for engaging and trading in agricultural commodities under AfCFTA include:

- Part of the Rule-based trading System
- The larger market size in Africa may encourage to increase diversification of the non-traditional agricultural products for exports like Soybean, Avocado, Onions and other agricultural products in Ethiopia
- An enlarged continental market provides incentives for inward foreign direct

investment (FDI). It also motivates domestic investment.

- The AfCFTA facilitates competitive interaction between Ethiopian and other firms in the African market,
- Better access to imported inputs and intermediary goods lowers the cost of innovation within Ethiopia,
- The AfCFTA can support economic diversification and a shift toward trade in manufactured goods,
- The AfCFTA creates a platform for cooperation and dialogue, including on infrastructure development, technology transfer, Innovation, Investment and conflict resolution
- Ethiopia – Djibouti preferential investment facilitation and property acquisition agreement
    - Ethiopia accorded National Treatment to Djiboutian investors and vice versa.
    - Exceptions: financial, broadcasting and press, areas closed for private investment
    - Newly opened investment areas will be accessible

9. Major Strategic Issues and Strategies for AfCFTA Implementation

9.1. Identification of Strategic Issues and Strategic Directions-Options

This AfCFTA Trade Strategy is designed to achieve the vision of the private sector and business communities in Ethiopia in capitalizing on the AfCFTA and leveraging the efforts of the country's Ten-Year Development Plan. The Intra-Africa export trade is governed by both National and International trade policies and strategies, trade governing rules, regulations and standards. As the pertinent State Parties (the National government authorities) has an overall mandate, role, and responsibilities toward effective implementation of trade under AfCFTA. The individual companies and firms also have a critical role to play as they are the main traders in the intra-African trade landscape. It is imperative to review the opportunities and benefits from AfCFTA in Ethiopia's engagement in its comparative advantages in agricultural products, assessing the overall challenges related to Ethiopia's structural problem in trade and related issues, and identifying major opportunities.

The following subsection highlights the summary of the situational analysis emanating from the internal and external environmental scanning that helps to iron out the major enablers and barriers from which the strategic options and strategic themes have been drawn for the pertinent private sector actors and Ethiopian government authorities to provide strategic leadership to the business communities to effectively implement AfCFTA.

Table 10: Major Enablers and Barriers Analysis with identified Strategic Options

Strategic Options	Enablers	Barriers
Institutionalization and domestication of AfCFTA in Ethiopia	• The Ethiopian Homegrown Economic Reform established based on market liberalizations which is the foundation of AfCFTA • Pertinent policy, strategy and enabling environment like the recent liberalization of the Telecom, Banking, Wholesaler-Retailers, Foreign Exchange Market etc. • The existing government structure and system which enable to establish country national steering committee; use the ECCSA and Other Business Membership Organization (BMO) structure and system to better align and harmonize AfCFTA share pertinent business information and intelligence • The government ministries and other agencies are willing to revise, align and harmonize the national regulatory mechanisms, procedures and standards to fit with AfCFTA requirements	• At present, the capacity of individual businesses to access information on regional and international markets is quite low, despite the advent of internet connectivity. • Sudden depreciation of the Ethiopia currency and high inflation effects in the short term • Growing Socio-Political Challenges (Internal Political & Social Conflicts, Violence and Social tensions)
Strengthen the Micro, Small, Medium	• Growing attentions and supports by the government and development partners to the	• Slow entrepreneurship development and BDS

Enterprises (MSMEs)	MSMEs to create and enhance entrepreneurial environment • The Establishment of the Ethiopian Business Advisory and Development Providers Association (EBASPA) Platforms	culture and practices in Ethiopia • Current BDS landscape is a barrier to MSME growth in Africa[47] • Lack of large- scale trading company that aggregates and exports goods from SMEs,
Increase productivity & production and ensuring high-quality agricultural products	• Increased government attention to agricultural sector • Growing and increasing expansion of Industrial Zones and Industrial parks • Regional Chambers engagement in supporting the lower-level producers, processors and exporters	• Maintaining quality of agricultural products has become a challenge • The political tensions and growing ethnic based conflicts affect domestic and cross boarder markets
Enhance trade promotion and allocation of National Budget for increasing demand for AfCFTA implementation	• The Ethiopian government ratified the AfCFTA and determination to join its African counterparts • The buy-in from leadership and engagement of the government authorities like MOFED, MoTRi is high	• Lake of proactive measures to enhance trade promotion and coordination • Slow engagement with the private sector to enhance AfCFTA
Strengthening the logistics, Supply Chain Management (SCM) to enhance export earning	• The existences of the key ministries and structures at different levels from producers to exporters • The launching of E-Commerce division in the Ethiopian Airline cargo facilities: E-commerce represents an important avenue to promote Ethiopian businesses in the African region.	• Inadequate harmonization and alignment, coordination and collaboration of the various stakeholders • Inadequate national resources to fill the wide gaps in the supply's requirements in the country

[47] AMI Case Study on Unlocking Africa's Entrepreneurial Ecosystem: The Case For Business Development Services Standards; africanmanagers.org/impactor

		• Lack of value addition in the Ethiopian Agricultural products and exportable
Technology and E-Commerce applications	• The Ethiopian Standard Institute (ESI) and the Africa Regional Standard Organization (ARSO) launched regional portals that support intra-Africa trade information exchange and E-commerce • The government E-Governance holds wide-ranging benefits to expediate the regulatory requirements and process in a timely way	• A significant portion of the population lacks the digital skills needed to use the internet. • Limited internet penetration in the rural part of the country • Lack of e-commerce infrastructure, including ICT infrastructure. • Absence of legal and regulatory framework for e-commerce(now WIP). • Inadequate customer' awareness of e-commerce
Individual and Institutional Capacity Building	• Potential for trainable work force to enhance the human capital of the country • There are capacity building efforts from both the government (mainly MoTRi) and the private sector membership associations (Mainly ECCSA) to create awareness and knowledge on AfCFTA • The formation of EBASPA and other entity like CAWEE have become active in providing capacity building supports for women exporters and youth Small & Medium Enterprises (SMEs). • The active engagement of the local universities to produce	• Limited highly skilled workforce to allow for further integration of Ethiopian firms into RVCs and for the provision of services to other African countries. • Limited budget/finance to conduct continuous capacity building interventions to maintain high educational standards • The capacity of individual businesses to access information on regional and international markets is quite low

	capable graduate to be engaged in business, Small, Medium and Large Enterprises (SMMEs)	• Lack of ensuring quality standards in the agricultural value chains • Inadequate formation of cooperatives and unions of producers, processors and exporters association to enhance local capacity • The capacity of individual businesses to access information on regional and international markets is quite low, despite the advent of internet connectivity
Collaboration, Partnership and Networking & Communications	• To achieve the overall objectives of AfCFTA, all relevant government, business, and development partners should effectively participate and contribute to the overall national AfCFTA implementation process. • The support of Multilateral and International organization on economic Ethiopia's liberalization programs and initiatives (IMF, WB, BMGF, Mastercard Foundation etc.) • Facilitate discussion between the public and private sector and establish/reinforce the platform for public-private dialogues • A potential to use the commercial attaches of Ethiopian embassies within African countries. (Suggested to Annex the contact address of all Ethiopian Embassies in Africa to	• Fragmented approach and lack of clarity in role and responsibility to bring the business communities toward a common vision • Absence of coordination mechanism • Inadequate inclusive platforms for all representative of key private sector actors • Lack of allocated budget for Coordination, Collaboration and Partnership Function

	the AfCFTA Trade Guide Document)	
Empower women enterprises to effectively engage in AfCFTA	• There are some donor's organization that have been financing Women Economic Empowerment (WEE) Initiatives which should be leveraged (USAID, BMGF, Mastercard Foundation, UNDP…)	• Absence of rural microfinance institution to finance Women owned businesses

9.2. Strategic Themes and Strategies

Strategy 1: Institutionalization and Domestication of AfCFTA

The AfCFTA implementation requires domestication and institutionalization of the AfCFTA in the government structure and system, including the private sector main actors like the ECCSA and its regional structures. The goal of the institutionalization of AfCFTA to align with the national polices and strategies and harmonize the national regulatory requirements, standards, procedures, and information sharing and knowledge management.

Strategies:

- Address the issues of domestication of the AfCFTA agreements into the country's own institutional frameworks and its national regulatory mechanism (alignment & harmonization)
- Alignment and harmonization of the policy, rule and procedures by the state ministries and agencies. For example, align the National Trade Law/Policy to fit the AfCFTA agreement
- Advocate for the establishment of the National AfCFTA Coordinating Office for Ethiopia
- Advancing AfCFTA institutionalization agenda by the pertinent government ministries, ECCSA -BSOs
- Integration of the Business Database and System between the MOTRi, ECCSA, and their lower structures
- Strengthen the National AfCFTA Steering or Technical Committee and expand it to the lower-level structures to ensure SSM integration into PHCUs
- Undertaking organizational change and effectiveness initiatives at different levels;
- Ensuring the sustainability of SSM in the FMOH' PHCU system across all the regions

Major Strategic Objectives:

- Clear regulatory process and system established by all pertinent government authorities to align requirements under AfCFTA
- Creating broad-based awareness and sensitization of relevant stakeholders within the private sector, ECCSA's members and non-members, disadvantaged groups and government ministries
- The voluntary Chamber membership changed to a mandatory membership model for a bigger impact
- The MOTRi Database and ECCSA database integrated for better access for real-time information and enhance the quality online system for all business communities

Strategy 2: Provision of Trade Intelligence

Ethiopia's trade profile bears certain similarities to that of its African peers, especially when it comes to intra-regional agricultural primary products. Competitions in the open single Africa continental market require timely business decision-making supported by strategic information and trade intelligence. This helps to enhance the diversity and quality of agricultural products to AfCFTA, including making key investments to make important value additions.

Strategies:

- Strengthen the ECCSA's internal research, market intelligence and knowledge management
- ECCSA and MOTRI to collaborate and work together on market intelligence and exchange information and data to enhance their effectiveness
- Encouraging participation of Ethiopian firms and associations in continental markets and fairs to increase visibility of Ethiopian exports and form new partnerships at the continental level
- Enhance Inter-Africa Trade Fairs participation by organizing large-scale, harmonized and coordinated participation by the inclusive business community participation
- Promote the formation and strengthening of the producers-exporters associations and unions
- Advocate for Large Size Aggregation Companies to be formed in Ethiopia to facilitate organized exports from Ethiopia in the Intra-Africa Trade
- Mobilization of the Ethiopian producers, processors and exporters (actors in the

value chains) through extensive awareness creation and sensitization

- Enhance government and private sector coordination and leadership consultations via periodic forums
- Government attention to support producers, processors and exporters to enhance production capacity and quality, diversify its agricultural exports with balanced technical support.

Major Strategic Objectives:

- Conducting regular market research on strategic export sectors in Africa and disseminating results among Ethiopian Firms
- Producing necessary trade documents (Laws, regulations, procedures, and administrative rulings) and ensuring their accessibility to the business community
- ECCSA and sectoral associations, as well as Government agencies that support private sector activities, should design programs that provide targeted support to businesses to better access African market information and ultimately get better access to the AfCFTA market.

Strategy 3: Enhancing Human and Institutional Capacities

In the context of the AfCFTA, it is incredibly important to ensure that individuals, firms, and associations can benefit from the Agreement. It is thus important to ensure that the business environment is conducive and that the different actors are appropriately supported. This implies having the necessary infrastructure in place, being able to access resources, and having the capacity to change and adapt to the dynamism of AfCFTA. Thus, in-depth analyses of stakeholders, human capacity, organizational capacity, and institutional gap assessments must be conducted to fully enhance the capacity of key actors in the agricultural value chains. To effectively eliminate the information gap among exporters, the Ethiopian authorities will have to ensure that there is a well-developed communication plan that allows for the dissemination of AfCFTA-related information to all relevant stakeholders, especially MSMEs.

Particular attention must be given to ensuring that information remains accessible to a wide range of different stakeholders. The goal is to increase individual and institutional capacities to effectively implement AfCFTA and increase Ethiopia's earnings from Intra-Africa trade exports.

Strategies:

- Enhance the quality of short-term and long-term training, awareness creation & sensitization workshops
- Increasing the leadership training and experience sharing platforms, and facilitating of AfCFTA
- The use of ICT & Technology in the provision of services & improving the e-commerce landscape
- Configuring the policies, practices, legal framework, code of conduct, culture, and systems that allow for the effective functioning of firms and associations.
- Enhance the regulatory capacity of the Ethiopian Customs Commission and MOTRI, MOA MOFA at different levels to simplify, align, and harmonize their system in line with the AfCFTA needs and requirements

Major Strategic Objectives:

- Enhancing human and institutional capacity of the pertinent government ministries and regional structures to support and facilitate the business companies and firms to enhance their exports and to access the AfCFTA Market.
- Enhancing human & institutional capacity of private firms to access the AfCFTA Market.
- Promoting internal structure, policies, and procedures that enhance firms' effectiveness
- Digital literacy in the private sector is also an important skill and expertise to further develop. E-commerce represents an important avenue to promote Ethiopian businesses
- Enhancing knowledge and providing skills training to enable individuals, firms and associations to perform at their optimal capacity and integrate Regional Value Chains (RVCs), including training to SMEs in regard to expected standards and requirements
- Ensure that Ethiopian businesses are appropriately equipped with all the essential and relevant information
- Train exporters, especially MSMEs, in relation to the different standards and requirements that they need to meet or fulfil to export to different African countries. Such training can also be extended to firms that are aspiring to export and require some technical training and assistance to become export-ready. One key component of such training could also focus on the different certifications,

labelling requirements, and any other documentation that may be required for export to Africa under the AfCFTA

Strategy 4: Trade Promotion and Diversifying Export Supplies

Ethiopian firms need to be motivated to increase exports to and imports from African countries in the interest of regionalization (AfCFTA). This is a key role and function of the export promotion agency, sectoral associations, and chambers of commerce. The goal is to enhance trade and business marketing and outreach in the other AfCFTA countries' markets.

Strategies:

- Enhance supply-side coordination and investment in diversified exportable agricultural commodities
- Enhance trade missions, trade advocacy, hosting and participating in Business to Business (B2B), Business to Consumer (B2C), and Business to Governments (B2G) events like regional/virtual trade fairs
- Improving access to finance through the accessibility of loans and bank credit, and improving access to foreign currency
- Increasing the operation of agricultural value addition by enhancing access to the Industrial Parks and
- Advocate and push for the establishment of a large-scale state or private firm for product aggregation, warehousing, logistics and transportation, and exporting facilities

Major Strategic Objectives:

- Designing market destination strategies, utilizing the Ethiopian Embassies in African countries (leveraging the Economic Diplomacy in MOFA), and establishing diplomatic centers to facilitate trade promotion and linking supply chains in Africa
- Establishing an online platform or portal to connect Ethiopian businesses with other businesses, helping them to establish contacts, discover new markets and opportunities, and find potential investors.
- Developing global partnerships in Africa in core interest areas
- Encouraging participation of Ethiopian firms and associations in continental markets and fairs to increase visibility of Ethiopian exports and form new partnerships at the continental level.

Strategy 5: Empowering Women, Youth in MSMEs

To effectively achieve the goal of the AfCFTA, it has become vital to enhance women and youth participation to address their economic empowerment in the agricultural value chains, including those who engage in Micro Small and Medium Sized Enterprises. This requires having a developed communication plan that allows for the dissemination of AfCFTA-related information to all relevant stakeholders, especially women-owned businesses and MSMEs. Particular attention must be given to ensuring that information remains accessible to a wide range of different stakeholders. The goal is to expand and enhance women and youth economic interventions, starting from the agricultural value chains at all levels.

Strategies:

- Integrate Women Economic Empowerment (WEE) and Youth interventions in the agricultural value chains
- Regional Chambers and RTRI Bureaus to advocate, encourage, and support women and youth cooperatives, MSMEs, unions and business associations as part of the AfCFTA
- Mobilize resources for WEE and Youth
- Create a linkage between WEE and youth with Microfinancing institutions
- Major Strategic Objectives:
- Strengthen Women and youth-owned businesses at all levels to enhance their participation in the AfCFTA markets
- Encourage and mobilize the Associations representing SMEs & those representing Women business to become members of ECCSA

Strategy 6: Collaboration And Partnership In AfCFTA

Engagement in AfCFTA requires a collaborative, close partnership and coordination to uplift the agricultural value chains actors. The goal is to enhance alignment and harmonization of the development partners in their technical assistance, support and resource mobilization to make Ethiopia's private sector participation in intra-African trade a success to reduce poverty and increase incomes in the value chains.

Strategies:

- MoTRi and ECCSA lead the multisectoral collaboration and partnership with pertinent government ministries and development partners
- Explore new donors and strengthen relationships with the development partners

like Mastercard Foundation, Bill and Melinda Gates Foundation (BMGF), USAID, WB to provide Tas, including support ECCSA efforts to build individual and institutional capacities…& to support & strengthen the Micro, Small, Medium Enterprises (SMEs)

- Enhancing Domestic and External Resource Mobilization

Major Strategic Objectives:

- Strengthen partnership with domestic and international partners
- Establish strong ties and collaboration with AfCFTA Secretariate and AU to have experience sharing forums

10. Conclusion and Recommendations

The findings of the assessment affirm that there is a lot to be done for the agricultural value chain actors to be sensitized, better informed and trained to see the benefits of AfCFTA implementation and to effectively enhance its productivity and production with sustained supply to the broader single market in Africa.

The need for integrated and coordinated multi-stakeholder engagement in AfCFTA with properly aligned and harmonized regulatory procedures and requirements has become highly essential. For this to be legalized, there should be a National AfCFTA Coordination Office that can actively engage the pertinent state and non-state parties (ministries and authorities), including ECCSA.

ECCSA needs to strengthen its market intelligence, export market promotion and research capacities within its internal structure from the head office down to the regional chambers.

The need for the establishment of large-sized state owned and/or private enterprises that can agglomerate products from local producers, processors and exporters, facilitate logistics and operations for shipment and cargo services in close collaboration with Ethiopian Airlines, and multiple shipping lines will be timely.

The Women Economic Empowerment, MSEs, and Youth active participation has been featured in the AfCFTA agreement and AfCFTA Secretariat Strategy document 2022-2030 which is a clear indication that Women Economic Empowerment (WEE) has become a priority issue under AfCFTA implementation, which need due attention in ECCSA's strategic leadership of the private sectors with inclusivity.

ECCSA needs to restructure and renew itself with a new legal framework that helps to expand its mandates as a private sector voice and contribute more to the Ethiopian Economy. It should also give priority to building its internal capacities with adequate experienced human resources and modern technologies.

Collaboration and Partnership with the Pertinent Government Ministries: The close working relationship ECCSA has with the MOTRI and MOI has to be further strengthened.

The private sector associations like ECCSA and other Business Support Organizations are expected to strengthen and expand their engagement with both the private sector actors and pertinent government and other partners at different levels, among others, in the following:

- As a national voice of the private sector, ECCSA has to form a national and regional level functional platforms to work proactively with the government bodies to address the gaps and utilize the opportunities; which also entails having a monthly forum with the MoTRI, MOR, Customs Commission and others; bi-annual forms for selected private sectors actors to engage companies and firms both at federal and regional levels to create mutual trusts and confidence on both the government and the private sectors as core players of the AfCFTA;
- Establish an AfCFTA Desk at the ECCSA and Regional Chambers level that can handle the day-to-day AfCFTA-related issues of its members and non-members, private companies and firms, including MSEs; Women business owners with trade licenses and registrations;
- Create increasing awareness and sensitization of the business communities on the AFCFTA;
- Strengthen the ECCSA's Trade facilitation unit with highly trained and experienced trade experts to provide pertinent technical assistance to the business communities and respective government offices through various modalities and channels, including information on the ECCSA's Website & Portal.

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Annexes

Annex 1: Ethiopian regulatory agencies involved in importation and exportation

S/N	Regulatory Agencies	Area regulated (related to imports and exports)	Responsibilities
1	Ministry of Trade & Regional Integration (MOTRI)	All import and export goods	• Issues Import Release Permit • Issues Import Release Permit for Legal-Metrology Instruments • Issues Export Release Permit
2	Ethiopian Investment Commission (EIC) and Regional Investment Bureaus	All goods imported and exported by investors	• Issues and renews Investment permit • Issues Custom Duty Free permission letter
3	National Bank of Ethiopia (NBE) and Commercial Bank (CBE)	Foreign Currencies	Registers sales contract agreement • Issues Export Bank Permit • Issues Foreign currency Approval • Issues Bank import permit • Letter of Credit • (Open L/C) • Advance Payment • Approves Purchase Order for CAD
4	Ministry of Agriculture & Natural Resources (MOANR	Import of plants, seeds, plant products, pesticides and fertilizers Export of animal feed, live animals and meat	• Issues Phytosanitary Certificate for reexport • Issues Veterinary Health Certificate • Issues Export Permit for Animal Feed • Issues pre-import permit for plant & plant Products • Issues pre-import permit for fertilizers & pesticide • Issues import release permit for plant & plant Products • Issues import release permit • for list of reg
5	Ministry of Industry (MoI)	Incentives related to manufacturing	• Issues Duty drawback authorization letter • Issues & renews Export trade duty incentive • Scheme Certificate • Issue and Renew 2nd Schedule Certificate •

			Approvals of raw material • supply contract agreement
6	Ethiopian Conformity Assessment Enterprise (ECAE)	Conformity with accepted standards	Issues Laboratory Test Report • Issues inspection report
7	Ethiopian Standard Institute	Standard and specifications of products	Issue Compulsory Ethiopian Standard
8	Food, Medicine and Health Care Administration and Control Authority (FMHACA)	Import & export of drugs, medical supplies or instruments, baby food, supplement food, cosmetics	• Issues pre-import permit and/or Special import permit • Issues export permit • Issues import release permit • Issues free sale certificate/letter • Issues health certificate • Issues list of registered drugs
9	Veterinary Drug and Feed Administration and Control Authority (VDFACA)	Import and export of veterinary drugs and animal feed	• Issues Pre-Import Permit • Issues Import Release Permit • Issues re/export Permit • Issues list of registered drugs
10	Information Network Security Agency (INSA)	Import of communication and security equipment	• Issues pre-import permit • Issues import release permit • Issues re/export permit
11	Ministry of Innovation and Technology (MINT	Import of Innovation and Technologies	• Issues pre-import permit • Issues import release permit • Issues re/export permit
12	Ministry of Communication and Information Technology (MCIT)	Import of telecommunication and network equipment	• Issues Pre-Import permit • Issues Import Release • permit • Issues Export/Re-export • permit • Issues Customs duty & tax • free permit
13	Ministry of Livestock and Fishery (MOLF	Import of live animals, animal products, and export of animal feed	• Issues pre-Import permit for live animals & animal products • Issues import release permit for live animals & animal products • Issues international veterinary health certificate for cattle, sheep & goat, meat & meat product, Hide & Skin • Issues export permit for animal feed

14	ECCSA - Ethiopia Chamber of Commerce & Sectoral Association	Goods Export to Member states of COMESA and any countries which have no preferential treatment agreement	• Issue COMESA Certificate of Origin • Issue Ordinary Certificate of Origin

NB: The details of the regulatory procedures and requirements of the CORE Institutions on Agricultural Goods Exports will be included in the Trade Strategy

Annex II: Some useful links on AFCFTA

African Continental Free Trade Area Agreement: https://au-afcfta.org/wp-content/uploads/2022/06/AfCFTA-Agreement-Legally-scrubbed-signed-16-May-2018.pdf
Protocols to AfCFTA Agreements including Annexes: https://au-afcfta.org/trade-areas/
AfCFTA Rules of Origin Manual: https://au-afcfta.org/wp-content/uploads/2024/01/RoO-Manual-English.pdf
AfCFTA e- tariff book: https://au-afcfta.org/etariff/
Non Tariff barriers: https://au-afcfta.org/operational-instruments/ntbs/
Reporting NTBs: https://www.tradebarriers.africa/
How to Export with AfCFTA- online training: https://www.afreximbankacademy.org/
The AfCFTA Questions and Answers Q & A on the AfCFTA | United Nations Economic Commission for Africa
The Basics of the Rules of origin under the AfCFTA (Practical guide) wco_practical-guide-for-the-implementation-of-afcfta-roo_en.pdf
The AfCFTA tariff Book AfCFTA e-Tariff Book (provide AfCFTA tariffs)
The Non-Tariff Barriers online reporting, monitoring and eliminating mechanism Non-Tariff Barriers :: Trade barriers in Africa

Annex III: AfCFTA Trade in Goods Protocol's Annexes

Annex IV: The Ethiopian Standard Institute (ESI) specifications for Avocado, Soybean and Onion

Annex V: Lists of Ethiopian Embassies in the African Countries and their Contact Address to be provided by the MOFA (ECCSA and MOFA consultation and MOU required)

Annex VI: Lists of Respondents for the Key Informant Interviews (KIIs)

Vulnerability to Multidimensional Food Insecurity: Empirical Evidence from Wheat Farmers in Arsi Zone of Ethiopia

Zenaye Degefu Agazhi[1]*, Melkamu Mada[2] and Mebratu Alemu[2]

Abstract

Although food security is multidimensional, most previous studies have measured households' vulnerability to food insecurity via unidimensional indices. To address this gap, this study assesses households' vulnerability to multidimensional food insecurity by employing the vulnerability-as-expected poverty technique for 422 randomly selected wheat-producing households from three districts of the Arsi Zone. Before estimating household vulnerability by the three-stage feasible generalized least squares approach, the multidimensional food security index was developed by using principal component analysis. The multidimensional food security index was then calculated to be 0.4825 by the geometric aggregation technique, and the descriptive summary indicated that 45.02% of the respondents were multidimensionally food secure. The three-stage feasible generalized least squares revealed that 57.11% of the respondents were vulnerable to multidimensional food insecurity. Moreover, 33.41% of the respondents had stable food security, 45.5% were chronically food insecure, 9.48% experienced transitory food insecurity, and 11.61% were vulnerable to multidimensional food insecurity. The results of the probit model, which is employed to identify the determinants of vulnerability, confirm that contact with agricultural extension agents, family size, and participation in off/nonfarm activities reduce vulnerability, whereas the dependency ratio, credit utilization, shock experience, and living in lowland areas increase it. Accordingly, it is important to adopt policies and strategies that enhance household interaction with agricultural extension agents and develop an efficient early warning system to build a resilient food security system. It is also crucial to promote financial education and provide special support to drought-prone areas by developing drought-tolerant agricultural technologies and reducing agriculture's rain dependency.

Keywords: Multidimensional Food Security, Vulnerability, Principal Component Analysis, Probit, Wheat farmers, Arsi Zone, Ethiopia

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[1] Oromia State University, Department of Economics, Batu, Ethiopia
* Corresponding Author: Zenaye Degefu Agazhi;
Email address: zizusgs.agroeco@gmail.com; ORCID: https://orcid.org/0000-0002-2870-2157; Contact Number: 0913736666

[2] Arba Minch University, Department of Economics, Arba Minch, Ethiopia

1. Introduction

Food security is an important topic of concern since 735.1 million people worldwide were undernourished in 2022 (FAO et al., 2023), and global hunger remains too high (Assefa & Abide, 2023; Drammeh et al., 2019; Mota et al., 2019), with progress on hunger reduction practically stagnant. FAO defines food security as when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 1996) and food insecurity exists when this condition is not satisfied. Food security is a multidimensional concept that encompasses food availability, economic and physical access to food, food utilization, and the long-term stability of the other three (FAO et al., 2013, 2023).

The 2030 Agenda for Sustainable Development aims to improve human well-being; however, the 2023 report indicates that the movement towards attaining these goals is significantly challenged, particularly the first SDG (no poverty) and the second SDG (zero hunger) are stagnating (Sachs et al., 2023). The world Global Hunger Index (GHI) score for 2023 is 18.3, which is considered a moderate hunger situation. However, the issue of household food insecurity is more pronounced in sub-Saharan African (SSA) countries like Ethiopia, where the GHI is 26.2, confirming the presence of a severe hunger condition throughout the country (Von Grebmer et al., 2023). Like other developing countries, poverty and food insecurity are common in Ethiopia, and 68.7% of the overall population was multidimensionally poor in 2021 (UNDP, 2023), with 26.4 million undernourished people and a 21.1% severe food insecurity rate (FAOSTAT, 2023).

In Ethiopia, 31% of households had insufficient caloric consumption (WFP & CSA, 2019), and empirical evidence suggests that more than half the population experiences food insecurity (Assefa & Abide, 2023; Tigistu & Hegena, 2022; Weldemariam et al., 2023; Woleba et al., 2023), which significantly affects human health and growth. This situation is even worse in rural areas, where 51% of people live in severe poverty and mostly rely on agriculture for a living, which accounts for about 77.2% of the total population (NBE, 2021). Even if the agriculture sector contributes 32.5% of Ethiopia's GDP, it cannot feed the alarmingly increasing population in Ethiopia due to insufficient adoption of agricultural technologies and low agricultural productivity (Assefa & Abide, 2023; WFP & CSA, 2019). In addition, Ethiopian agriculture is highly vulnerable to climate change, which mostly results in the loss of crops and livestock (Abate et al., 2023); substantially altering food availability, and that increases households' vulnerability to food insecurity (VuFI) in the country (Gebre & Rahut, 2021).

Households’ VuFI in Ethiopia is also related to poverty, where 75% of low-income households are unable to purchase food to fulfill the recommended level of daily calorie intake (WFP & CSA, 2019). Better income allows households to purchase sufficient food and be resilient to food price increases and economic shocks, which reduces their VuFI in developing countries like Ethiopia (Beyene et al., 2023; Eshetu & Guye, 2021; Masha et al., 2023; Ojo et al., 2019; Woleba et al., 2023). In addition, currently, political instability and civil unrest are highly prevalent in Ethiopia, particularly in the Oromia, Amhara, Tigray, and Afar regions (Nigatu, 2023; Teka, 2024). These events disrupt food production and supply systems and cause economic crises such as inflation of food prices, job losses, and disruptions to households' means of livelihood (García-Díez et al., 2021; Subramaniam et al., 2023), which increases the household's VuFI and malnutrition (FAO et al., 2017).

Furthermore, households' VuFI in rural Ethiopia is affected by limited access to productive resources, such as land (where the typical farmer owns 1.1 hectares) (ESS, 2023a), and agricultural inputs, including improved seed, fertilizer, and irrigation water (Bogale, 2012; Debebe et al., 2022; Sileshi et al., 2019). Households employ a variety of strategies to deal with food insecurity, including cutting back meal frequency or quantity, selling assets, taking out loans, sending family members to live with relatives, and depending on less desirable or inexpensive food (Masha et al., 2023; Sani & Kemaw, 2019; Weldemariam et al., 2023).

Given that food security has multiple dimensions (FAO et al., 2013), no single indicator can address all of its dimensions (FAO, 2012; Headey & Ecker, 2012). However, the majority of VuFI studies in Ethiopia rely on unidimensional food security indicators (Bogale, 2012; Debebe et al., 2022; Eshetu & Guye, 2021; Sileshi et al., 2019; Welderufael, 2015) that mostly address either the utilization or access dimension of food security in assessing vulnerability. Knowing the multidimensional food security (MFS) status of households and their vulnerability to multidimensional food insecurity (VUMFI) improves the reliability and credibility of the findings (FAO, 2012) and helps to make informed decisions in policy formulation to create a resilient food system (Manikas et al., 2023). Therefore, this study employs multiple indicators to address MFS indices, assess households’ VUMFI, and identify its determinants using cross-sectional data.

This study was conducted in the Arsi Zone, which is one of the administrative zones of the Oromia regional state of Ethiopia, whose livelihood mainly relies on agriculture, which is highly vulnerable to climate change. Even though the zone has a high wheat production potential, it experiences severe food insecurity (Habtewold, 2018; Ketema & Megento, 2021). This study contributes to the existing empirical gap, first by analyzing households' MFS level since food security is multifaceted, contrary to the study of Gebre & Rahut (2021); Masha et al. (2023); Sani & Kemaw (2019); Sisha (2020); Woleba et al. (2023) and Yohannes et al. (2023) that estimate households' food security using unidimensional indicators. Second, this study estimates households' VUMFI and its determinants in the Arsi Zone of Ethiopia, which is important to consider since food security is dynamic (Capaldo et al., 2010). Understanding the level of households' VUMFI and its determinants helps to make a targeted intervention to create a more resilient food security system within the country.

2. Research Methodology

2.1. The Study Area

This study was undertaken in the Arsi zone located in the Oromia region of Ethiopia. It has a total area of 19,825.22 km², and the population was officially estimated to be 3,980,967 people in mid-2022, with 49.92% males and 50.07% females (ESS, 2023b). The total population is made up of 88.14% rural residents, 11.59% urban residents, and 0.27% pastoralists. Wheat, barley, maize, tef, sorghum, and coffee are among the most important crops grown in the region. Wheat is the most important crop grown by 360,697 households, accounting for 43.7% of the zone's total cereal production from its 39.8% zonally cultivated lands.

2.2. Sample Size and Sampling Procedure

This study was based on cross-sectional data collected by a semi-structured questionnaire and interviews with farm households that were selected randomly using a multistage sampling technique. In the first stage, the Arsi zone was purposively selected because of its wheat production potential. In the second stage, accessible major wheat-producing districts were identified for each agroecological zone with the help of key informants. The highland districts of Digeluna–Tijo, the lowland district of Dodota, and the midland district of Ludehetosa were then chosen randomly. In the third stage, the total number of kebeles (Kebele is the lowest administrative unit in Ethiopia) in each district that corresponded to the district's agroecological class was listed. Then, based on the proportion of kebeles in each district, three kebeles from Ludehetosa, three from Digeluna-Tijo, and two from Dodota were randomly selected. Then, from the kebele-level administrative office, a list of households that produced wheat during the main agricultural production season of 2022/2023 was obtained. In the fourth stage, a total of 422 wheat farmers were selected and distributed for each district based on the proportion of their total wheat farmers using a simple random sampling technique that was determined by using Kothari's formula specified below (Kothari, 2004).

$$n = \frac{Z^2 pqN}{e^2(N-1)+Z^2 pq} \quad \textbf{(1)}$$

where n is the desired sample size; Z is the standard cumulative distribution that corresponds to the level of confidence with a value of 1.96; e is the desired level of precision; p is the estimated proportion of an attribute present in the population with a value of 0.5, as suggested by (Israel, 1992), to obtain the desired minimum sample size of households at a 95% confidence level and ±5% precision; and q=1-p. N is the size of the total population from which the sample is drawn; in this case, the total number of wheat-producing households is 360,697 (ESS, 2022). After accounting for the 10% contingency, a total of 422 sampled respondents were interviewed.

2.3. Method of Data Analysis

In this study, alongside descriptive statistics, econometric models were employed. Before data analysis, data cleaning and management were performed. To develop the MFS index, principal component analysis (PCA) was used to create a unified index from selected indicator variables for each dimension of food security by following the steps suggested by Vyas & Kumaranayake (2006). PCA is the most commonly used linear dimensionality reduction technique. It is a statistical data analysis technique that splits the initial set of input variables into several sets of linear combinations, or principal components (PCs), which reduce the dimensions while maintaining information (Bicciato et al., 2002). This method obtains a linear combination of the indicator variables with the highest variance that reduces it to fewer or a single index (Zeller et al., 2006), which demonstrates the best linear connection between the original variables (Conte, 2005). As PCA does not require any distributional assumptions as a descriptive tool, it has an adaptable exploratory technique that may be used for numerous types of data (Jollife & Cadima, 2016). However, this technique is ineffective for evaluating nonlinear systems (Mizuta, 2012). The same procedure was utilized by Adem et al. (2023); Demeke et al. (2011) and Qureshi (2007) to generate a composite food security index.

Given n correlated indicator variables (X) for each dimension of food security, PCA generates a variety of uncorrelated components, each of which is a linearly weighted sum of the original variables. Mathematically, PCA is specified in equation 2 as follows:

$$PC_{11} = \rho_{11}X_1 + \rho_{12}X_2 + \dots \dots \dots \dots \dots + \rho_{1m}X_m$$

$$PC_{nm} = \rho_{n1}X_1 + \rho_{n2}X_2 + \dots \dots \dots \dots \dots + \rho_{nm}X_m \qquad \textbf{(2)}$$

where ρ_{ij} represents the weight for the variable X_j in the i^{th} household and j^{th} PC (i= 1, 2, …, n and j = 1, 2, …, m).

The estimated PCs are ranked in decreasing order; thus, the first PC explains the most variation in a dataset if the total of the squared weights equals one ($\rho_{i1}^2 + \rho_{i2}^2 + \rho_{i3}^2 + \dots \dots + \rho_{ij}^2 = 1$). If the original variables are highly correlated, fewer components are needed to capture the common information (Vyas & Kumaranayake, 2006). Upon identifying the potential components, the household's food security index for each pillar was calculated as follows:

$$FSI_i = \sum F_j \left(\frac{X_{ij} - \mu_j}{\sigma_j}\right) \qquad \textbf{(3)}$$

where FSI_i represents the i^{th} household food security index, which is assumed to follow a normal distribution with a mean of 0 and a standard deviation of 1; F_j represents the weight of variable j in the PCA model; X_{ij} represents the value of the j^{th} variable for the i^{th} household; and μ_j and σ_j represent the mean and standard deviation, respectively, of the j^{th} variable for all farm households.

The index from each pillar of food security was then aggregated using the geometric aggregation technique, which is a less compensatory approach than additive aggregation, which has a fully compensatory nature of aggregation in which high-performance indicators can compensate for low-performance indicators (Fagerberg, 2002).

$$MFSI = [(FAVI * FACI * FUI * FSI)^{1/4}] \qquad \textbf{(4)}$$

MFSI= Multidimensional Food Security Index, FAVI = Food Availability Index; FACI = Food Accessibility Index; FUI =Food Utilization Index; FSI = Food Stability Index

In this study, indicators for each food security component were chosen by reviewing the current literature on food security (Adem et al., 2023; Bashir et al., 2012; Demeke et al., 2011; Magrini & Vigani, 2016), as indicated in Table 1.

Table 19: Indicators of food security

Pillars of Food Security	Measurement	Expected Effect
Food Availability (FAV)		
Total land holding	Hectare	Positive
Total amount of crop production	Quintal	Positive
Total amount of crop stored	Quintal	Positive
Amount of food gift received	Kg	Positive
Food Access (FAC)		
Total income of farm households (Real)	Birr/Month	Positive
Real food consumption expenditure	Birr/Month	Positive
Distance from the food market	Minute	Negative
Food Utilization (FU)		
Dietary Diversity Score (DDS)-(Number of food varieties consumed in last 7 days)	Number	Positive
Number of crops produced	Number	Positive
Edible Livestock Holding	TLU	Positive
Drinking and cooking water consumed per month	Liters	Positive
Food Stability (FS)		
Total Assets in Birr	Birr	Positive
Number of income sources	Number	Positive
Number of months with food shortage in a year	Number	Negative

Source: Own summary from literature reviews

After developing MFSI, households' VUMFI was estimated following the vulnerability as expected poverty (VEP) approach as suggested by Chaudhuri et al. (2002) and Christiaensen & Subbarao (2005) by using MFSI as a measure of food security. The main assumption of the VEP technique is that the environment is stable and that the variance of the residuals in cross-sectional MFS regressions, or the portion of household MFS that cannot be explained, is not only a measurement error, and is also not uniform across households. The influence of idiosyncratic and covariate shocks on MFS is well captured, and several observable household factors may explain this impact. This presumption leads straight to the fundamental benefit of the VEP method, which allows the estimation of vulnerability from cross-sectional data (Günther & Harttgen, 2009), in contrast to vulnerability as low expected utility and vulnerability as the threat of poverty approaches, which require panel data. This study considers household shock experiences and coping strategies, which may influence the chance of falling below the cut-off marks. The vulnerability of households during the current period is expressed as:

$$V_{ht} = P(M_{it+1} < Z) \quad \text{`} \qquad \textbf{(5)}$$

The current vulnerability of a household (V_{ht}) is determined by the likelihood that the future household MFSI (M_{it+1}) will be less than the threshold level (Z=0.5). The VEP approach estimates are based on the households' MFSI predicted mean and variance. The predicted mean of the MFSI is determined by household characteristics, but the variance in the MFSI incorporates the idiosyncratic shocks that lead to differences in MFS levels among households with comparable features (Bogale, 2012; Günther & Harttgen, 2009).

Following Chaudhuri et al. (2002), a variant of VEP from the MFS index function estimated empirically as:

$$M_i = x_i\beta + \varepsilon_i \qquad \textbf{(1)}$$

where M_i represents the MFS index for the ith household, x_i represents an array of household characteristics, β is a vector of parameters, and ε_i is a disturbance term with a mean of zero and is heteroscedastic. However, with heteroscedasticity, standard regression approaches may produce inefficient estimates but are not biased by the main parameters of interest. This means that the variances of the error term differ among households depending on x_i.

The squared residuals from equation 6 are then regressed on household characteristics (x_i) to generate estimates for the expected variances, specified as:

$$\sigma^2\varepsilon_i = x_i\theta + \tau_i \qquad \textbf{(7)}$$

where θ represents the vector of parameters and where τ represents the error term. As proposed by Amemiya (1977), Chaudhuri et al. (2002), and Christiaensen & Subbarao (2005), the estimates of β and θ can be obtained using three-stage feasible generalized least squares (FGLS). The three-stage FGLS is the most efficient econometric technique that is used to address heteroscedasticity problems in ordinary least squares (OLS). This starts by estimating equation 6 using OLS. Then, equation 7 is estimated using the square of the error term from equation 6 as the dependent variable. To obtain asymptotically efficient estimates of θ, re-estimate equation 7 with OLS using predictions of equation 6 after each residual is weighted by $x_i\theta$(Chaudhuri et al., 2002). This study adopts the approach used by Chaudhuri et al. (2002) and Sileshi et al. (2019) to obtain asymptotically efficient estimates of β by re-estimating equation 6 after using efficient θ and weighted least squares.

$$\frac{\hat{\varepsilon}^2 OLS,i}{x_h \hat{\theta} OLS} = \left(\frac{x_h}{x_h \hat{\theta} OLS}\right)\theta + \frac{\tau_i}{x_h \hat{\theta} OLS} \quad \textbf{(8)}$$

The standard deviation of the variance can then be obtained by the following equation:

$$\hat{\sigma}_{\varepsilon,\mathrm{i}} = \sqrt{\mathrm{x_i}\hat{\theta}\mathrm{FGLS}} \quad \textbf{(9)}$$

Finally, equation 6 is transformed, as given in equation 10, to estimate β.

$$\frac{M_i}{\hat{\sigma}_{\varepsilon,i}} = \left(\frac{x_i}{\hat{\sigma}_{\varepsilon,i}}\right)\beta + \frac{\varepsilon_i}{\hat{\sigma}_{\varepsilon,i}} \quad \textbf{(10)}$$

The estimates of β and θ can be used to directly estimate the expected MFS index and the variance in the MFS index for each household, as indicated in equations 11 and 12, respectively.

$$E[M_i/x_i] = x_i\hat{\beta} \quad \textbf{(11)}$$

$$V[M_i/x_i] = x_i\hat{\theta} \quad \textbf{(12)}$$

Assuming that the MFS index is normally distributed, each household's VUMFI at time $t + 1$ can be expressed as in the following equation:

$$\hat{V} = \hat{P}(M_i < Z/x_i) = \emptyset \frac{Z - x_i\hat{\theta}}{\sqrt{x_i\hat{\beta}}} \quad \textbf{(13)}$$

where Φ is the cumulative density of the standard normal distribution; $x_i\hat{\theta}$ and $x_i\hat{\beta}$ are the predicted values of the household MFS index and the standard error of the regression, respectively; Z is the threshold level, which is equal to 0.5; and V is the likelihood that each household's VUMFI ranges from zero to one. Then, households with an estimated vulnerability coefficient ($\hat{V}$) above or equal to 0.5 were grouped as vulnerable (Chaudhuri et al., 2002; Pritchett et al., 2000) and not vulnerable otherwise.

After determining households' VUMFI, factors that affect the status of households' VUMFI were estimated by using a probit model. The probit model is a binary response where the response probability is the standard normal cumulative distribution function evaluated as a linear function of the explanatory variables (Wooldridge et al., 2016). Here, the dependent variable is the household VUMFI, which takes a value of 1 if $\hat{V}$ is greater than or equal to 0.5, which indicates vulnerable households, and 0 otherwise. Following Chan & Tobias (2020), the econometric specification of the model is given as follows:

$$Y_j^* = X_j\beta + e_j \quad \textbf{(14)}$$

where Y_j^* is an unobserved (latent) random variable that defines households' VUMFI status, X_ja matrix of explanatory variables associated with individual j that are summarized in Table 2. β is a vector of coefficients associated with the explanatory variables, whereas e_j represents the random error terms assumed to be independently and identically distributed; i.e., e_j~N(0, 1). The probability of the event occurring is the cumulative density function of e_j evaluated at given values of the independent variables.

$$Pr(Y_j = 1|X) = \Phi(X_j\beta) \quad \textbf{(15)}$$

where Φ is the standard normal cumulative distribution function for the probit model. Then, to interpret the result, the marginal effect was calculated. The marginal effect of the independent variable $X_j$on the probability $Pr(Y_j = 1|X)$ is given by:

$$\frac{\partial \Pr(Y_j=1|X)}{\partial X_j} = \emptyset(X\beta).\beta_j \quad \textbf{(16)}$$

where $\emptyset$ is the probability density function of the standard normal distribution and β_j is the coefficient associated with the independent variables X_j.

2.4. Variable Definition and Working Hypothesis

The Dependent Variable

Households' Vulnerability to Multidimensional Food Insecurity (VUMFI): This dummy variable is assigned a value of 1 if the probability of a household's VUMFI being equal to or exceeding 0.5 when households are vulnerable and 0 otherwise (Chaudhuri et al., 2002; Pritchett et al., 2000).

The Independent Variable

Sex of Household Head (1=Male): This denotes the gender of the household head, which suggests that being female may increase household vulnerability, as women often face limited access to land ownership, credit, and other productive resources, thereby restricting their capacity to produce or acquire enough food (Debebe et al., 2022; Woleba et al., 2023).

Age Household Head (Year): It is expected to inversely correlate with vulnerability, reflecting accumulated agricultural resources, knowledge, and social capital increases, which potentially reduce VUMFI (Eshetu & Guye, 2021; Ibukun et al., 2022; Sileshi et al., 2019).

Education level: It is the number of years of schooling, which is anticipated to lower households' VUMFI as education provides farmers with essential cognitive skills for informed decision-making, effective resource management, and strong problem-solving abilities, serving as a crucial factor in reducing vulnerability by improving agricultural productivity (Ibukun et al., 2022; Masha et al., 2023; Melese et al., 2021; Ojo et al., 2019).

Distance from the main market: This continuous variable quantifies the distance from the household residence to the main market, measured in kilometers. It is predicted that greater distances will increase households' vulnerability, as increased travel distance leads to higher transportation costs for both buying food and selling agricultural products (Sani & Kemaw, 2019).

Frequency of extension contact: This continuous variable reflects how often farm households have interacted with extension agents over the past 12 months, which is expected to decrease households' VUMFI. This impact is mediated by the agents' role as essential channels of knowledge, promoting the adoption of improved agricultural practices that enhance production and productivity, thereby reducing household vulnerability (Aweke et al., 2020; Debebe et al., 2022; Masha et al., 2023).

Family size: This continuous variable represents the size of households in terms of adult equivalents. It is proposed that a larger adult equivalent leads to a stronger labor force, which in turn boosts productivity, raises income, and ultimately lowers households' VUMFI (Bogale, 2012; Gebissa & Geremew, 2022).

Dependency ratio: This continuous variable reflects the economic burden faced by the working-age population. It is hypothesized that this burden increases households' VUMFI by exerting considerable pressure on financial resources and economic productivity, leading to reduced overall income. This financial strain makes it more challenging to afford sufficient food, thereby aggravating the vulnerability (Ibukun et al., 2022; Masha et al., 2023).

Credit utilization (1=Yes): The dummy variable for credit utilization captures the household's leveraging of credit to create a consistent cash flow mechanism, a practice hypothesized to offer resilience against financial crises, which is expected to lower VUMFI (Eshetu & Guye, 2021; Sileshi et al., 2019).

Off/non-farm participation: This dummy variable is coded as 1 if the household head engages in off-farm or non-farm activities, and 0 if not. Participation in these activities is expected to decrease households' VUMFI by providing an additional source of income (Assefa & Abide, 2023; Ibukun et al., 2022; Ojo et al., 2019)

Coping Strategy Index (CSI): The CSI involved compiling the primary methods that households implement to combat food insecurity during periods of shortage. These methods consist of relying on less preferred or cheaper food, reducing or skipping meals, borrowing food or using credit to buy food, seeking assistance from friends or relatives, and sending family members out for help, as suggested by Maxwell & Caldwell (2008). This continuous variable is anticipated to lower household VUMFI by enhancing economic stability, improving nutrition, and facilitating sustainable access to food. It functions as both a diagnostic and monitoring tool, aiding in the prevention, mitigation, and response to food insecurity by directing timely and effective interventions (Ojo et al., 2019).

Crop or livestock loss: This dummy variable is coded as 1 for households that have experienced crop or livestock loss in the past 12 months, and 0 for those that have not. It is anticipated to increase VUMFI, as such losses negatively impact the livelihoods of wheat farmers (Eshetu & Guye, 2021).

Death, serious injury, or disease: This dummy variable is set to 1 if households have experienced death, serious injury, or illness in the past 12 months, and 0 if they have not. It is expected to worsen household VUMFI by leading to income loss, higher medical costs, diminished labor capacity, and social disruption (Eshetu & Guye, 2021).

Table 20: Summary of hypothesized variables with expected effect on VUMFI

Variables	Measurement	Expected Effect	Related Empirical Evidence
Sex of Household Head	Dummy (1 if Male)	-	(Debebe et al., 2022; Woleba et al., 2023)
Age Household Head	Years	+	(Eshetu & Guye, 2021; Ibukun et al., 2022; Sileshi et al., 2019)
Education level	Years of schooling	-	(Ibukun et al., 2022; Masha et al., 2023; Melese et al., 2021; Ojo et al., 2019)
Distance from the main market	KM	+	(Sani & Kemaw, 2019)
Frequency of extension contact	Days per year	-	(Aweke et al., 2020; Debebe et al., 2022; Masha et al., 2023)
Family size	Adult equivalent	-	(Bogale, 2012; Gebissa & Geremew, 2022)
Dependency ratio	Number	+	(Ibukun et al., 2022; Masha et al., 2023)
Credit utilization	Dummy (1=Yes)	-	(Eshetu & Guye, 2021; Sileshi et al., 2019)
Off/non-farm participation	Dummy (1=Yes)	-	(Assefa & Abide, 2023; Ibukun et al., 2022; Ojo et al., 2019)
CSI	Number	-	(Ojo et al., 2019)
Crop or livestock loss	Dummy (1=Yes)	+	(Eshetu & Guye, 2021)
Death, serious injury, or disease	Dummy (1=Yes)	+	(Eshetu & Guye, 2021)

Source: Own Summary

3. Results and Discussion

3.1. Socioeconomic Characteristics of Respondents

As indicated in Table 3, this study included 422 randomly selected wheat farmers from three districts of the Arsi Zone of Ethiopia, with 89% male-headed households. Approximately 31.28% of the respondents utilized credit, while nearly 67% of them engaged in off-farm or nonfarm activities. Concerning household shock experiences, 43.84% and 40.28 % of households faced crop or livestock loss and death or health shock, respectively, within the past 12 months.

Table 21: Descriptive summary of categorical variables for vulnerability analysis

Variables	Response	Frequency	Percentage
Sex	Male	375	88.86
	Female	47	11.14
Credit	Yes	132	31.28
	No	290	68.72
Off/non-farm participation	Yes	281	66.59
	No	141	33.41
Crop or livestock loss	Yes	185	43.84
	No	237	56.16
Death or health shock	Yes	170	40.28
	No	252	59.72
Districts	Digeluna Tijo	178	42.18
	Ludehetosa	121	28.67
	Dodota	123	29.15
Total		422	100

Source: Own computation, 2024

The data presented in Table 4 indicate that the mean age of sample households was 46.2 years, while the average years of education and livestock holdings were 7.01 years and 6.47 TLU, respectively. The mean frequency of contact with the agricultural extension agent, which is the primary source of agricultural information, was 4.44 days per year. The mean household distance from the main market is 7.08 km, and the average family size is 4.38 adult equivalents, with a dependency ratio of 0.46. In addition, the average food insecurity coping strategy index (CSI) was 14.33, which was used by households to cope with food insecurity during food shortages.

Table 22: Descriptive summary of continuous variables for vulnerability analysis

Variables	Mean	Standard Deviations	Min	Max
Age of Household Head	46.22	10.37	22	81
Education level	7.01	3.46	0	16
Distance from Main Market	7.08	3.91	0.3	18
Extension Contact	4.44	3.84	1	25
Family size	4.38	1.69	0.8	9.5
Dependency ratio	0.46	0.51	0	3
CSI	14.33	3.61	7	27

Source: Own computation, 2024

Table 5 shows the descriptive summary of indicators for each food security dimension. In this study, the FAV component of food security is addressed by total land holdings, total crop output, the quantity of crop stored, and the amount of food gift received in the past 12 months, with mean values of 2.45 hectares, 60.02 quintals, 9.29 quintals, and 16.1 kg, respectively. To address the FAC dimension, the real monthly income per adult equivalent (PAE), real food consumption expenditure PAE, and distance from the food market were used, with mean values of 1125.64 Birr, 675 Birr, and 20.43 minutes, respectively. The FU dimension of food security is addressed by the DDS, the number of crops cultivated, drinking and cooking water consumed per month, and edible livestock held in the TLU, with average values of 6.62, 2.88, 670.55 litres, and 5.23 TLU, respectively. The total value of assets in Birr, the number of months with insufficient food, and the number of income sources were used to capture the FS dimension, with mean values of 25,946 Birr, 2.26 months, and 2.99, respectively.

Table 23: Descriptive summary of food security indicators

Food Availability	Mean	SD	Min	Max
Total land holding	2.45	1.69	0.26	7.02
Total crop production	60.02	47.04	7	275
Amount of crop stored	9.29	0.97	2	12
Amount of food gift received	16.1	5.84	0	40
Food Access	**Mean**	**SD**	**Min**	**Max**
Real income per month PAE	1125.64	1437.6	54.27	13729.62
Real food consumption expenditure per month PAE	675.58	404.15	131.51	3505.28
Distance from the food market (time)	20.43	8.55	5.00	100.00
Food Utilization	**Mean**	**SD**	**Min**	**Max**
DDS	6.62	1.53	4	10
Number of crops cultivated	2.88	1.14	1	6
Drinking and cooking water consumed per month	670.55	123.31	400	1000
Edible Livestock Holding	5.23	3.13	0	17.09
Food Stability	**Mean**	**SD**	**Min**	**Max**
Total Asset	25946.2	23835	0	102200
Number of months with food shortage in a year	2.26	1.3	0	5
Number of income sources	2.99	0.87	1	5

Source: Own computation, 2024

3.2. Multidimensional Food Security of Households

Table 6 summarizes the results of the PCA, which was estimated to capture the MFS level of households. Before PCA, this study adopted the Kaiser–Meyer–Olkin (KMO) measure of the sampling adequacy test (Kaiser, 1974), which compares the magnitudes of the observed correlation coefficients to the magnitudes of the partial correlation coefficients. The KMO overall statistic takes values from 0 to 1, with small values indicating that overall, the variables have too little in common to warrant a PCA. It is stated that 0.5 is the borderline for acceptability (Kaiser, 1974), and to perform PCA, it should be greater than 0.6 (OECD, 2008). Accordingly, in this study, it is appropriate to employ PCA for developing MDFI since the KMO values for all dimensions of food security are greater than 0.6.

In addition, Bartlett's test of sphericity was performed to test the null hypothesis that the sub-indicators in the population correlation matrix are uncorrelated; that is, the correlation matrix is an identity matrix (Bartlett, 1954). Bartlett's test statistic is based on a chi-square transformation of the determinant of the correlation matrix. In this study, all the results of Bartlett's test of sphericity were significant at less than the 1% level of statistical error, which confirms that the strength of the relationships among the selected variables is strong and that the correlation matrix is not an identity matrix, as is required by the PCA to be valid (Table 6).

This study utilized a total of 14 variables (4, 3, 4, and 3 for the availability, access, utilization, and stability dimensions of food security, respectively), and the number of relevant components was determined by following Kaiser's rule, which states that all components with eigenvalues greater than one should be considered for further analysis to construct index (OECD, 2008). Accordingly, only the first component for all dimensions of food security was utilized as indicated in Appendix 5 to Appendix 8, since their eigenvalues were greater than one, which contributed to 64.38%, 55.19%, 53.73%, and 56.39% of the total variation in the FAV, FAC, FU, and FS dimensions of food security, respectively.

As indicated in Table 6, the component loading coefficients indicate a positive association among all indicators of the FAV dimension of food security, which is associated with higher food security indices (Vyas & Kumaranayake, 2006). Here, total landholding and total crop production make the greatest contributions to FAV, with component loading coefficients of 0.5628 and 0.5592, respectively. In the FAC dimension, except for distance from the food market, household income and food expenditure are positively associated with FAC. In this dimension, food market distance and household food expenditure contribute to the highest share of FAC, with values of -0.6175 and 0.6127, respectively.

Similarly, in the FU dimension of food security, all indicators are positively correlated, and edible livestock ownership and DDS account for the largest share, with component loading coefficients of 0.5799 and 0.5679, respectively. In the FS dimension, total assets and the number of income sources are positively related to the FS, but the number of months of insufficient food per year is negatively linked. In this dimension, the component loading coefficient verifies the number of months with inadequate food, and the total asset value has the highest proportion, with scores of 0.6320 and 0.5852.

Table 24: Summary of the PCA outputs to develop food security index

Pillars of Food Security		Pillars of Food Security	
Food availability	Component Loadings	Food Utilization	Component Loadings
Total land holding	0.5628	DDS	0.5679
Total crop production	0.5592	Number of crops cultivated	0.4096
Amount of crop stored	0.4769	Drinking and cooking water per month	0.4165
Amount of food gift received	0.3783	Edible Livestock Holding	0.5799
Eigenvalues of the first component	2.58	Eigenvalues of the first component	2.15
The proportion of Variation Explained	0.6438	The proportion of Variation Explained	0.5373
KMO	0.734	KMO	0.624
Bartlett test of sphericity (Chi2)	738.053***	Bartlett test of sphericity (Chi2)	444.221***
Food Access	Component Loadings	Food Stability	Component Loadings
Real income per month per AE	0.4932	Total Asset	0.5852
Real food consumption expenditure	0.6127	Months of food shortage in a year	-0.6320
Distance from the food market	-0.6175	Number of Income sources	0.5080
Eigenvalues of the first component	1.66	Eigenvalues of the first component	1.69
The proportion of Variation Explained	0.5519	The proportion of Variation Explained	0.5639
KMO	0.605	KMO	0.602
Bartlett test of sphericity (Chi2)	134.58***	Bartlett test of sphericity (Chi2)	151.15***

*** indicates significance at the 1% level of statistical error

Source: Own computation, 2024

After PCA, the index for each pillar of food security was calculated and is summarized in Table 7. The average FAV, FAC, FU, and FS indices are 0.5273, 0.5110, 0.5275, and 0.4524, respectively, which is in line with the findings of Adem et al. (2023). The MFS index was created by combining the indices of the four food security indicators using a geometric aggregation technique, as specified in equation 4, and the mean MFS index was 0.4825.

Table 25: Summary of the food security index

Food Security Indicators	Mean	Standard Deviation
Food Availability	0.5273	0.1752
Food Access	0.5110	0.1001
Food Utilization	0.5275	0.2164
Food Stability	0.4524	0.1876
Multidimensional Food Security Index	0.4825	0.1369

Source: Own computation; 2024

Subsequently, based on the calculated index, households can be categorized into food-secure and food-insecure groups. Researchers have adopted diverse thresholds for establishing the boundary between food-secure and food-insecure households. For instance, Adem et al. (2023) employed a data-driven approach, using the mean MFS index value as the dividing line: households with an index value exceeding the mean were classified as food secure, and those below as food insecure. Similarly, Napoli et al. (2011) use the food insecurity multidimensional index to develop thresholds, with households scoring over 50 being considered highly food insecure (50–59.99: alarmingly food insecure, and greater than 60: extremely alarming food insecurity). Accordingly, in this study, households with scores greater than 0.5 were classified as relatively food secure, whereas those with values less than or equal to 0.5 were considered relatively food insecure.

Consequently, as indicated in Table 8, in the FAV dimension of food security, 49.29% of the sampled respondents were food secure, whereas 50.95% were secure in the FAC dimension of food security. Moreover, nearly 50.47% of the respondents were food secure in the FU dimension, whereas 40.28% were secure in the FS dimension. A total of 14.93% of the households were secure in all dimensions, whereas 81.04% were secure in at least one dimension. Moreover, 45.02% of the sampled households were multidimensionally food secure, whereas the remaining 54.98% were multidimensionally food insecure.

Table 26: Summary of food security status

Household State of Food Security	Food Secure		Food Insecure	
	Frequency	%	Frequency	%
Food availability	208	49.29	214	50.71
Food access	215	50.95	207	49.05
Food utilization	213	50.47	209	49.53
Food stability	170	40.28	252	59.72
Secure in all dimensions	63	14.93	359	85.07
Secure in at least one dimension	342	81.04	80	18.96
Multidimensional Food Security	190	45.02	232	54.98

Source: Own computation; 2024

Table 9 shows the decomposition of the MFS status and each dimension of food security in each district of the Arsi zone. Except for the stability dimension, the highest food security status in all dimensions was recorded in the Digeluna Tijo district, and the lowest was recorded in the Dodota district for all food security indicators, with statistically significant differences. As indicated in Table 9, in the Digeluna Tijo district, 64.61%, 68.54%, 64.04%, and 49.44% were secure in the availability, access, utilization, and stability dimensions of food security, respectively. Similarly, in Ludehitosa District, 63.64%, 45.45%, 52.89%, and 50.41% of the respondents were food secure in the availability, access, utilization, and stability dimensions, respectively. However, in the Dodota district, only 13.01%, 30.89%, 28.46%, and 17.07% were food secure in the availability, access, utilization, and stability dimensions, respectively.

The highest level of MFS status was recorded in the Digeluna Tijo district, where nearly 60% were multidimensionally food secure. In contrast, the lowest MFS status was recorded in Dodota, where only 16.26% were multidimensionally secure households. This disparity may be because Dodota district is a lowland area that is drought-prone and highly vulnerable to rainfall variability, which is important for agricultural production and productivity, in contrast to Digeluna Tijo district (Skoufias et al., 2024).

Table 27: Decomposition of the state food security of respondents

Districts	Digeluna Tijo		Ludehitosa		Dodota		Chi2
	Insecure	Secure	Insecure	Secure	Insecure	Secure	
Dimensions	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	
Food availability	63(35.39)	115(64.61)	44(36.36)	77(63.64)	107(86.99)	16(13.01)	91.4***
Food access	56(31.46)	122(68.54)	66(54.55)	55(45.45)	85(69.11)	38(30.89)	43.3***
Food utilization	64(35.96)	114(64.04)	57(47.11)	64(52.89)	88(71.54)	35(28.46)	37.3***
Food stability	90(50.56)	88(49.44)	60(49.59)	61(50.41)	102(82.93)	21(17.07)	38.9***
MFS status	71(39.89)	107(60.11)	58(47.93)	63(52.07)	103(83.74)	20(16.26)	59.9***

*** indicate 1% levels of statistical errors.

Source: Own computation, 2024

3.3. Household Vulnerability to Multidimensional Food Insecurity

Household VUMFI was estimated using three-stage FGLS methods, which account for heteroscedasticity. The analysis is used to capture households' future probability of scoring below the cut-off point of the MFS index, which is the output of PCA. In this study, households were grouped as vulnerable if they scored 0.5 or above the estimated vulnerability coefficient by the following Chaudhuri et al. (2002).

After the 3-stage FGLS estimation, the result was summarized in Table 10, and the mean future MFS index was predicted to be 0.4823 with minimum and maximum values of 0.2569 and 0.7477, respectively. Subsequently, the households' VUMFI was calculated by deducting the predicted MFS index from the cut-off points (in this case, 0.5) and dividing it by the standard error of the regression. The average calculated household vulnerability probability score was 0.5743, which ranges from 0 to 1.

Table 28: Summary of predicted MFS index and probability of vulnerability

Variables	Mean	Std. dev.	Min	Max
Predicted MFS index	0.4823	0.0971	0.2569	0.7477
Probability of Vulnerability	0.5743	0.3894	5.82e-36	1

Source: Own computation; 2024

Then the households that scored 0.5 or more were grouped as vulnerable to multidimensional food insecurity (MFI) and not vulnerable otherwise (Chaudhuri et al., 2002; Pritchett et al., 2000). Accordingly, 57.11% were vulnerable, whereas the remaining 42.89% were not vulnerable to MFI (Table 11), which is in line with the findings of Sileshi et al. (2019), who reported that 54% of households were vulnerable. However, the recorded level of household VUMFI is higher than the findings of Welderufael (2015), who reported that nearly 48% of households were vulnerable, but lower than the findings of Debebe et al. (2022), which were 75.51%, and Eshetu & Guye (2021), which were 73.34%.

Table 29: Dynamics of household multidimensional food security

Vulnerability Status		Multidimensional Food Security Status				
		Food Secure		**Food Insecure**		**Total**
		Frequency	**%**	**Frequency**	**%**	**Frequency (%)**
	Not Vulnerable	141	33.41	40	9.48	181(42.89)
	Vulnerable	49	11.61	192	45.5	241(57.11)
Total		190	45.02	232	54.98	Chi2= 138.4***

*** indicates significance at the 1% level of statistical error

Source: Own computation; 2024

The dynamics of the MFS of households are summarized in Table 11. A total of 33.41% of the respondents experienced stable MFS status, as they were multidimensionally food secure and not vulnerable to MFI. Even if these households experienced stable MFS levels, it is important to maintain their livelihoods. In addition, approximately 11.61% were vulnerable to MFI since they are secure now, but vulnerable in the future. These households are at risk of MFI if they are exposed to shocks, since they cannot cope with these risks. Nearly 9.48% of the participants were transitory food insured, as they were currently insecure but not in the future. These households require immediate assistance, as they are currently food insecure due to existing temporal shocks. The remaining 45.5% of the respondents were chronically food insecure, as they were currently food insecure and vulnerable to MFI. These households lack sufficient resources to achieve multidimensional food security now and in the future. Accordingly, these households require targeted and consistent support, such as direct food aid or cash assistance, to make them resilient to food insecurity (FAO, 2008; Sileshi et al., 2019).

3.4. Determinants of Households' Vulnerability to Multidimensional Food Insecurity

Before identifying the correlates of households' VUMFI, tests for the independence of vulnerability status with categorical and mean comparison tests of continuous variables were performed by households' vulnerability statuses. The summary indicates that vulnerable households exhibit a markedly higher rate of credit utilization and experience agricultural and health shocks while demonstrating a significantly lower rate of engagement in off-farm or non-farm activities (Table 12). The mean comparison test result also indicates that vulnerable households are generally younger and have smaller family sizes in terms of adult equivalents when compared to non-vulnerable households. They are also located significantly far from the main market, have less interaction with agricultural extension agents, and exhibit a high dependency rate within the household (Table 13).

Table 30: Summary of categorical variables by household vulnerability status

Variables		Vulnerability to Multidimensional Food Insecurity						
		Vulnerable		Not-Vulnerable		Total		Chi 2
		Freq.	%	Freq.	%	Freq.	%	
Sex	Male	241	88.80	161	88.95	375	88.86	0.0025
	Female	27	11.20	20	11.05	47	11.14	
Credit	Yes	84	34.85	48	26.52	132	31.28	3.34*
	No	157	65.15	133	73.48	290	68.72	
Off/non-farm participation	Yes	145	60.17	136	75.14	281	66.59	10.41***
	No	96	39.83	45	24.86	141	33.41	
Crop or livestock loss	Yes	146	60.58	39	21.55	185	43.84	63.96***
	No	95	39.42	142	78.45	237	56.16	
Death or health shock	Yes	132	54.77	38	20.99	170	40.28	49.02***
	No	109	45.23	143	79.01	252	59.72	
Districts	Digeluna Tijo	72	29.88	106	58.56	178	42.18	79.45***
	Ludehetosa	58	24.07	63	34.81	121	28.67	
	Dodota	111	46.06	12	6.63	123	29.15	
	Total	241	57.11	181	42.89	422	100	

***, and * indicate significance at 1% and 10% levels of statistical errors, respectively

Source: Own computation; 2024

Table 31: Mean comparison test between vulnerable and non-vulnerable households

	Vulnerability to Multidimensional Food Insecurity					
Variables	**Vulnerable**	**Not-Vulnerable**	**Total**			
	Mean	**Mean**	**Mean**	**Mean Difference**	**Std. Err.**	**t-value**
Age of household head	45.02	47.81	46.22	2.79	1.01	2.75***
Education level	6.83	7.24	7.01	0.41	1.22	1.22
Family size	3.97	4.92	4.38	0.95	0.16	5.94***
Distance from the Main market	7.69	6.27	7.08	-1.42	0.38	-3.75***
Extension contacts	2.99	6.38	4.44	3.38	0.34	9.95***
Dependency Ratio	0.56	0.32	0.46	-0.25	0.05	-5.12***
Coping Strategy Index	14.40	14.24	14.33	-0.16	0.36	-0.44

*** indicate significance at 1% levels of statistical errors, respectively

Source: Own computation; 2024

The probit model was estimated to identify the determinants of households' VUMFI, as summarized in Table 14. A preliminary assessment of multicollinearity among the independent variables was undertaken before proceeding with probit model estimation. This assessment revealed no evidence of significant multicollinearity among the predictors (Appendix 9), thereby ensuring the stability and interpretability of the subsequent model results. Furthermore, a model specification test was performed, and its result provided strong support for the model's specification in identifying the determinants of household VUMFI (Appendix 10).

The model result indicates that the overall model fitness test (LR chi2(14)) is 271.01, which is significant at a 1% level of statistical error and confirms that at least one variable significantly affects the likelihood of households' VUMFI. Out of the 13 hypothesized variables, eight of them significantly affect households' VUMFI. The frequency of contact with agricultural extension agents, family size in adult equivalent, and household head participation in off/nonfarm activities decrease households' VUMFI, whereas the dependency ratio, credit utilization, crop or livestock loss, death or health shock, and district dummy (Dodota district) increase households' VUMFI.

The frequency of contact with an agricultural extension agent decreases households' VUMFI since it is the primary source of vital information for agricultural production, which increases production and productivity. When the frequency of contact with agricultural agents increases by one day, the likelihood of VUMFI decreases by 2.69%, which is significant at the 1% level of statistical error. The same result was reported by Debebe et al. (2022), confirming the positive role of agricultural extension in reducing households' VuFI. A study by Aweke et al. (2020) and Masha et al. (2023) also indicated that contact with agricultural extension agents reduces food insecurity. This finding suggests that improving extension services by developing the capacity of development agents, providing adequate funding, and encouraging a community-based approach is critical to reducing household VUMFI.

Family size, which is measured in adult equivalents, was found to be negatively correlated with the VUMFI, which is significant at the 1% level of statistical error. As the family size increases by one adult equivalent, the probability of being vulnerable to MFI is reduced by 4.67%, since a higher adult equivalent is related to better productivity, which increases income and reduces the household's VUMFI. The same result was reported by Bogale (2012), which confirms the positive role of family size in reducing VuFI. In contrast, the dependency ratio increased households' VUMFI at a 1% level of statistical error. The result confirms that as the dependency ratio increases by one unit, the likelihood of households' VUMFI increases by 10.82% since a higher dependency ratio creates burdens, as they are not working groups. A similar finding was reported by Ibukun et al. (2022), confirming that a higher dependency ratio aggravates households' VuFI, as it creates economic stress through higher expenses. The result implies that the Ministry of Health and other healthcare stakeholders should endeavor to promote and expand access to family planning to minimize household VUMFI.

Contrary to the hypothesis, the model results confirm that credit utilization increases VUMFI, which is significant at the 1% level of statistical error. Compared with their counterparts, households that take credit have a 10.9% greater probability of being vulnerable to MFI, which is contrary to the findings of Eshetu & Guye (2021) and Sileshi et al. (2019). This may be because current credit utilization increases households' VUMFI, as it creates a debt repayment burden, particularly when credit is invested in less productive sectors due to poor financial knowledge. The findings presented here suggest that before lending to farm households, credit providers should offer loans for less risky ones after conducting a careful risk evaluation, as well as promote financial education before credit provision and strict follow-up after loan provision, to make credit more productive and reduce farmers' VUMFI.

Household head participation in off/nonfarm activities was found to reduce households' VUMFI at a 5% level of statistical error since the activities serve households as a means of additional income. As the household head participates in off/non-farm activities, the likelihood of VUMFI is reduced by 8.13% as compared to their counterparts. The same result was reported by Ibukun et al. (2022) and Ojo et al. (2019), confirming the positive role of off/nonfarm participation in reducing the household VUMFI as it diversifies the income source. This finding implies that to reduce household VUMFI, it is critical to encourage diverse income streams by supporting their side businesses, boosting infrastructure development to improve market linkage, and devising methods that do not undermine agricultural performance.

Table 32: Determinants of vulnerability to multidimensional food insecurity

Covariate	Coefficient	Std. errs.	Marginal effect
Sex of household head	0.3001	0.2953	0.0603
Age	-0.0054	0.0094	-0.0011
Education level	-0.0181	0.0272	-0.0036
Distance from the main market	0.0078	0.0221	0.0016
Frequency of extension contact	-0.1337	0.0388	-0.0269***
Family size	-0.2323	0.0562	-0.0467***
Dependency ratio	0.5385	0.1852	0.1082***
Credit utilization	0.5426	0.1856	0.1090***
Off/nonfarm participation	-0.4049	0.1940	-0.0813**
CSI	0.0048	0.0230	0.0010
Crop or livestock loss experience	0.9354	0.1761	0.1880***
Death or health shock	1.2846	0.1785	0.2581***
District			
Ludehitosa	0.1039	0.1929	0.0252
Dodota	1.2068	0.2572	0.2657***
Constant	0.4487	0.7444	
Pseudo R2	0.4701		
LR chi2(14)	271.01***		
Log-likelihood	152.72		

***, and ** indicate significance at the 1% and 5% levels of statistical error, respectively.
Source: Own computation; 2024

Household shock experiences that were captured by two important events (crop or livestock loss and death or health shock) were found to significantly increase households' VUMFI at a 1% level of statistical error. The model results confirmed that, compared with their counterparts, households that experienced crop or livestock loss and death or health shock increased their VUMFI by 18.8% and 25.81%, respectively. The same finding was reported by Eshetu & Guye (2021); that may be because households that experience these major shocks at the current time will reduce their future food security status, as it reduces their stability in income and food production, which increases their VUMFI. This finding suggests that the Ethiopian Disaster Risk Management Commission and other stakeholders involved in shock and disaster management should increase farmers' risk-taking capacity by supporting resilient income streams while encouraging early warning systems and efficient shock response mechanisms.

Furthermore, at a 1% level of statistical error, it was found that the district dummy (living in the Dodota district that represents the lowland agro-ecological zone) increased households' VUMFI by 26.57% in comparison to the reference district, Digeluna Tijo. This may be because lowland areas are highly susceptible to climate variability and water storage, which are very important for agricultural production (Skoufias et al., 2024), compared to highland areas. The study findings imply that, because lowland households are highly vulnerable to drought, the Ministry of Agriculture (MOA) and Agricultural Research institutes must develop drought-resistant agricultural varieties, promote climate-smart agricultural technology, and work on developing an irrigation facility to develop resilient agriculture, increase agricultural productivity, and reduce household VUMFI.

4. Conclusion and Policy Implications

In this study, households' VUMFI was assessed using a three-stage FGLS technique following the VEP approach, which relied on households' MFSI derived from PCA. The factors affecting households' VUMFI were subsequently identified using a Probit model. The result of PCA indicates that the majority of the respondents were multidimensionally food insecure. The decomposition of the MFS status of households indicates that the highest level of food insecurity was recorded in the Dodota district, which suggests a need for special support and targeted intervention for drought-prone areas, since this district was sampled to represent the lowland area.

In addition, the result of the three-stage FGLS was used to estimate VUMFI, and the result indicated that the vast majority of the total households were vulnerable to MFI. Moreover, nearly half of the respondents were chronically food insecure and suffered from MFI now and in the future, and required immediate food aid and cash assistance, whereas around a third of them experienced stable food security. The results from the probit model suggest that the frequency of contact with agricultural extension agents, family size in adult equivalents, and household head participation in off/nonfarm activities decrease households' VUMFI, whereas the dependency ratio, credit utilization, agricultural and health shock, and district dummy (Dodota district) increase the likelihood of households to VUMFI.

Accordingly, to reduce household VUMFI and create a more resilient food security system, it is important to develop policies and strategies that enhance contact with extension agents, promote off/nonfarm activities, develop an early warning system to reduce crop or livestock loss, develop fast emergency response mechanisms, and promote health care services to reduce the health shock that aggravates the prevalence of household VUMFI. It is also crucial to promote financial education targeted at improving credit utilization. In addition, providing special support to Dodota districts (lowland areas) by developing drought-tolerant agricultural practices and reducing rain dependency is indispensable. However, the temporal dynamics of the MFS and household VUMFI in the research area are not examined since this study is based on cross-sectional data. Consequently, further studies are recommended with repeated measures and a larger sample size, even for crop producers other than wheat, using country-level data.

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Examining Ethiopia's Sectoral Competitiveness for Free Trade Amidst the African Continental Free Trade Area (AfCFTA) and World Trade Organization (WTO) Accession

Abay Agidew[1] *, Nobuhiro Hosoe[2]

Abstract

As Ethiopia deepens its engagement with international trade regimes, marked by its signing of the African Continental Free Trade Area (AfCFTA) in 2018 and ongoing efforts to join the World Trade Organization (WTO), understanding sector-specific readiness becomes increasingly vital. This study assesses Ethiopia's sectoral competitiveness using trade indicators, Revealed Comparative Advantage (RCA), Nominal Rates of Protection (NRP), and Effective Rates of Protection (ERP), to evaluate which sectors stand to gain or lose under trade liberalization. The findings reveal that transport and cereal sectors are competitive and lightly protected, suggesting they are well-positioned for growth in a liberalized trade environment. Conversely, sectors such as fuel oil, light manufacturing, plastic, tobacco and beverage, and energy and extraction lack competitiveness and are heavily protected, indicating significant vulnerability. The textile and leather sectors, often flagged as sensitive, exhibit divergent results: leather is competitive with moderate protection, while textiles remain uncompetitive despite high levels of protection. These insights underscore the need for Ethiopia to adopt a dual approach: scale up support for globally competitive sectors through targeted investment and trade facilitation, while implementing adjustment mechanisms for vulnerable industries. Such a differentiated policy strategy will help ensure that trade liberalization translates into maximizing the gains from free trade.

Keywords: Trade liberalization; Trade Indicators; Comparative Advantage; Revealed Comparative Advantage Indicators; Level of Protection Indicators; Sectoral Competitiveness.

[1] Addis Ababa University, Addis Ababa, Ethiopia;
* Corresponding author. Email: abay.agidew@aau.edu.et
[2] National Graduate Institute for Policy Studies, Tokyo, Japan

1. Introduction

For many years, international trade has played a pivotal role in the global economy, acting as a fundamental pillar for economic growth and development across numerous countries. This profound influence has spurred the development of various multilateral and regional free trade agreements. Following the end of the Second World War (WW II), the General Agreement on Tariffs and Trade (GATT) was formed to promote world trade at the global level. Since its establishment, several rounds of negotiations have been conducted to reduce trade barriers, resulting in a significant reduction. Despite its achievements, GATT had faced various setbacks, especially in negotiations to reduce tariffs on highly protected industries, such as agriculture. In addition, its scope was limited only to goods trade and lacked mechanisms to effectively resolve trade disputes among countries. Consequently, in 1995, following the conclusion of the Uruguay Round, the World Trade Organization (WTO) was established, succeeding the GATT. Currently, the WTO is the largest group among all free trade agreements, consisting of 164 members and 25 observers, accounting for 98% of global trade (WTO, 2021).

Despite the WTO's expansive reach, countries have increasingly favored establishing regional free trade agreements (RTAs), notably following the failure of the Doha negotiation round. Challenges in achieving consensus among countries and the time-consuming and costly nature of global free trade agreements have driven this shift towards RTAs. Unlike global agreements, RTAs offer flexibility, allowing countries to exempt sensitive sectors from tariff reductions seen as globally uncompetitive. Moreover, RTAs are favored for facilitating deeper integration with specific countries, perceived as more beneficial compared to global ones. Consequently, for these reasons, the focus of free trade arrangements has shifted towards smaller-scale ones, such as regional or bilateral agreements, which are easier to navigate and comply with.

WTO (2023) reports more than 360 RTAs worldwide. North American Free Trade Agreement (NAFTA), Mercosur, European Union (EU), Association of Southeast Asian Nations (ASEAN) Free Trade Area (AFTA), and Trans-Pacific Partnership (TPP) are among the famous regional trade agreements. In Africa, there are more than 30 RTAs, such as East African Community (EAC), the Economic Community for Central African States (ECCAS), the Economic Community of Western African States (ECOWAS), the Southern African Customs Union (SACU), the Southern African Development Community (SADC), West African Economic and Monetary

Union (WAEMU), Arab Maghreb Union (AMU), and Common Market for Eastern and Southern Africa (COMESA). However, the implementation of these RTAs has been poor and not successful in achieving their target of promoting intra-regional trade (Hartzenberg, 2011; Yang & Gupta, 2005). These existing RTAs in Africa were formed by neighborhoods, and their market size is limited. As they often export agro-food products and import manufacturing goods, gains from trade cannot be exploited among members with industrial structures.

On top of these existing RTAs, Africa ratified the African Continental Free Trade Agreement (AfCFTA) in 2018, which aimed to create a unified and large market size for goods and services across the continent. As of February 2022, 46 of the 55 countries had deposited their instruments of ratification with the chair of the African Union Commission, and trade operations were formally launched in January 2022 (UNECA, 2023). After abstaining from free trade memberships for a long time, Ethiopia has become one of the signatory members of AfCFTA. Additionally, the country has resumed negotiations to join the WTO, which paused in 2013.

Joining FTAs presents both advantages and concerns. They offer increased market access for imports and exports, augmenting productivity and attracting higher foreign direct investment. However, they also pose a risk to weak industries. In Ethiopia, manufacturing sectors are considered incompetent (Makonnen & Lulie, 2014; Alemu & Zerihun, 2005; Africa Development Bank Group, 2014). Notably, textile and leather are labeled as "sensitive sectors" demanding protective measures in the recent negotiations in the African Continental Free Trade Agreement (The Reporter Newspaper, 2023). In contrast, the agricultural sector is viewed as competitive and is expected to encounter minimal challenges from free trade (Ben et al., 2006).

Given Ethiopia's limited experience with Free Trade Agreements (FTAs), the commitment to join AfCFTA and WTO evokes a mix of hope and apprehension about its economic future. Comprehensive studies that analyze the sectoral competitiveness of Ethiopia are imperative to take measures that maximize gains and mitigate adverse effects. While some studies have examined Ethiopia's sectoral competitiveness, these analyses primarily rely on cost-based assessments and lack comparative insights into global industries (Makonnen & Lulie, 2014; Alemu & Zerihun, 2005; Africa Development Bank Group, 2014). This gap underscores the need for studies to fill this critical void. Thus, we examine Ethiopia’s sectoral competitiveness for free trade using trade indicators. This introductory section is followed by Section 2, which describes the methodology of the study and the data source. Section 3 discusses the results, and Section 4 concludes the study.

2. Methodology of the Study

Our study employs a trade indicators methodology to evaluate Ethiopia's sectoral competitiveness for free trade. Trade indicators are valuable tools for assessing and summarizing countries' trade dynamics and patterns. They are widely used for assessment due to their simplicity and minimal data requirement. The trade indicators employed in our study encompass indicators of comparative advantage and level of protection indicators (nominal rates of protection and effective rates of protection). The data for our analysis is derived from the GTAP 10 database (base year 2014). We aggregated the commodities in GTAP 10 into 16 sectors to extract the necessary information on exports, imports, output, intermediate inputs, and tariff data for our trade indicators analysis. The sectors include Agriculture, Meat and Livestock, Vehicles, Machinery, Cereals, Energy and Extraction, Leather, Textile, Processed Food, Fuel Oil, Light Manufacturing, Plastics, Heavy Manufacturing, Services, Tobacco and Beverages, and Transport3.

2.1. Comparative Advantage Indicators

Comparative advantage indicators help to identify sectors that are likely to expand under a free trade scenario, while level of protection indicators help to predict sectors that may experience increased imports. The classical trade theory predicts that trade patterns are influenced by disparities in relative productivity across countries. Countries tend to export goods with a comparative advantage while importing goods lacking such an advantage. Balassa (1965) made a pioneering contribution to assessing countries' comparative advantage by introducing the Revealed Comparative Advantage (RCA) index. Balassa's RCA, BRCA hereafter, measures the country's sectoral comparative advantage by comparing a country's export profile with the global average. Lafay (1992) proposed its improvement by introducing the Trade Balance Index (TBI), a comprehensive measure that considers both the import and export data. Alternative RCA indexes are also proposed for mathematical and statistical convenience: the Additive Revealed Comparative Advantage (ARCA) by Hoen & Oosterhaven (2006) and the Symmetric Revealed Comparative Advantage (SRCA) by Laursen (2015). Each of these indexes has a unique approach and calculation methodology, enabling us to assess countries' comparative advantages in international trade. While they capture the initial situation before free trade, a post-free trade situation needs to be inferred by intuition. For example, a high RCA suggests a competitive industry, leading to the inference that

[3] Sectoral aggregation list is shown in Appendix table A1

the industry, currently constrained by tariffs imposed by trade partners, would likely experience enhanced visibility of its competitiveness, resulting in further growth in exports and output.

2.1.1. Balassa's Revealed Comparative Advantage

The BRCA index is calculated by comparing the share of a specific product's exports in a country's total exports with the share of the same product's exports in the total global exports.

It is calculated as follows:

$$BRCA_{cg} = \left(\frac{X_{cg}}{X_c}\right) \Bigg/ \left(\frac{X_{wg}}{X_w}\right)$$

Where

X_{cg} : exports of good g by country c

X_c : total exports of country c

X_{wg} : world exports of good g

X_w : total world exports

The BRCA value ranges from 0 to positive infinity. A country is said to have a revealed comparative advantage if the value of the index exceeds 1, which implies the country exports more than the world average. Conversely, if the index falls below 1, it indicates a revealed comparative disadvantage for the country.

2.1.2. Symmetric Revealed Comparative Advantage

The asymmetric criticism of BRCA prompted the development of symmetric RCA. Laursen (2015) transformed the asymmetric form of BRCA to a symmetric form as shown in the following formula.

$$SRCA_{cg} = \frac{BRCA_{cg} - 1}{BRCA_{cg} + 1}$$

Where,

$BRCA_{cg}$: Balassa's RCA of good g in country c

The SRCA values range from -1 to 1. A positive SRCA value indicates a country has a comparative advantage in a specific sector, implying that it exports more than the world average. Conversely, a negative SRCA value indicates a lack of comparative advantage in that sector, indicating that the country's exports are lower than the world average.

2.1.3. Additive Revealed Comparative Advantage

The additive RCA considers the difference in the share of a country's total exports of a particular sector in its total exports and the share of world exports of the same sector in total world exports. It is calculated using the following formula:

$$ARCA_{cg} = \frac{X_{cg}}{X_c} - \frac{X_{wg}}{X_w}$$

Where,

X_{cg} : exports of good g by country c

X_c : total exports of country c

X_{wg} : world exports of good g

X_w : total world exports

The ARCA index values range from -1 to 1. A value of zero indicates that the sector's export share is equivalent to that of the reference countries. If the index exceeds zero, it signifies that the country has a revealed comparative advantage, whereas a value below zero indicates a revealed comparative disadvantage for the country.

2.1.4. Trade Balance Index

The trade balance index is calculated by considering the net value of trade, which includes imports and exports, normalized by total trade (i.e., the sum of exports and imports). It is calculated as follows:

$$TBI_{cg} = \frac{(X_{cg} - M_{cg})}{X_{cg} + M_{cg}}$$

Where

X_{cg} : Exports of good g by country c

M_{cg} : Imports of good g by country c

The TBI index values range from -1 to +1. A positive TBI value indicates the country's comparative advantage, while a negative TBI value signifies a comparative disadvantage.

2.2. Level of Protection Indicators

Revealed Comparative Advantage (RCA)'s straightforward narrative of competitiveness is rarely realized due to the presence of many other factors, such as a country's tariff protection, inter-sectoral linkages within the domestic economy, and interactions among members of an FTA. Missing these indirect and hidden factors, such as simple indicators, tends to fail in precisely predicting the consequences of free trade. Among these factors, the level of protection plays the most important role in predicting the direct impact of tariff removals on domestic industries. For these purposes, the level of protection indicators, NRP and ERP, is employed.

2.2.1. Nominal Rates of Protection

NRPs are tariff rates imposed on the output. They indicate the extent to which domestic producers are protected from international competition through tariffs. A higher NRP value signifies a heightened level of trade protectionism (higher prices on imported goods to safeguard domestic industries). Sectors protected with higher tariffs are expected to face greater challenges when exposed to free trade. These industries are more likely to experience negative consequences as they encounter increased competition from foreign counterparts. Conversely, sectors with lower tariffs are expected to be less affected, as they are relatively less protected and open to international competition.

2.2.2. Effective Rates of Protection

ERP provides valuable insight into the degree of protection granted to domestic industries through tariffs applied to both final products and intermediate inputs. It quantifies the percentage change in the value-added of a particular industry when subject to tariffs, as compared to operating under free trade. It is calculated using the following formula:

$$ERP_j = \frac{V_j - V^*_j}{V^*_j} * 100$$

Where,

V_j : Value added under tariff (before trade liberalization)

V^*_j : Value added without tariff (after trade liberalization)

To calculate V_j and $V^*{}_j$ we used the following formula:

$V_j = Z_j - X_j$

$V^*{}_j = Z^*{}_j - X^*{}_j$

Where,

Z_j : Output of the jth good with tariff

X_j : Intermediate inputs used by the jth sector J with tariff

$Z^*{}_j$: Output of the jth good under free trade

$X^*{}_j$: Intermediate inputs used by the jth sector under free trade

While output and intermediate input under tariff are observed, those under free trade are hypothetical and thus need to be calculated by removing the effects of tariffs on them using the following formula:

$Z_j^* = \frac{Z_j}{1+T_j}$

$X_j^* = \frac{X_j}{1+T_j}$

Where

T_j : tariff rate on the jth sector

A positive ERP indicates that the sector benefits from the protection system, resulting in resource gain from other less-protected sectors compared to free trade (Balassa and Associates, 1982). However, sectors with a high positive ERP would face challenges from international markets once the protection is removed in a free trade environment (Diakantoni & Escaith, 2014). By contrast, a negative ERP arises when tariffs on intermediate inputs exceed tariffs on final outputs. This situation reduces competitiveness for sectors operating under the protective tariff regime.

3. Results of the Study

The results from the four comparative advantage indicators show similar outcomes for sectors with the highest comparative advantage (

Table **1**). BRCA, SRCA, and ARCA report that agriculture, meat and livestock, leather, transport, cereal, and service sectors demonstrate a comparative advantage; TBI shows a slight difference. The validation of the transport sector's comparative advantage necessitates careful deliberation. This result is attributed partly to the prevailing dominance of Ethiopian Airlines in the African air transport market, which significantly strengthens Ethiopia's overall comparative advantage in the transport sector. However, as a landlocked country, Ethiopia has been compelled to establish resilient ground transportation systems to mitigate the significant expenses associated with storing goods at ports for prolonged durations. This necessity has consequently catalyzed the growth of robust transport sectors within the nation.

In contrast to these top sectors, the results for sectors with a comparative disadvantage differ across the indicators. This unreliability seems to stem from the nature of these indicators, which largely rely on data on exports, which are observed in the less competitive sectors rarely or only in a limited amount. BRCA and SRCA indicate that fuel oil, plastic, and heavy manufacturing are the sectors that lack a comparative advantage the most and would be significantly negatively impacted under free trade. ARCA indicates that heavy manufacturing, fuel oil, and vehicles lack comparative advantages and would face significant challenges under free trade. TBI, which uniquely exploits data both in exports and imports, indicates that only the agriculture, transport, leather, and meat and livestock sectors possess a comparative advantage. Conversely, fuel oil, plastic, and machinery are identified as sectors lacking comparative advantage and are projected to experience substantial declines under free trade.

Table 1: Results of Comparative Advantage Indicators and Ranking

Sector	BRCA	SRCA	ARCA	TBI	Ranking			
					BRCA	SRCA	ARCA	TBI
Agriculture	23.076	0.917	0.399	0.964	1	1	1	1
Transport	6.079	0.717	0.188	0.203	2	2	2	3
Meat and livestock	3.648	0.570	0.039	0.883	3	3	3	2
Leather	1.989	0.331	0.011	0.196	4	4	5	4
Cereal	1.297	0.129	0.001	-0.573	5	5	6	6
Service	1.135	0.063	0.020	-0.179	6	6	4	5
Textile	0.595	-0.254	-0.015	-0.673	7	7	8	8
Processed food	0.290	-0.551	-0.021	-0.734	8	8	9	10
Light manufacturing	0.230	-0.626	-0.166	-0.812	9	9	16	11
Energy and extraction	0.173	-0.705	-0.038	-0.673	10	10	11	8
Tobacco and beverage	0.171	-0.708	-0.006	-0.662	11	11	7	7
Machinery	0.064	-0.880	-0.059	-0.956	12	12	12	14
Vehicles	0.063	-0.882	-0.089	-0.917	13	13	13	12
Plastic	0.044	-0.916	-0.021	-0.966	14	14	9	15
Heavy manufacturing	0.042	-0.920	-0.141	-0.951	15	15	15	13
Fuel oil	0.000	-1.000	-0.101	-1.000	16	16	14	16

Source: Author's calculation from GTAP database 10 (base year = 2014)

Note: Sectors are sorted by the BRCA ranking.

Turning to the predictions offered by NRP and ERP, we find large discrepancies between them. According to NRPs, textile, leather, tobacco and beverage, meat and livestock, and agriculture sectors are highly protected by tariffs, compared with other sectors (Table 2). Removing such strong protections would lower their output prices significantly and thus negatively affect their value-added under free trade. Relatively lower protections are granted to the service, transport, fuel oil, and cereal sectors. However, it is worth noting that the NRPs do not consider the potential benefits that could arise from tariff removals on inputs, which may limit the prediction power of NRPs. The ERP analysis, which considers protections on inputs additionally, indicates that the fuel oil, light manufacturing, and plastic industries receive substantial levels of protection and would face significant challenges once free trade removes strong protections on them. Fuel oil and light manufacturing, which are predicted to be less affected by NRP, emerged in ERPs as the top two sectors impacted under free trade. The leather and textile sectors are predicted by NRPs to face a significant impact but by ERPs only a marginal impact. The agriculture, meat and livestock, and transport sectors are predicted to face moderate challenges under free trade, which is consistent with the RCA-based predictions (Table 2). Conversely, the vehicles, machinery, and textile sectors are the least protected sectors and thus predicted to face marginal challenges under free trade, while the RCAs predict their negative prospects under free trade.

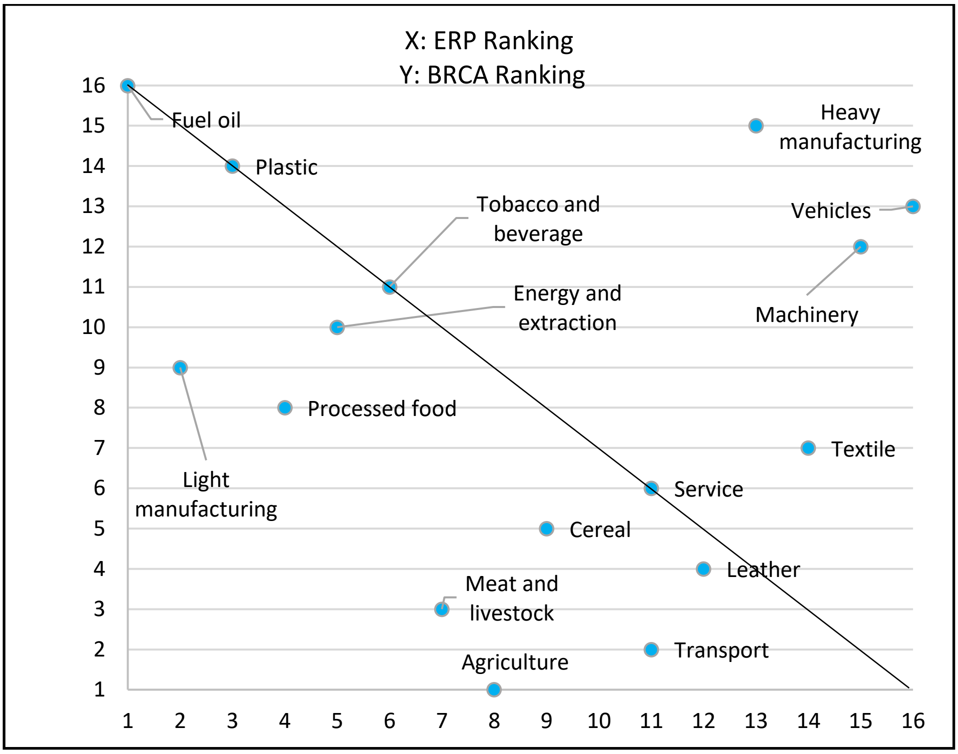
Comparing the results of RCA and the level of protection indicators, using the rankings of BRCA and ERP, we find consistent predictions in some sectors, which are located along the 45-degree line in Figure 3. Both BRCA and ERP predict significant challenges for fuel oil, light manufacturing, plastic, tobacco and beverage, and energy and extraction. The effects on other sectors remain uncertain, making confident predictions challenging. Around the northeastern corner, BRCA predicts a significant challenge in heavy manufacturing, textiles, vehicles, and machinery. Meanwhile, ERP predicts only moderate challenges by tariff removals for these sectors. The agriculture, meat and livestock, and transport sectors are found to be competitive under BRCA, while ERP predicts moderate challenges under free trade. Examination of “sensitive sectors”– leather and textiles – uncovers intriguing disparities in the analyses. BRCA designates leather as competitive, while textiles are deemed less competitive. In contrast, ERP predicts relatively minimal challenges for both sectors under free trade.

Table 2: Results of NRP, ERP, and Ranking

Sector	NRP	ERP	Ranking	
			NRP	ERP
Fuel oil	2	2542	14	1
Light manufacturing	10	651	11	2
Plastic	16	190	5	3
Processed food	15	187	7	4
Energy and extraction	15	177	7	5
Tobacco and beverage	31	114	3	6
Meat and livestock	17	32	4	7
Agriculture	16	22	5	8
Cereal	5	9	13	9
Service	0	-1	15	10
Transport	0	-1	15	10
Leather	33	-253	1	12
Heavy manufacturing	12	-384	9	13
Textile	32	-471	2	14
Machinery	7	-747	12	15
Vehicles	11	-902	10	16

Source: Author's calculation from GTAP 10 database (base year = 2014).
Note: Sectors are sorted by the ERP ranking.

It should be noted that the observed competitiveness, indicated by RCAs, may be attributed either to the innate strength of a sector or to the protection conferred by tariffs on imports. We cannot distinguish them given the observed trade patterns. For example, although the agriculture and meat, and livestock sectors are found to be competitive by BRCA, they are moderately protected as indicated by ERP. Similarly, the light manufacturing and processed food sectors show moderate competitiveness under strong protection. BRCA might be reporting disguised competitiveness for them. ERP, as well as NRP, measures protections granted to a sector, assuming foreign goods are perfectly substitutable with domestic goods. As they are not necessarily fully substitutable (Armington, 1969), the actual impacts of tariff removals would depend on the degree of import penetration and export dependency in a sector.



Source: plotted based on the results of Table 1 and 2

Figure 3. Predictions by BRCA and ERP

4. Conclusion

We used the trade indicators to examine Ethiopia's sectoral competitiveness for free trade. They provide clues for us to predict consequences in trade and subsequently output by sector. The findings of the RCA indicators exhibit consistent predictions for sectors showcasing strong comparative advantages. Agriculture, transport, meat and livestock, and leather sectors possess a comparative advantage across all indicators. The results for sectors with a comparative disadvantage differ across the indicators. Both BRCA and SRCA result indicates that fuel oil, plastic, and heavy manufacturing lack a comparative advantage. ARCA result indicates that heavy manufacturing, fuel oil, and vehicles lack comparative advantages. TBI indicates fuel oil, plastic, and machinery lack a comparative advantage. Level of protection indicators (ERP/NRP) reveals notable inconsistency in the prediction. NRP indicates that leather, textile, tobacco and beverage are highly protected, and predicted to suffer under free trade, consistent with previous studies. Conversely, transport, service, and fuel oil are less protected and are expected to face minimal challenges. On the other hand, the ERP result has shown that fuel oil, light manufacturing, and plastic are highly protected and would face significant challenges under free trade. Vehicles, machinery, textiles, and heavy manufacturing are less protected, and their ERP result signifies that they face marginal challenges under free trade.

The predictions derived from BRCA and ERP demonstrate certain commonalities in identifying weak sectors. Fuel oil, light manufacturing, plastic, tobacco and beverage, and energy and extraction are predicted to face significant challenges by both BRCA and ERP. They, however, bring different predictions in some key sectors in Ethiopia. The agriculture sector, which is often regarded as competitive in Ethiopia (Ben et al., 2006), is indeed found to be competitive by BRCA but predicted by ERP to face moderate challenges. The textile and leather sectors, which are regarded as “sensitive sectors" in prior studies, are predicted by ERP to experience minimal challenges. Meanwhile, the weakness of the textile sector found by BRCA aligns with earlier studies, but that of the leather sector diverges from those.

Based on our study results, we draw the following policy implications and recommendations. Our study reveals the presence of competitive and weak sectors. Notably, the transport, leather, and cereal sectors are found to be competitive and less protected, demonstrating potential for expansion under free trade agreements. However, it is important to acknowledge that alongside the overall gains, there are multiple negative impacts on specific sectors in the economy, such as light manufacturing, plastic, tobacco and beverage, which lack competitiveness and would be adversely affected by trade liberalization.

In light of our findings, to maximize the gains from competitive sectors, the Ethiopian government should take strategic measures aimed at facilitating their expansion. These measures may include investment in infrastructure to ensure smoother transportation of products and inputs, augmentation of productivity and efficiency, enhancement of value addition, improvement in product quality, branding of exports, and integration into the global value chain. Additionally, providing financial incentives to these competitive sectors and creating a favorable regulatory environment that promotes investment and innovation would also increase Ethiopia’s benefits. Investing in workforce development and providing training for workers and managers of small and medium enterprises to acquire essential skills would mitigate losses in the weak sectors and enhance gains in competitive sectors. This comprehensive approach will effectively address negative sectoral impacts while maximizing the broader benefits of free trade for Ethiopia's economy.

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Appendix A: Sectoral Aggregation

Sectors in the GTAP database are aggregated in to 16 sectors for the convenience of our analysis as seen in Table A1.

Table A1: Sectoral aggregation

Sectors	List
Agriculture	sugarcane, sugar beet, plant-based fibers, forestry, fishing, fruits, vegetable, Nuts, oil seeds, Stimulants, cut flower, flower seeds
Meat and livestock	Bovine cattle, sheep and goats, Animal products nec, raw milk, wool, silk-worm cocoons, Bovine meat products, meat products nec, Dairy products,
Vehicles	Motor vehicles and parts, Transport equipment's nec
Machinery	Machinery and equipment's nec
Cereals	Paddy Rice, Wheat, Cereal grains nec,
Energy and extraction	Coal, mineral nec, coal products, mineral products, gas
Leather	Leather products
Textile	Textiles, wearing apparel
Processed food	Food products nec, sugar, processed rice, vegetable oils and fats
Fuel oil	Petroleum, fuel, oil
Light manufacturing	wood products, paper products, publishing, chemical products, pharmaceutical products, ferrous metals, metals nec, metal products, manufactures nec,
Plastic	Rubber and plastic products
Heavy manufacturing	Computer, electronic and optic, electrical equipment,
Service	Dwellings, human health and social work, education, public administration and defense. Recreational and other services, business services, warehousing and supporting activities communication, electricity, real estate activities, insurance, financial services, construction, water, gas manufacture and distribution, accommodation food and service, trade
Tobacco and beverage	Beverages and tobacco products
Transport	Transport nec, water transport, air transport

Source: Authors aggregation from GTAP 10 database

Modeling The Current Land Suitability and Future Dynamics for Coffee (Coffea Arabica L.) Cultivation Under Climate Change Scenarios in Western Ethiopia with Maxent Model

Tesfaye Akafu[1], Diriba Korecha[2], Weyessa Garedew[1], Abayineh Amare[1]

Abstract

Coffee is the world's most popular beverage crop and the second-most traded commodity next to petroleum products. However, the production of coffee is heavily dependent on specific environmental conditions, making it vulnerable to the effects of climate change. Therefore, studying coffee crop responses to climatic conditions is crucial to developing strategies to support coffee crop resilience. This study aimed to model the current land suitability and future dynamics for coffee (Coffea arabica L.) cultivation under climate change scenarios in West Wallaga Zone, Western Ethiopia. The study used bioclimatic variables and the current occurrence data of Coffea arabica. Modeling was done for current and anticipated shared socioeconomic pathways (SSP) at intermediate (SSP245), and very high (SSP585) emissions scenarios for 2050 and 2070. ArcGIS was used for overall data processing, whereas MaxEnt (Maximum Entropy) model was used for predicting coffee suitability. The result showed 5294.30 km2 (50.8%) of the total land in the area is presently suitable for Coffea arabica cultivation. The predicted model shows 19-24% of the current suitable coffee cultivation areas may become unsuitable, while 20-22% more areas may become suitable for coffee cultivation. Based on Maxent model, the total suitable land for Coffea arabica cultivation could be reduced by 40.3 km², and 136.11 km² in 2050 under the SSP245, and SSP585 scenarios, respectively. The model simulation for 2070 indicates declines of 164.6 km2, and 177.8 km2 in SSP245, and SSP585, respectively. Therefore, designing a plan for species conservation and implementing climate change adaptation strategies are essential for sustaining the suitability of existing coffee growing areas.

Keywords: Climate Change; Coffea arabica; ArcGIS; MaxEnt; Land Suitability Modeling

[1] Jimma University, College of Agriculture and Veterinary Medicine, Jimma, Ethiopia
[2] University of California Santa Barbara, Santa Barbara, California, USA
Corresponding author: tesfayeakafu65@gmail.com

1. Introduction

Coffee is the world's most popular beverage crop and the second most traded commodity next to petroleum products (DaMatta et al., 2019). Nearly 25 million farmers globally, the majority of whom are smallholders, are engaged in the cultivation of coffee across an estimated 80 tropical countries (Bermudez et al., 2022). Brazil leads global coffee production and exports, followed by Vietnam and Colombia (Bilen et al., 2023). The European Union, the United States, and Japan are major consumers and importers (Bermudez et al., 2022). While over 125 coffee varieties exist (Davis and Rakotonasolo, 2021), Arabica (Coffea Arabica Linnaeus) and Robusta (Coffea Canophera) coffees account for 99% of worldwide bean production (DaMatta, 2018). These are also responsible for 57% and 43% of the world coffee market, respectively (ICO, 2022).

Coffee production requires specific agroecological conditions (DaMatta et al., 2019). Temperature and precipitation patterns are crucial factors that have a significant impact on coffee production. This sensitivity to climatic conditions makes coffee, particularly C. arabica, highly vulnerable to the negative impacts of climate change (Bunn et al., 2015). The optimal average mean annual temperature ranges for C. arabica lie between 18–23 ^{o}C (Davis et al., 2012). However, certain C. arabica cultivars had significantly adapted to mean temperatures of 24–25 ^{o}C (DaMatta, 2018). The rainfall requirements are between 1600–2000 mm (Chemura et al., 2015), with a dry period ranging from 3–4 months near to harvest period (DaMatta et al., 2018).

In Ethiopia, the average yearly temperature has risen by 1^{o}C over the last forty years, with significant fluctuations in precipitation trends showing increases in some regions and decreases in others. However, there has been a documented 10% reduction in rainfall across Ethiopia (World Bank, 2020). Projection of the high emission scenario revealed that mean annual temperature will rise by 1.8^{o}C and 3.7^{o}C by 2050 and 2080, respectively, accompanied by an overall increase of total annual precipitation from 3 mm to 6 mm (USAID, 2024). Nevertheless, there is high uncertainty in predicted precipitation distributions in space and time (MFA, 2018). Species (IPCC, 2022), especially coffee varieties, may experience heightened climatic pressures in their natural habitats, as they are particularly vulnerable to the effects of climate change (DaMatta et al., 2019). Therefore, examining the response of coffee crops to climatic conditions is crucial in developing strategies to support the crop's resilience toward the adverse impacts of climate change.

One way to investigate how climate change affects coffee production in coffee-producing regions is to employ contemporary analytical instruments like species distribution modeling (SDM). The SDM identifies the distribution among environmental variables and biophysical characteristics from the species occurrence and predicts the suitability of the habitat across space and time (Elith & Leathwick, 2009). Recent national-level modeling studies, which depend on projections of rising temperatures and shifting precipitation patterns, have predicted noticeable declines in the areas suitable for Arabica coffee cultivation in Ethiopia(Moat et al., 2017). Interestingly, regional studies by Bunn et al. (2015) and Ovalle-Rivera et al. (2015) predicted that there is less decline in areas for Arabica coffee production, and in some cases, suitability areas could increase over some coffee-producing parts of Ethiopia. This indicates that the findings are not easily generalizable regionally, with some contradicting each other and obscuring national context studies. As a result, greater identification of the impact of climate change on particular locations or local coffee areas will be required.

West Wallaga coffee is a wet-processed varietal grown in Western Ethiopia at elevations between 1493 m and 1798 m above sea level. In this zone, farmers and stakeholders in the coffee industry have been noticing a gradual decline in overall coffee yield. Good harvests, which were previously a yearly occurrence, have now become sporadic, manifesting only once every second or even third year. Furthermore, in their study, Moat et al. (2017) made a significant prediction that the coffee-producing area of Wallaga is likely to face a high level of vulnerability to climate change. However, a more recent investigation by Chemura et al. (2021) provided contrasting insights. The contrasting conclusions of the two studies underscore the complexity and uncertainty often associated with climate change projections, emphasizing the critical need for sustained research to fully understand and prepare for the potential consequences facing the study area. Thus, this study aimed at modeling the current land suitability and future dynamics for coffee (Coffea arabica L.) cultivation under climate change scenarios in West Wallaga Zone, Western Ethiopia

2. Methods and Materials

2.1. Study Site Descriptions

The research was conducted in the West Wallaga Zone, located in western Ethiopia (Figure 1). This zone consists of 23 districts, with 20 being rural and 3 urban administrations. Gimbi Town is the capital of the zone. The West Wallaga Zone situated between 9o 00’ N latitude and 35o14’E longitude, bordered by Kelam

Wallaga Zone to the west, Benishangul Gumuz Region to the north, and East Wallaga Zone to the east. It also adjoins Illu Abbaa Boora, Buno Bedele Zones, and Benishangul Gumuz to the southeast. The surface area of the zone is 10,430.28 km2. According to Hurni (1998), the agroecology of the West Wallaga Zone has been classified into three zones: lowland 19.1% (1100–1700 m), midland 78.4% (1701–2200 m), and highland 2.5% (2201–2850 m). The zone exhibits monomodal rainfall patterns, with the wet season occurring from June to September (Korecha & Barnston, 2007).

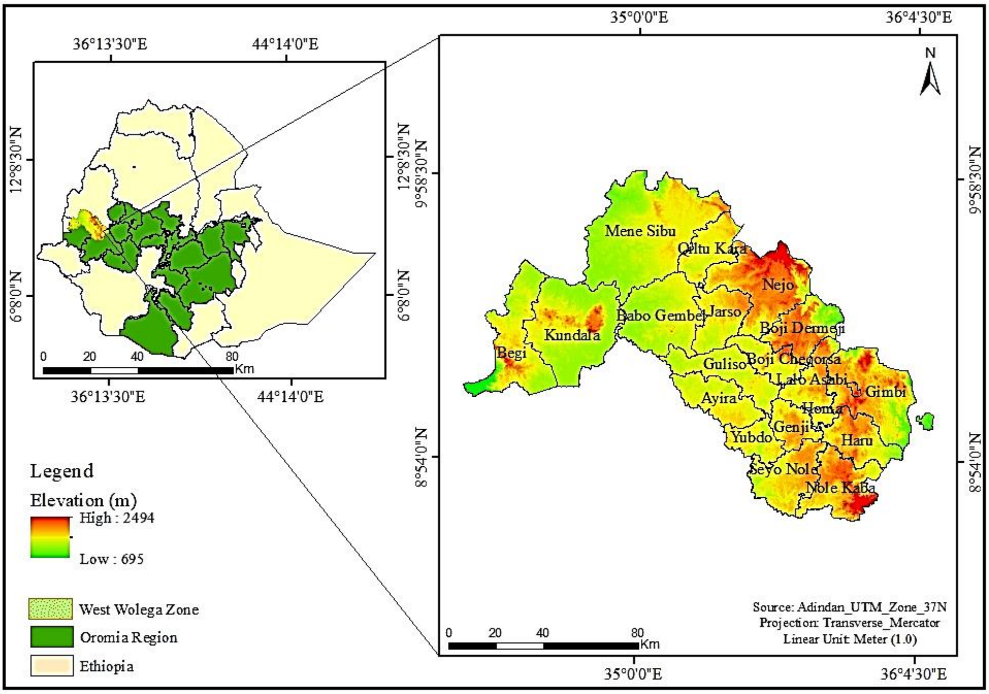

Figure 4: Study area map

2.2. Data Collection

A total of five hundred geographic coordinate points were collected from existing locations where C. arabica naturally occurs in the west Wallaga zone. To map the current land suitability, climate data averaged over 30 years (1970–2000) was downloaded from WorldClim at 30 arc-second (~1 km2) spatial resolution. The database contains 19 bioclimatic variables. To predict land suitability in 2050 and 2070, ensembled bioclimatic variables from four General Circulation Models (GCMs) in the Coupled Model Intercomparison Project Phase (CMIP6) were used. These models include the HadGEM3-GC31-LL, ACCESS-CM2, INM-CM5-0, and the MRI-ESM2-0, all accessible at www.worldclim.org at a 30 arc-second resolution. The future prediction used shared socioeconomic pathways (SSP) at intermediate (SSP245), and very high (SSP585) emissions scenarios.

2.3. Modeling Approach

The study used ArcGIS 10.5 for data processing and MaxEnt version 3.4.4 to model suitable cultivation areas for C. arabica. In the Maxent model, we used ASCII bioclimatic variables as environmental predictors, and the geographic coordinates of coffee as sample data. Out of the 477 C. arabica occurrence samples, 75% were assigned for model training, while the remaining 25% for model validation.

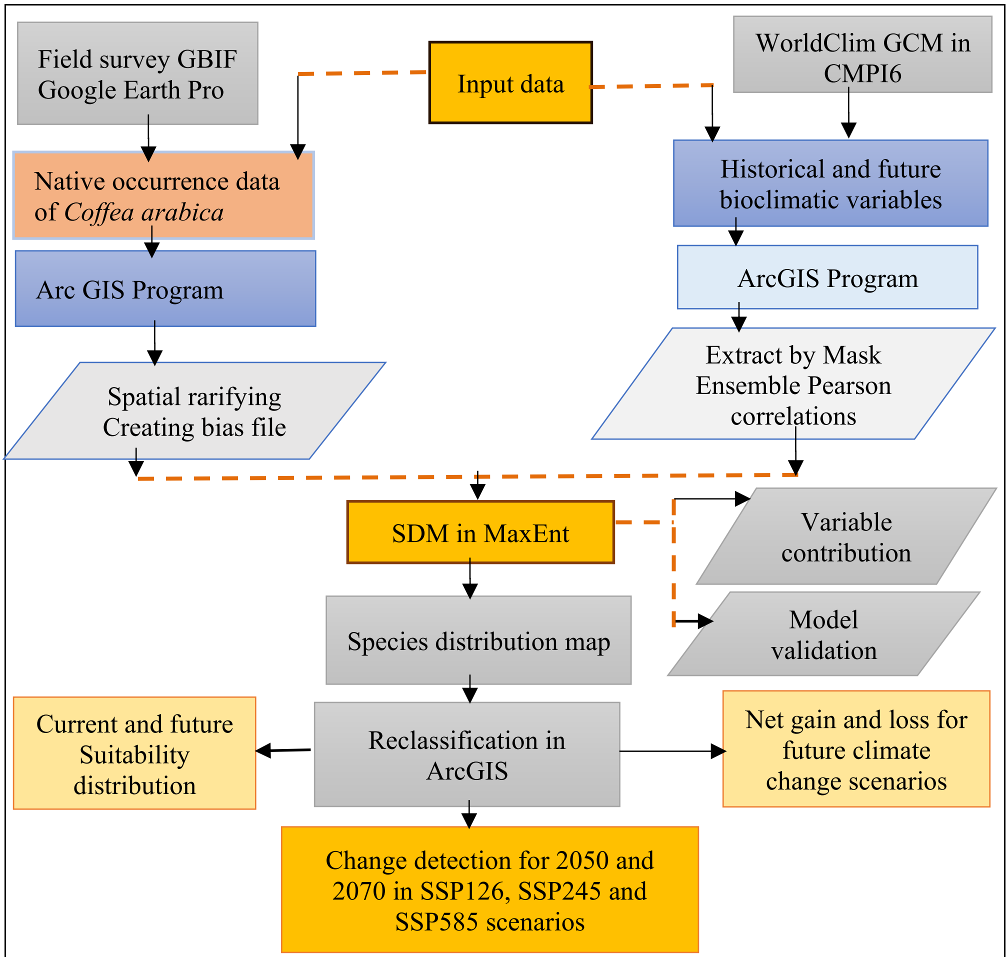

Figure 2: Schematic representation of the overall modeling procedures

Logistic regression was applied in the model the likelihood of coffee plantation in each pixel (Elith et al., 2011). The model was run using independent datasets with 11 bioclimatic variables in 15 replicates for current and projected climates in 2050 and 2070, considering moderate (SSP245), and very high (SSP585) emissions scenarios. Figure 2 summarizes the overall modeling approach and model output.

3. Result and Discussions

3.1. Model Evaluation

The model performance for the current, 2050, and 2070 suitability models is displayed in Figures 3 (a-e). In the figures, the red line indicates the average outcome derived from 15 individual runs, while the blue shades indicate fluctuation around the mean value and one standard deviation. The MaxEnt model consistently demonstrated accuracy and reliability, as reflected by the impressive range of AUC values between 0.77 and 0.78. These values underscore the model's exceptional performance in predicting the presence/absence of C. arabica distribution in various scenarios (Elith et al., 2006). These results corroborate the findings documented by many authors, including (Jayakody et al., 2024; Nguyen & Leung, 2022).

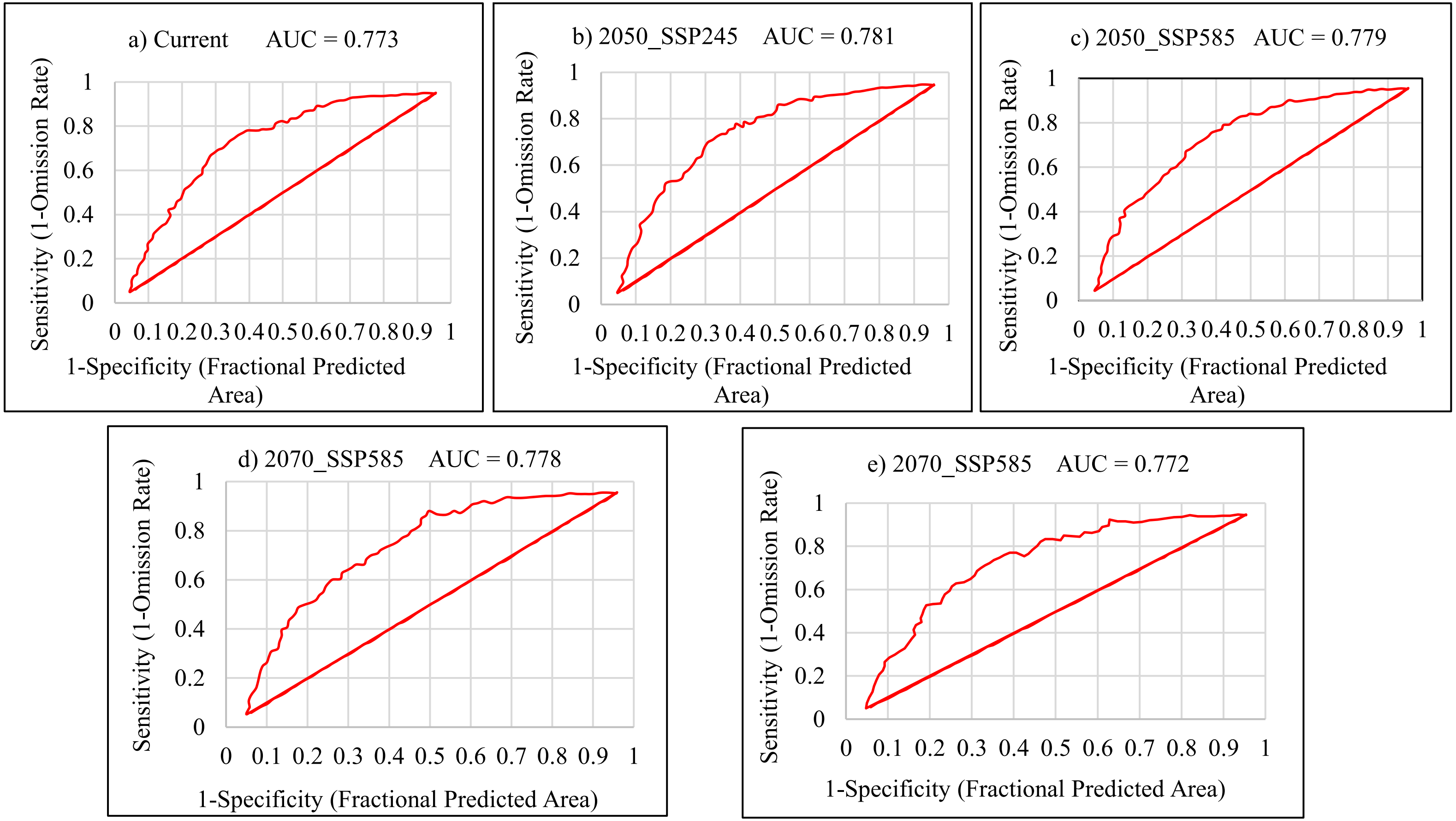

Figure 3: The ROC curve averages over replicate runs for the current and predicted suitability of C. arabica distribution in the West Wallaga Zone, Western Ethiopia

3.2. Environmental Variables Contribution

Table 1 displays environmental variables entered in the Maxent for model simulation and their predicted contributions under the climate change scenario. The warmest month's maximum temperature and the mean diurnal range temperature are among the temperature variables that had the higher predictive contribution for the present and future coffee suitability models. Of the precipitation variable, precipitation in the coldest quarter was the most significant factor for land suitability prediction. This was followed by precipitation in the driest month and annual precipitation. Other variables had less influence on the model, with the driest quarter's mean temperature being the least important. Overall, temperature variables were a key factor in determining Arabica cultivation suitability under all climate change scenarios. This aligns with previous studies by Bunn et al. (2015) and Gomes et al. (2020) documenting the importance of temperature in coffee distribution modeling. In contrast, Chemura et al. (2015) in Zimbabwe and Benti et al. (2022) in Jimma Zone, Ethiopia,

Table 1: Estimates of bioclimatic variables' contributions to the Maxent model

Code	Bioclimatic variables	Percentage contribution				
		Current	2050		2070	
			SSP245	SSP585	SSP245	SSP585
BIO1	Annual Mean Temperature	0.7	4.1	7.8	2.9	4.1
BIO2	Mean Diurnal Range	16.4	18.6	16.7	16.5	18.2
BIO3	Isothermality (BIO2/BIO7) (×100)	2.9	4.1	1.5	8.4	3.2
BIO4	Temperature Seasonality	4.3	9.1	10.2	9	9.6
BIO5	Max Temperature of Warmest Month	34.3	13.3	14.9	18.4	15.9
BIO7	Temperature Annual Range	5.5	0.9	2	2.1	1.5
BIO9	Mean Temperature of Driest Quarter	0.3	0.3	0.9	0.2	0.8
BIO12	Annual Precipitation	6.9	6.9	8.6	7.5	7
BIO14	Precipitation of Driest Month	13.7	14.9	15.3	13.2	14.3
BIO15	Precipitation Seasonality	6.2	2.9	1.8	6.6	0.8
BIO19	Precipitation of Coldest Quarter	8.8	24.9	20.3	15.2	24.6

Current and future suitability

The receiver operating curve (ROC) results in an AUC value that ranges from 0 to 1, indicating the level of overall model accuracy to discriminate unsuitable areas from suitable ones. However, following prior research on the modeling of species distribution (Abebe et al., 2024; Gruter et al., 2022; Zafirah et al., 2021), we reclassified this value into four suitability classes: <0.2 (unsuitable), 0.2–0.4 (low suitable), 0.4–0.6 (moderately suitable), and >0.6 (high suitable). The distributions of coffee under the current and predicted scenarios of climate change are shown in Figure 4a-e. In the current suitability map (Figure 4a), only 989.64 km2 (9.5%) of the area is classified as high coffee suitability, followed by 2743.90km2 (26.3%) moderately suitable, 3069.62 km2 (29.4%) low suitable, and a high proportion 3627.98 km2 (34.9%) of the study area falls under unsuitable.

The model predictions presented in Figure 4b-e for 2050 and 2070 revealed varying distributions in climatic suitability for coffee cultivation. The results for all climate change scenarios indicated significant potential for land transformation (Table 2). This suggests that areas currently classified as unsuitable for coffee cultivation may witness a shift in their classification to become suitable (low to high) for coffee cultivation zones. Conversely, areas deemed ideal for coffee cultivation may be unsuitable. Additionally, the transfer of one suitable area of land to a different suitability classification could be observed. This corroborates the findings of Davis et al. (2012).

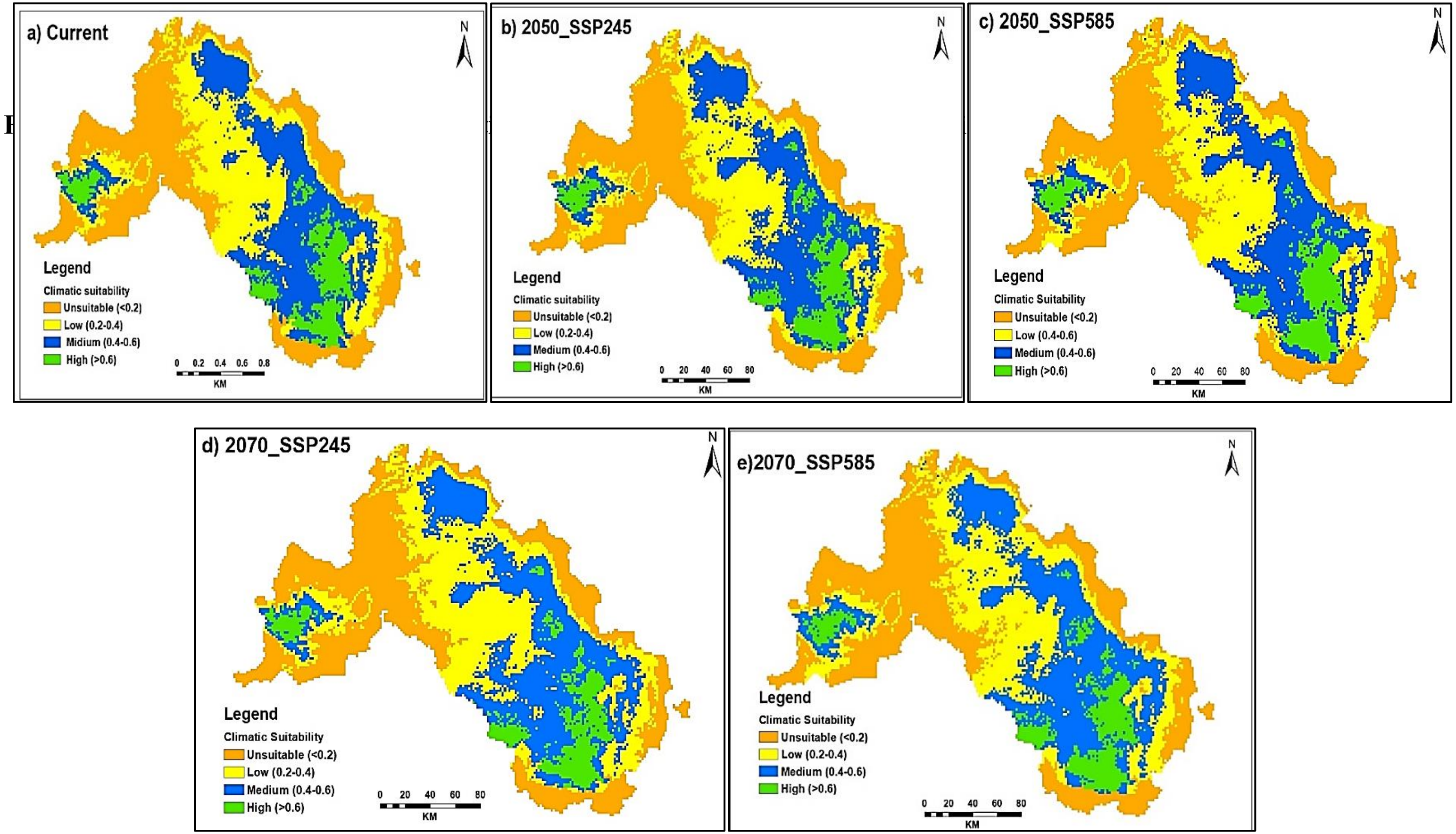
a) Current
N
Legend
Climatic suitability
Unsuitable (<0.2)
Low (0.2-0.4)
Midium (0.4-0.6)
High (>0.6)
0 0.2 0.4 0.6 0.8
KM
b) 2050_SSP245
N
Legend
Climatic suitability
Unsuitable (<0.2)
Low (0.2-0.4)
Medium (0.4-0.6)
High (>0.6)
0 20 40 60 80
KM
c) 2050_SSP585
N
Legend
Climatic Suitability
Unsuitable (<0.2)
Low (0.4-0.6)
Medium (0.4-0.6)
High (>0.6)
0 20 40 60 80
KM
d) 2070_SSP245
N
Legend
Climatic Suitability
Unsuitable (<0.2)
Low (0.2-0.4)
Medium (0.4-0.6)
High (>0.6)
0 20 40 60 80
KM
e)2070_SSP585
N
Legend
Climatic Suitability
Unsuitable (<0.2)
Low (0.2-0.4)
Medium (0.4-0.6)
High (>0.6)
0 20 40 60 80
KM

Table 2: Coffee arabica suitability distribution under future climate change scenarios in the West Wallaga zone, Western Ethiopia

Period	Scenarios	Land suitability area in square kilometers and percentage							
		Unsuitable		Low suitable		Moderate suitable		High suitable	
		km^2	%	km^2	%	km^2	%	km^2	%
2050	SSP245	3532.14	33.86	3143.23	30.13	2808.49	26.92	947.27	9.08
	SSP585	3659.93	35.09	2958.50	28.36	2862.66	27.44	950.05	9.11
2070	SSP245	3491.86	33.48	3181.43	30.50	2883.49	27.64	874.35	8.38
	SSP585	3614.79	34.65	2946.69	28.25	2932.11	28.11	937.55	8.99

3.4. Predicted suitability losses and gains

The predicted change in climate is likely to negatively impact the areas currently suitable for coffee cultivation. As evident from Figure 5 (a-d) the predicted model indicates that certain areas of the west Wallaga zone may experience a significant loss in the current suitability for coffee cultivation, while other areas that were currently unsuitable in this zone are likely to witness an expansion in the availability of suitable land for fostering coffee cultivation. This shift in coffee cultivation patterns is expected to create a mixed impact across the zone, with some individuals facing challenges while others find new opportunities to enhance their agricultural practices. Our research is consistent with the conclusions drawn by Moat et al. (2017), which indicated that a significant segment of the Wallaga coffee areas is likely to face a substantial level of vulnerability to the projected effects of climate change.

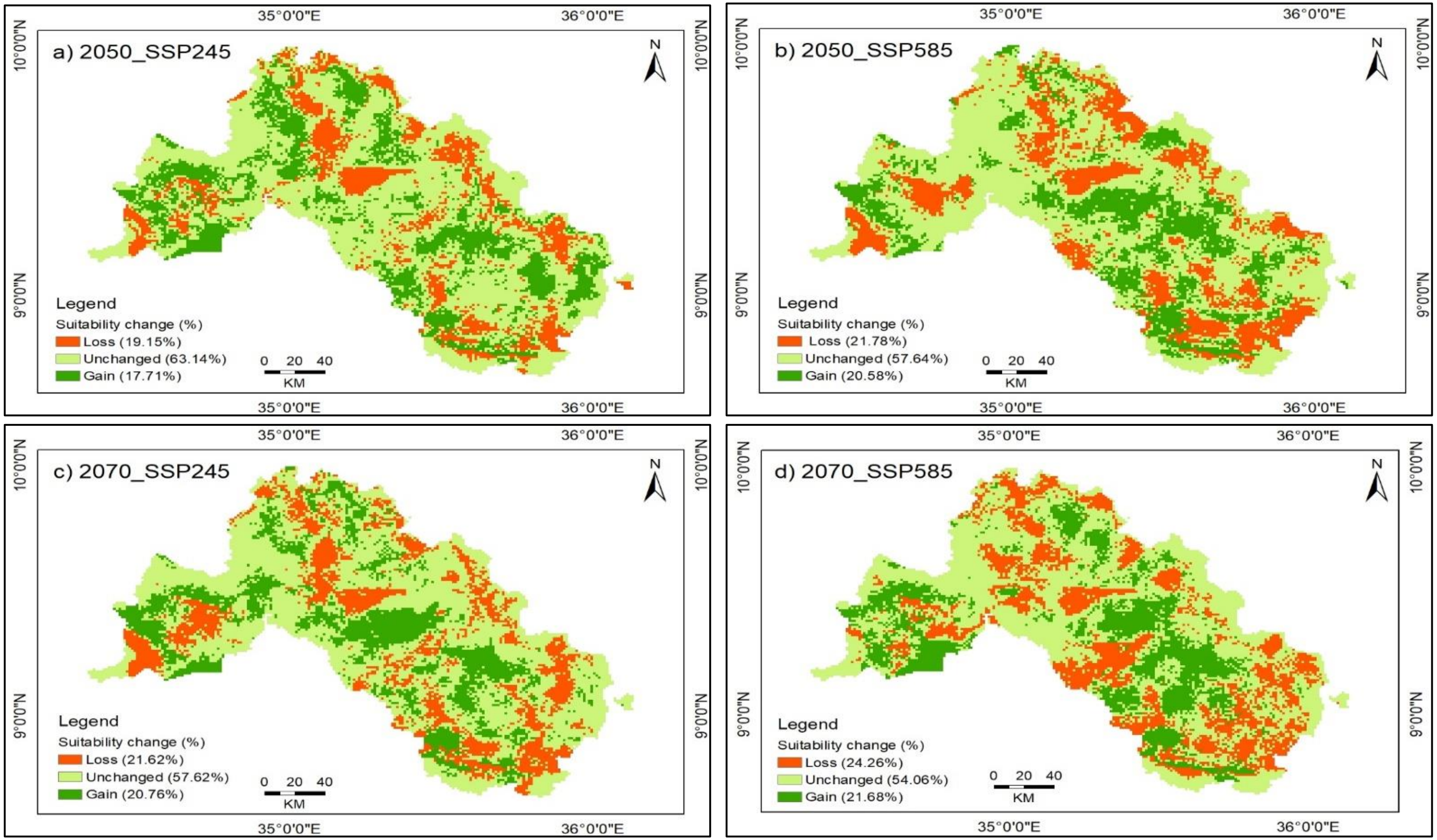

Figure 5: The predicted suitability changes for Coffea arabica cultivation under climate change scenarios in the West Wallaga Zone, Western Ethiopia

3.5. Predicted change in total suitability areas

The land suitability area for coffee cultivation under current and future climate change scenarios are shown in Figure 4. Whenever several authors designate distinct thresholds between suitable and unsuitable groups of criteria, there is no clear procedure for defining thresholds; instead, the model classification is based on a single threshold value derived from the maxent outputs. In the current study, the 10th percentile training presence logistic threshold values (Phillips et al., 2006) were used to reclassify the average prediction model results into binary distinct suitable and unsuitable areas using ArcGIS. The classification system denotes that values falling below the designated threshold are believed unsuitable, whereas values above the specified threshold signify potential suitability for C. arabica cultivation(Merow et al., 2013). The study result reveals that the potential land areas suitable for C. arabica cultivation could be reduced in all projected climate change scenarios as compared to the currently suitability areas (Table 3). The reduction in areas suitable for C. arabica cultivation has also been documented at both regional and global levels (Bunn et al., 2015; Gruter et al., 2022). This underscores the urgency of collaborative efforts and tailored strategies to mitigate the adverse effects on coffee production.

Table: 4: Predicted total suitability changes in Coffea arabica cultivation compared to current areas in the West Wollega zone, Western Ethiopia

Period	Scenarios	Total suitability area (km2) and % of land				Total suitability change	
		Unsuitable		Suitable		Δ (Km^2)	Δ (%)
		Km^2	%	Km^2	%		
Current	Baseline	5135.98	49.25	5294.30	50.75	-	-
2050	SSP245	5176.25	49.63	5254.03	50.37	-40.28	0.38
	SSP585	5272.08	50.55	5158.20	49.45	-136.11	1.3
2070	SSP245	5300.55	50.82	5129.73	49.18	-164.58	1.57
	SSP585	5313.75	50.95	5116.53	49.05	-177.77	1.7

4. Conclusions

The research employed ArcGIS and MaxEnt model to map the current land suitability and future dynamics for Coffea arabica cultivation under climate change

scenarios. The study used bioclimatic variables and coffee presence data for the suitability model. The analysis considered the current conditions as well as two distinct climate change projection periods, specifically 2050 and 2070, under three climate change scenarios. Based on the MaxEnt output, approximately half of the lands in the West Wollega Zone were identified as currently suitable for Coffea arabica farming. The projected result revealed that while current coffee cultivation areas may see a significant decline in their suitability, certain areas that were presently unsuitable for coffee cultivation will become suitable. The magnitude of the predicted losses and gains vary across scenario. In addition, a decrease in the total land area appropriate for coffee cultivation has been detected across all climate change scenarios in comparison to the current total land deemed suitable for coffee production. Overall, the sustainability of Coffea arabica cultivation is facing significant challenges in a substantial portion of the coffee-growing areas within the west Wollega Zone. This highlights the need to prioritize the development and implementation of effective adaptation and mitigation measures to ensure the long-term sustainability of coffee cultivation in the face of evolving climatic conditions.

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Land use and land cover dynamics in Yayu Coffee Forest Biosphere Reserve, Southwest Ethiopia

Ferede Abuye Jeldu[1]

Abstract

The Yayu Coffee Forest Biosphere Reserve (YCFBR) in Southwest Ethiopia is a vital natural resource for the local economy and the global community. However, the reserve is facing significant challenges due to land use and land cover (LULC) changes resulting from anthropogenic disturbances. To address this issue, it is instrumental to have up-to-date information on the spatial and temporal LULC dynamics of these changes. Therefore, this research examines the dynamics of LULC in the YCFBR over a 26-year period from 1996 to 2022 using Landsat satellite imagery. The study classified the land use and land cover into six categories, namely dense forestland, farmland, grazing land, open forestland, settlement land, and shrub land. The results showed that, before biosphere establishment, dense forest land decreased by 6,947.75 ha (-5.02%) (1996-2010), then increased to 6,094.67 ha (4.40%) after biosphere establishment (2010-2022), resulting in a net gain of 29,411.4 ha (21.22%) over the study period (1996-2022). Similarly, open forestland decreased by 24,218.46 ha (-17.49%) before biosphere establishment, then it increased to 23,017.29 ha (16.62%) after biosphere establishment with net change of 33.7 ha (0.02%) over the study period (1996-2022). This indicates a considerable afforestation effort of dense forests after the establishment of the biosphere. Factors driving afforestation in the area include participatory forest management, national green development programs, community engagement on conservation of YCFBR and different initiatives involved on forest conservation activities by organizations such as nature and Biodiversity Conservation Union (NABU) and others. This research highlights the positive impact of biosphere reserve establishment on forest conservation and the importance of government support and community involvement in sustainable land use practices.

Keywords: conservation interventions, deforestation, driving afforestation, participatory forest management

[1] PhD in Climate Change and Bioenergy Development; Mettu University, Bedele Campus, Bedele, Ethiopia
Mobile: +251987989081, Email: feredeabuye@gmail.com

1. Introduction

A biosphere reserve (BR) is a 'living laboratory' for testing out and demonstrating integrated management of land, water and biodiversity (UNESCO, 2023). A biosphere reserve is a living laboratory established to test and promote a balanced relationship between humans and nature (UNESCO, 2013). BR benefits both people and the environment by focusing on balancing nature conservation with sustainable development (SD) for and with communities. The three main functions of BR are conservation, which supports conserving biodiversity, restoring and enhancing ecosystem services, development and contributing to sustainable development and building human well-being, logistic support by training, education & supporting climate change mitigation and adaptation (UNESCO, 2023). From this standpoint, monitoring biosphere reserves in their long-term sustainability is necessary (DeVries et al., 2016). Therefore, this biosphere reserve management needs to be strengthened by focused research for sustainable development and support for mitigation and adaptation to climate change and other global environmental changes (Špulerová et al., 2023). Because this creates the possibility of evaluating current results and development and changes in the BR in the context of other socio-economic activities. If BR cannot ensure balanced fulfillment of the three functions of the BR, it leads to withdrawal from UNESCO & simple announcement submitted to the MAB Secretariat (MAB, Article 9, Statutory Framework) (UNESCO, 2023). For instance, the withdrawal of the Untere Lobau Biosphere Reserve, Austria, established in 1977, however reviewed in 2006 and consultation with stakeholders and local authorities confirmed that this BR would not meet the stated function, and the stakeholders preferred national park status, then withdrew (UNESCO, 2013).

Southwestern moist Afromontane forests are providing an important source for the surrounding environment and international communities by reducing the GHGs concentration (DeVries et al., 2016). The Moist Afromontane forest of Ethiopia is mainly found in the Southwest escarpment of Ethiopia (Mengesha Asefa et al., 2020), where most of the country's Biosphere reserves (Yayu, Kafa, Sheka and Majang) are located and known as "Ethiopia's green lungs" (Semegnew Tadese et al., 2021). Currently, there are about 738 biosphere reserves in the world, similarly, 75 are found in Africa, whereas, Ethiopia has five internationally recognized BRs namely Kafa biosphere reserve, nominated in 2010, Yayu Coffee Forest Biosphere Reserve nominated in 2010, Sheka biosphere reserve nominated in 2012, Lake Tana biosphere reserve nominated in 2015 and Majang Forest Biosphere reserve in 2017

(UNESCO, 2023). However, the inconsistency between the objectives and actual management of these reserves is a pressing concern (Ferreira et al., 2020). Ethiopia is not unique in this, and referred to as “paper parks” highlight the inconsistency between the official designation of protected areas and the reality on the ground (Oostdijk, 2021).

Few studies were conducted about this YCFBR before, but they are very rare. Most of the studies so far have concentrated on the impacts of human use and implications for in situ conservation of wild Coffea Arabica. As well as the impacts of human activities on wildlife, genetic variability in Yayu coffee and different case studies were conducted (Semegnew Tadesse et al., 2023), but they were not focused on the continuous state of forest cover change in YCFBR. The YCFBR is a unique ecosystem comprising three distinct zones, namely the core, buffer, and transitional zones. However, the reserve is facing significant challenges due to LULC changes. While previous studies have explored land use and land cover changes within the entire biosphere reserve, there exists a research gap in understanding the specific dynamics caused by human interference in the buffer and transitional zones. The core zone of the YCFBR is legally protected according to the principles of biosphere reserve management and remains largely unchanged due to minimal human interference. Thus, analyzing this area repeatedly is redundant and does not provide new insights into LULC dynamics, which is similar to the previous studies.

Therefore, this study focuses on the buffer and transitional zones, which are more dynamic and influenced by human activities. Excluding the core zone from analysis is an innovative approach that avoids redundancy and can serve as a model for future LULC dynamics studies in similar contexts. Although several studies have been conducted on LULC change in Ethiopia, none of them have specifically analyzed the spatiotemporal dynamics of land use and land cover in relation to deriving forces and significant impacts of the biosphere reserve in the YCFBR. Additionally, at present, no comprehensive study on the factors that drive land use change in the YCFBR exists.

This study started cutting point from 1996 for land use dynamics, because of the following scientific relevance for this study’s objectives. In 1996, Ethiopia adopted a new forest policy aimed at addressing issues related to deforestation, forest degradation, and biodiversity conservation (Mengist, W., & Asfaw, 2023). Starting the study from 1996 rather than 1991 makes a clear baseline for assessing the impact of these adopted policies with the absence of a biosphere reserve on forest cover dynamics to compare the effects of these policies after YCFBR establishment. This allows direct comparison between pre-reserve (1996-2010) and after the establishment of the biosphere reserve (2010-2022). In addition, between 1991 and 1996 it was the time for new policies to be formulated, implemented, and take to have tangible effects on the ground (Ayana et al., 2013; Mengist, W., & Asfaw, 2023). Also, the cumulative effects of both the Derge regime and the new forest policy implemented after the fall of the regime were considered. This enhances the scientific validity of the study findings, because the impacts of the policy implemented cannot be seen over a single night. Therefore, starting from 1996 enables to capture of consistent and fair data for comparisons of conservation interventions without a biosphere reserve and with the presence of a biosphere reserve, which are critical factors influencing the success of conservation initiatives. This research aims to fill this gap by examining the extent of human-induced changes in these zones over a period of 26 years and the improvement of forest cover after biosphere reserve establishment (1996-2022). Therefore, analyzing LULC dynamics on biosphere reserve (BR) impacts on forest cover as an alternative strategy for sustainable land use management and ecosystem restoration is crucial to provide evidence-based policy decisions for conservation of ecological resources. Thus, this study, anchored on two hypotheses, these are: a) Human interference significantly influences land use and land cover changes of YCFBR, and b) The establishment of the YCFBR has significantly reduced the deforestation rate compared to the pre-reserve period. Therefore, investigating the LULC changes' dynamics and drivers in the YCFBR is the overall objective of this study and suggest possible options for planning its sustainable management.

2. Materials and Methods

2.1. Study Area Description

This study was conducted at YCFBR, located at 582 KM from Addis Ababa in Southwest Ethiopia (Figure 1). This biosphere is one of the largest remaining patches of the Afromontane Rainforest in the Southwestern part of Ethiopia. The YCFBR was registered in 2010, and it is one of the five UNESCO-registered biosphere reserves in Ethiopia (Gole, et al., 2009). The biosphere covers six districts: namely Yayu, Hurumu, Bilo-Nopa, Dorani, Alge-Sachi and Chora. Geographically, it lies between latitudes 8° 0′ 42″ to 8° 44′ 23″ N and longitudes 35° 20′ 31″ to 36° 18′ 20″ E (Gole, et al., 2009). The total area of YCFBR is about 167,021ha and its core, buffer and transition zones cover 27,733, 21,552, and 117,736ha, respectively, with altitudes ranging between 1240m and 2400m above sea level (Beyene et al., 2019). The area receives bimodal rainfall with the mean annual rainfall of 1798 mm per year. The mean annual temperature of the study area is 18.70C, and the mean maximum and minimum temperatures are 27.70C and 11.10C, respectively (Jeldu, et al., 2023).

Vegetation types of the area is predominantly classified as moist Afromontane forests (Gole, et al., 2009). Most dominant species in the YCFBR are Diospyros abyssinica, Argomuellera microphylla Pax, Ocotea kenyensis, Celtis africana, Millettia ferruginea, Dracaena afromontana Mildbr., Albizia grandibracteata, Albizia gummifera, Cordia Africana, Teclea nobilis, Ficus sur, Ficus vasta, Ficus thonningii, Trichilia dregeana, Croton macrostachyus, Manilkara butugi, Olea capensis subsp. welwitschi, Sapium ellipticum, Ehretia cymosa, Bridelia micrantha, Mimusops kummel and Vangueria volkensii (Jeldu, et al., 2023).

In this study, we focused on buffer & transitional zones because the core zone is legally protected from human disturbances, as stated by the principles of BR management and zonation classification and socio-economic activities are not allowed in the core zone (Figure 1). Therefore, it is significant and valid to analyze LULC dynamics of the YCFBR for buffer and transitional zones, because these zones are more dynamic and influenced by human interference for their socio-economic activities. Since it is not expected that the new land use dynamics in the core zone in this case, rather than redundant work and this study improved the existing methodology by making an analysis of LULC change only for the two zones (buffer and transitional zones), which were not touched by the previous researcher. As indicated on the map (Figure 1), the white area represents the core zone, which is excluded from image analysis. Because the researcher is not expecting the new land use dynamics in the core zone in this case. The core zone area has a high wild coffee population, and high species diversity, less human disturbance risk, and should not encompass areas owned by individual farmers (Fite Getaneh, 2008).

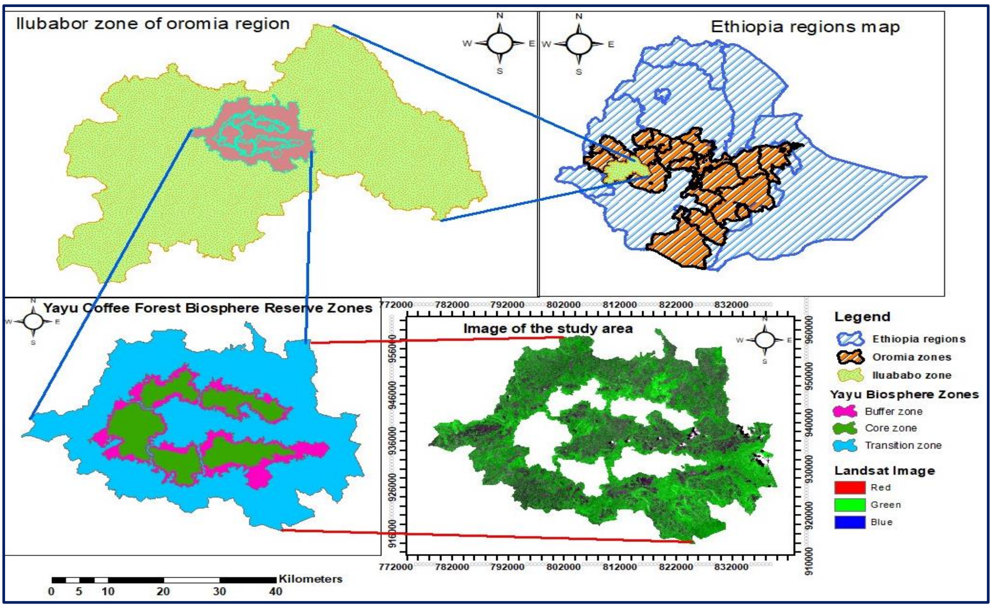


Figure 5: Map of the study area for the Yayu Coffee Forest Biosphere Reserve

2.2. Data Collection Methods for LULC Change

Satellite imagery was used from different time points (1996, 2010, and 2022) and evaluated LULC dynamics over the study periods by comparing LULC before BR (1996-2010) and after BR establishment (2010-2022) for comparisons of conservation interventions with and without presence of BR and field surveys to validate and understand local human activities related to land use changes. The cutting point was started from 1996 for land use dynamics, because of the following scientific relevance for this study's objectives. In 1996, Ethiopia adopted a new forest policy aimed at addressing issues related to deforestation, forest degradation, and biodiversity conservation (Mengist, W., & Asfaw, 2023). This allows direct comparison between pre-reserve (1996-2010) and after the establishment of the biosphere reserve (2010-2022). Also, the cumulative effects of both the Derge regime and the new forest policy implemented after the fall of the regime were considered. This enhances the validity of the study findings because the impacts of the policy implemented cannot be seen over a single night. Therefore, starting from 1996 enables to capture consistent and fair data for comparisons of conservation interventions without a biosphere reserve and with the presence of a biosphere reserve, which are critical factors influencing the success of conservation initiatives. Also, Focused Group Discussions (FGD), Key Informant Interviews (KII), and field observations were employed to gather information on local LULC changes and understand the drivers of deforestation in the YCFBR study area. KII was selected from forest experts, members of the biosphere reserve management unit, women association representatives, and NGO representatives from the area using snowball methods. Their selection was based on their knowledge and elaborating their views on the impacts of the biosphere reserve on forest conservation. Totally, three (3) FGD were conducted and one FGD at each kebele comprising 8-10 participants, and individual selection was based on homogeneity of information gathered, and gender (Male FGD and Female FGD) consideration. Data collection took place from January 2022 to December 2023 in the Yayu, Hurumu, Dorani, and Chora districts, selected randomly. Ten key informants were purposively selected based on their knowledge of local historical events and interviewed at each kebele under study. Ground control points (GCP) were collected with a Global Positioning System (GPS), while inaccessible areas were mapped using Google Earth for the three selected years (1996, 2010, and 2022). Then, the qualitative information collected was integrated with geographic information system (GIS) and remote sensing (RS) data to analyze the spatio-temporal dynamics of forest cover change in YCFBR.

2.2.1. Image preprocessing and classification

Landsat satellite imagery for 1996, 2010, and 2022 was used to classify LULC types using a supervised classification algorithm. Pre-processing steps such as geometric correction and registration were performed to improve image quality. Unsupervised classification was also done to identify spectral classes. Post-classification change detection analysis was conducted using ERDAS2015 and ArcGIS. The majority filter tool in ArcGIS was applied to eliminate misclassified areas. For this, the following image data, instrument and Landsat 5 TM Image and Landsat 9 OLI Image software were used for Path number 170 and row number 54 for data acquisitions and analysis (Table 1).

Table 33: Satellite imagery of YCFBR, data sources and instrument employed

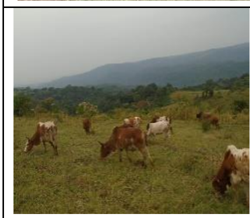
Acquisition date	Images and tools employed	Path/Row	Resolution (in meter)	Source
16/12/1996	LANDSAT 5 TM Image	170/54	30m	WGS84
16/12/2010	LANDSAT 5 TM Image	170/54	30m	WGS84
8/12/2022	LANDSAT 9 OLI Image	170/54	30m	WGS84
Tools used		**Version**		
ArcGIS		10.6		
GPS map		72s		
ERDAS		2015		

2.2.2. Land use and land cover class definitions and description

In LULC classification, standardized systems such as Anderson's and Hardy's were used (Anderson, et al., 1976; Hardy et al., 1973). However, the number of classes chosen depending on study objectives, with consideration of prior knowledge of the area(Hardy et al., 1973). For example, the study made use of Landsat 1973, 1986 and 2001 Remote Sensing Satellite Image analysis to come up with the final biosphere reserve map; dense forest, open/disturbed forest, farmlands, settlement, and grasslands have been identified as the major land use land cover types in the study area and reviewed (Fite Getaneh, 2008). Using all this baseline information, six LULC classes were identified and classified as dense forestland, farmland, grazing land, open forestland, settlement land and shrub land (Table 1). Forests were divided into dense and open categories based on NDVI values, and with field verification (Fite Getaneh, 2008).

Table 34: Description of LULC classes used to measure the changes in YCFBR (1996-2022).

Sample of field photo	Classified LULC types	Description for each LULC based on (Hardy et al., 1973; Anderson et al., 1976)
	Dense forest land	A place where covered with dense trees
 	open forest land	Wood land or a land cover which dominated with low forest density and exposed ground surface, domesticated plant species.

	Shrub land	Open-sparse vegetation cover type, somewhat taller than bush and shorter than trees
 	Farmland	Cultivated land, farming (agriculture). Areas of land ploughed/prepared for growing various crops or cleared for tillage purpose, cultivated wetlands.
	Grazing land	Rangeland, grassland, no or minimum tree cover, or a part of range land dominated with grass and herbaceous.
 	Settlement land	Settlements, industrial, residential places (Towns and villages)

2.2.3. Accuracy assessment

Classification accuracy is an important measure of the quality of a map, with a minimum accuracy level of 85% recommended for interpreting remote sensing data (Anderson et al., 1976). Accuracy assessments involve computing error matrices to determine producers' and user's accuracy, as well as the kappa coefficient. Thus, the most common means of describing classification accuracy is the presentation of a classification error matrix table. To verify accuracy, field surveys were conducted with a total of 720 ground control points collected for six LULC classes by sampling 30 sample points for each LULC and multiplying by the selected four districts (30 x 4=120 per LULC, then total GCP = 120*6 = 720 points).

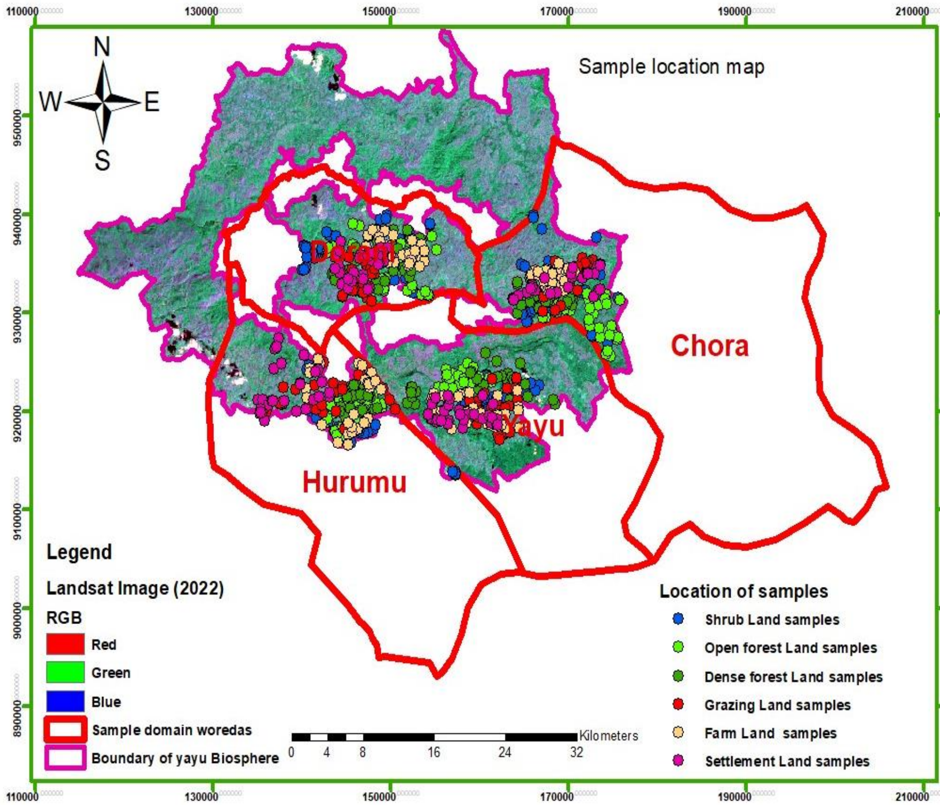


Figure 6: Point map for the ground control point sample collections

Accuracy was assessed using producers and user's accuracy, as well as overall accuracy using the following equations.

$$Producer's\ accuracy = \frac{Total\ number\ of\ pixels\ in\ a\ category}{Total\ number\ of\ pixels\ of\ that\ category\ derived\ from\ the\ reference\ data\ (row\ total)}$$

$$User's\ accuracy = \frac{Total\ number\ of\ pixels\ in\ a\ category}{Total\ number\ of\ pixels\ of\ that\ category\ derived\ from\ the\ reference\ data\ (column\ total)}$$

$$Overall\ accuracy = \frac{Sum\ of\ the\ diagonal\ elements}{Total\ number\ of\ accuracy\ sites\ pixels\ (column\ total)}$$

$$LULC\ Change\ percentage\ (\%) = \frac{Present\ LULC\ area - Previous\ LULC\ area}{Previous\ LULC\ area} * 100$$

Also, Kappa coefficient was used to measure the difference between actual and chance agreement. Because it measures the difference between the actual agreement and random agreement between the map and the validation data on the ground (Congalton & Green, 2009).

$$K\text{^} = \frac{N \sum_{\substack{i=1 \\ j=1}}^{m} D_{ij} - \sum_{\substack{i=1 \\ j=1}}^{m} R_i * C_j}{N^2 - \sum_{\substack{i=1 \\ j=1}}^{m} R_{i*} C_j},$$

where: $K\text{^} - \text{Kappa} - \text{cofficient}, N - \text{total number of pixels}, m - \text{number of classes},$

$\sum \text{Dij} - \text{total diagonal elements of an error matrix (the sum of correctly clxels in all images)},$

$\text{Ri} - \text{total number of pixels in row i}, \text{Cj} - \text{total number of pixels in column j}.$

Interpretation of agreement ranged from almost perfect (1) to poor (0), with values multiplied by 100 for a percentage measure of classification accuracy. The error matrix shows the similarity between GCPs collected on each LULC category on the satellite image and the classified LULC classes using ground information, as shown on table Table 3). Out of 720 sample points, 104, 108, 98, 108, 105, and 110 points were correctly classified as shrub land, open forest land, dense forest land, grazing land, farm land, and settlement land, respectively (Table 3). However, there were misclassified areas. For example, under shrub land column 6, 1, 3, 3, and 3 points classified as shrub land on the satellite image but as different land cover categories in the classified image, i.e., open forest land, dense forest land, grazing land, farm land, and settlement land on the classified land use land cover classes. The error matrix highlights areas where the classification may be inaccurate. Generally, the column total of 121 points depicts that the shrub land on the satellite image, from which only 104 points are correctly the same LULC category on the classified image. All of the remaining rows and columns can be interpreted in the same way.

Table 35: Image classification matrix table for ground control points for LULC classification accuracy for YCFBR

Classification Error Matrix Table							
	Reference Data						
Classified Data	**Shrub Land**	**Open Forest Land**	**Dense Forest Land**	**Grazing Land**	**Farm Land**	**Settlement Land**	**ROW Totals**
Shrub Land	104	6	1	3	3	3	120
Open Forest Land	3	108	3	2	2	2	120
Dense Forest Land	5	4	98	3	6	4	120
Grazing Land	4	2	2	108	2	2	120
Farm Land	2	3	3	5	105	2	120
Settlement Land	3	2	1	2	2	110	120
Column Total	121	125	108	123	120	123	720

As it is shown in Table 4, the overall classification accuracy for this study was 87.92%, exceeding the minimum requirement of 85% (Anderson et al., 1976). Whereas producers' accuracy ranged from 85.95% to 90.74% for different land cover classes, indicating the likelihood of sample points on the ground being classified correctly (Table 4). Similarly, users' accuracy ranged from 81.67% to 91.67%, representing the probability of sample points on the image matching the ground truth for different land cover classes (Table 4).

Table 36: Image classification accuracy totals for land use land cover types

Accuracy totals table					
Class Name	**Reference Totals**	**Classified Totals**	**Number Correct**	**Producers Accuracy**	**Users Accuracy**
Shrub Land	121	120	104	85.95%	86.67%
Open Forest Land	125	120	108	86.40%	90.00%
Dense Forest Land	108	120	98	90.74%	81.67%
Grazing Land	123	120	108	87.80%	90.00%

Accuracy totals table					
Class Name	**Reference Totals**	**Classified Totals**	**Number Correct**	**Producers Accuracy**	**Users Accuracy**
Farm Land	120	120	105	87.50%	87.50%
Settlement Land	123	120	110	89.43%	91.67%
Totals	720	720	633	---	----
Overall Classification Accuracy = 87.92%					

The Kappa coefficient is an overall accuracy parameter that measures the chance agreement between classes, indicating the likelihood that samples are mapped correctly. In this study, a Kappa coefficient of 0.8550 (85.50%) was obtained, indicating strong agreement between the classification map and the ground reference information (Table 5).

Table 37: Image classification KAPPA (K^) STATISTICS

KAPPA (K^) STATISTICS Table
Overall Kappa Statistics = 0.8550
Conditional Kappa for each Category

Class Name	**Kappa**
Shrub Land	0.8397
Open Forest Land	0.879
Dense Forest Land	0.7843
Grazing Land	0.8794
Farm Land	0.85
Settlement Land	0.8995

3. Results And Discussions

3.1. Land Use and Land Cover Classification Output of the Years 1996, 2010, and 2022

The results for the LULC show that, in 1996, the dominant land cover types were open and dense forest lands, and shrub lands (Table 6). However, by 2010, settlement lands became the dominant land cover, followed by farm lands and grazing land (Table 6). In the last study period (2022), dense and open forest lands expanded and became the dominant land cover types, while settlement land and grazing land decreased (Table 6). This was possibly due to natural regrowth or reforestation efforts, farm lands expanded into dense and open forest lands and shrub lands. Approximately 24,218.44 hectares (ha) of open forest cover were lost due to various socio-economic activities and anthropogenic factors from 1996 to 2010, however, it was improved after the biosphere reserve was established due to various positive forest interventions implemented in the area. Before BR designation, the conversion of dense forest land and shrub land to settlement land and farm land can lead to habitat loss and fragmentation, impacting biodiversity. Therefore, it is essential to consider the long-term ecological and socio-economic impacts of these LULC changes in the area.

Table 38: Area and percentage of LULC classes in 1996, 2010 and 2022 of the YCFBR

LULC types	1996		2010		2022	
	ha	%	ha	%	ha	%
Shrub Land	10629.1	7.68	5536.58	3.99	7548.37	5.45
Open Forest Land	30275.9	21.86	6057.46	4.37	29074.83	21.00
Grazing Land	24095.6	17.40	29702.3	21.45	22528.20	16.27
Dense Forest Land	37063.8	26.77	30116	21.75	36213.38	26.15
Settlement Land	12616.4	9.11	34063.3	24.60	15048.73	10.86
Farm Land	23786.9	17.18	32992	23.83	28060.44	20.26
Grand Total	138474	100.00	138474	100.00	138474	100.00

3.2. LULC Dynamics before the Biosphere Reserve (1996-2010) and After Biosphere Reserve Establishments (2010-2022).

Results revealed that there have been significant changes in LULC over the 12-year period (after biosphere reserve), i.e., from 2010 to 2022 (Table 7). For example, dense forest land and open forest land increased, while farm land decreased. These shifts have positive implications for biodiversity and ecosystem services. The decrease in farm land, settlement land and grazing lands and the increase in dense forest land, open forest land and the shrub lands suggest a significant improvement of forest cover, which can have positive consequences for biodiversity and ecosystem services due to the implementation of biosphere reserve establishments in the area. In contrast, before biosphere reserve the conversion of dense forest land and shrub land into other LULC categories, such as grazing land, farm land, and settlement land, indicates changing land use practices, potentially driven by human activities such as urbanization and agricultural expansion, including grazing land use types. These changes have implications for wildlife habitat, soil erosion, and water availability. For instance, the expansion of grazing land contributes to the intensification of livestock production, which can lead to overgrazing and degradation of grassland ecosystems. Overall, the LULC changes observed in this area highlight the dynamic nature of land use due to the implementation of YCFBR in the area and the importance of considering the implications of these changes for ecological integrity and human well-being. Therefore, it is essential to monitor and manage these changes to ensure the long-term sustainability of the biosphere reserve and the surrounding ecosystems.

Before the biosphere reserve was established (1996-2010), there was deforestation and degradation of dense forest land, but after its establishment (2010-2022), there was afforestation and reforestation. This was because behavioural and coordinated housing policies that broaden relocation options can make mitigation measures more effective in settlement land transformation for emission reduction and afforestation actions. This shows a positive engagement of both community and government in participation in forest conservation, which can contribute to climate change mitigation measures, as forests act as carbon sinks and help reduce GHG emissions too. The decrease in farm land and grazing land suggests a shift in agricultural practices and livestock management. The decrease in settlement land may be attributed to conservation efforts or urbanization control measures. The increase in dense forest land and shrub land indicates habitat expansion and biodiversity conservation, while the decrease in settlement land raises questions about human displacement and its impact.

Furthermore, the loss of forested areas may lead to decreased carbon sequestration, increased vulnerability to climate change, and a reduction in ecosystem services such as water regulation and soil fertility. Additionally, the expansion of settlement areas and agricultural activities may lead to increased pressure on natural resources and potential conflicts between conservation efforts and human development, which is consistent with the previous study (Wondimagegn Mengist et al., 2021). For instance, the post-1991 Period (After the Dergue), Ethiopia's forests coverage was destroyed and shrink to 2.4% compared to the estimated 40% initial coverage (Tedla, 1998). This was happened due to absence of popular participation in resource management has resulted in the rejection of government policies formulated and implemented from the central government, policies such as villagization, and resettlement (Tedla, 1998). Therefore, it is crucial to involve local communities and stakeholders in decision-making processes to ensure the long-term success and sustainability of conservation efforts within the biosphere reserve.

Table 39: The spatio-temporal changes of the YCFBR over 1996-2022

LULC types	Before Biosphere establishment		After Biosphere establishment		Over the study periods (dynamics)	
	1996-2010		2010-2022		1996-2022	
	ha	%	ha	%	ha	%
Open Forest Land	-24218.46	-17.49	23017.29	16.62	33.7	0.02
Dense Forest Land	-6947.75	-5.02	6094.67	4.40	29411.4	21.22
Farm Land	9205.17	6.65	-4932.93	-3.56	-7600.4	-5.48
Grazing Land	5606.67	4.05	-7175.30	-5.18	-14147.5	-8.26
Settlement Land	21446.92	15.49	-19015.30	-13.73	-11448.6	-8.26
Shrub Land	-5092.55	-3.68	2011.56	1.45	3751.5	2.71

A series of FGD and KII were conducted with local community members in various villages to identify the major factors driving LULC changes in the area. Results from FGD & KII also consistence with the results of image analysis. Respondents noted that, before BR, there was low motivation for tree planting, which led to deforestation. However, after YCFBR established this culture improved due to local community engagement on conservation of YCFBR and government support on green legacy initiatives, resulting in afforestation and reforestation in the area by mass participation on seedling production and plantation, and then the status of forest cover has improved. They suggested local community engagement is highly essential for forest conservation. Factors driving afforestation in the area include PFM, EGLI, REDD+ and initiatives by organizations such as Nature and Biodiversity Conservation Union (NABU), OFWE and others.

Generally, elders and key informants forwarded their opinion, as “Coffee farm expansion in to core zone, forest corruption, and encroaching in the forest are the major driving factors for YCFBR deforestation” (12 April 2023). They suggested efficient forest conservation is achieved if the forest is conserved by forest (forest-by-forest) or “Bosona Bosonatu Bulcha” (Afaan Oromoo), which means forests close to surrounding communities are crucial and instrumental for forest conservation.

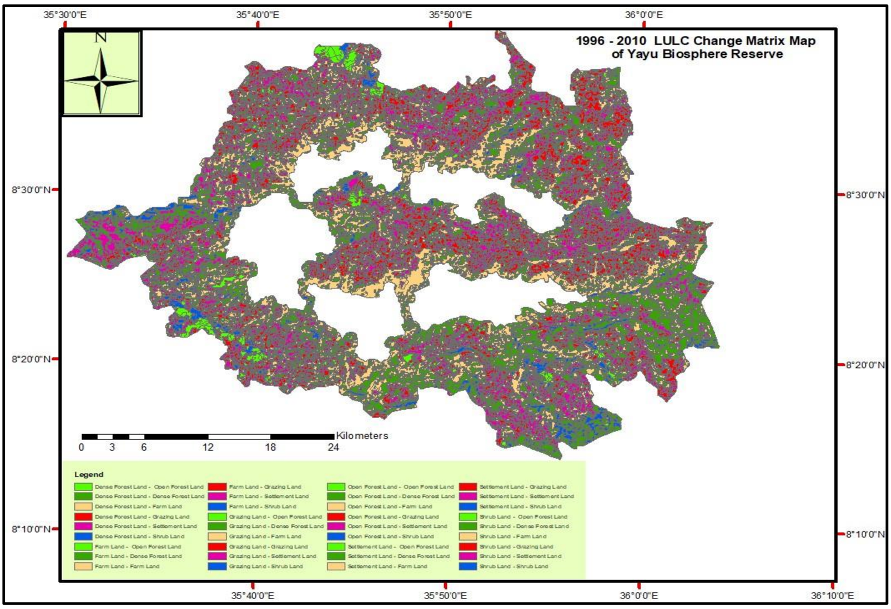


Figure 7: LULC change matrix map of YCFBR before biosphere reserve (1996-2010).

Note: From the above image, the white area is the core zone

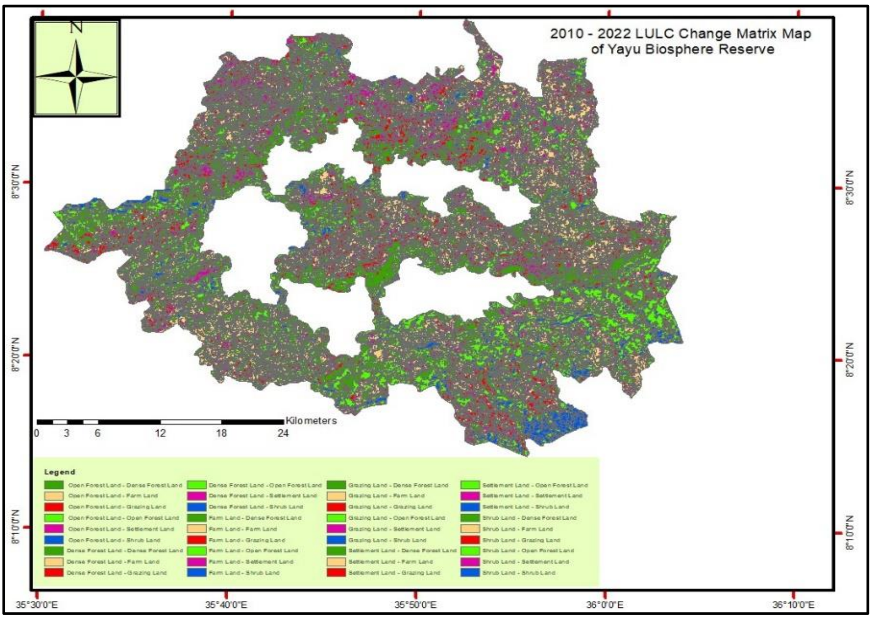


Figure 8: LULC change matrix map of YCFBR after biosphere reserve (2010-2022)

Note: From the above image, the white area is the core zone

3.3. Implications of the Findings for Biodiversity and Climate Change Mitigation

The changes in LULC in this area have important implications for biodiversity and ecosystem services. Because land use and land cover are widely recognized as the major drivers of biodiversity depletion in Ethiopia. The decrease in dense and open forest land and the increase in farm and settlement land suggest significant forest cover loss, which can have negative consequences for the local ecosystem and communities. Conversion of shrub land into grazing, farm and settlement land indicates changing land use practices driven by human activities. Expansion of grazing land intensifies livestock production, leading to overgrazing and ecosystem degradation. Fragmentation of the landscape due to these changes poses challenges for biodiversity conservation and ecosystem services provision, impacting human dependencies. Therefore, sustainable land management strategies are needed to mitigate these impacts and preserve biodiversity. The changes in LULC dynamics have implications for climate change mitigation, with potential impacts on carbon sequestration and GHG emissions. Ethiopia is particularly vulnerable to the impacts of climate change, with LULC changes affecting local climate through GHG emissions and altering land surface properties. For instance, clearing forests for agriculture can lead to increased drought and flooding risks (Ricketts et al., 2013; IPCC, 2023). Therefore, this study highlights the importance of analyzing LULC changes in YCFBR and tropical forest areas to sustainably manage ecosystems and reduce anthropogenic impacts for climate mitigation efforts.

4. Conclusions and Recommendations

A biosphere reserve has a positive impact on forest conservation and increases forest cover. Local community engagement, especially forest-surrounding communities, are highly essential for forest conservation, and government support is also imperative for forest conservation. BR implementation helps in shaping conservation policies and ecosystem restoration. For instance, this study's findings highlight that, before biosphere reserve, there was a decrease in forest cover; however, it increased after biosphere reserve.

Further delineation of the buffer zone into sub-zones as buffer1 and buffer2, to stop the expansion of the buffer into to core zone, is essential. Criteria for buffer & core zone classification should not be based only on the presence or absence of coffee. The FGD and KII suggestion highlights that, renaming of Yayu Coffee Forest Biosphere Reserve (change of name of BR) becomes important in order to make the biosphere reserve reflect the 6 districts it encompasses. The introduction of community-based forest management (CBFM) and Gada administration system (Oromo cultural administration systems) is essential for efficient and sustainable management of YCFBR. Factors affecting the implementation of PFM and forest corruption in forest conservation and climate change mitigation should be future research questions. A verification study is needed for comparisons of this BR with other forest ecosystems. Further research is needed for the assessment of past forest ecosystem services, this BR to determine the rate of recovery of forest ecosystem services across zones.

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The Effects of Climate Variability on Rural Women in Agriculture: A Case Study Evidence from Amhara Region, Ethiopia

Melkamu Tadesse Wazza[1, 2, *], Zerihun Berhane Weldegebriel [1, 3], Melaku Tsegaye H/Mariama[1]

Abstract

Climate variability has a strong effect on agricultural production and food security. The effect is severe in countries like Ethiopia, with high economic dependency on rain-fed farming, and experiencing gender inequality. The study examines how climate variability affects women in the Amhara Region of Ethiopia whose livelihoods depend on agriculture. Qualitative data were employed, substantiated by deseasonalized trend analyses of historical meteorological data. The findings indicated a trend with a statistically significant increase in minimum annual temperature at Fogera by 0.18 ℃ and maximum yearly temperature at Kemkem by 0.076 ℃ per annum. The rainfall trend in Kemkem also showed a statistically significant increase of 1.73 mm per annum, indicating an increased risk of flooding. The areas exhibited high annual rainfall variability, which makes them vulnerable to drought. The adverse events affected women in agriculture more severely than men, particularly through crop damage and yield reduction. With a subsequent loss of income, the condition led women to a vulnerability trap. Positioning disaster risk management towards a gender-responsive community-based approach that incorporates the needs and capabilities of poor rural women would help sustainable rural development.

Keywords: Climate variability, deseasonalized trend, drought, flooding, Ethiopia

[1] Department of Project Management, PBTAfrica College, P.O. Box 62045, Addis Ababa
[2] Department of Rural Development, Wolaita Sodo University, P.O. Box 138
E-mail: melkamu.tadesse@wsu.edu.et; melkamtw@gmail.com
* Corresponding author
[3] Centre for African and Asian Studies, Addis Ababa University, P.O.Box 1176
E-mail: zerihun.berhane@aau.edu.et

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1. Introduction

Climate variability is a variation in climate parameters from their usual values, and it is becoming more evident than ever. Its effects usually vary with development level, poverty status and gender disparity (Tadesse, 2010; WaterAid, 2022). Consequently, the impact in developing countries, sub-Saharan Africa, in particular, is great. It is mainly on agricultural production and food security (Hamadjoda Lefe et al., 2024; Tadesse, 2010). East Africa, where Ethiopia is located, displays the highest climate abnormalities (Bedair et al., 2023). Moreover, since the country's economy depends on rain-fed crop farming by smallholders (79%) (OECD/PSI, 2020), the effect of climate variability would conceivably be higher, for climate is the fundamental factor behind agricultural productivity for such countries (Khand et al., 2020).

Across the globe, though both men and women are affected by climate variability, the magnitudes of effects are not equal. The effect is higher on women (Belachew & Iqbal Zuberi, 2015; WaterAid, 2022). In Ethiopia, there is a gender gap of more than 30 points to fill (a gender gap index of 0.69 in 2021[4]). Multidimensional poverty is also high (84%) (OECD/PSI, 2020). Weak adaptive capacity exacerbates the vulnerability of poor people to climate variability. The poverty status combined with gender inequality made the effect on poor women even worse (Team & Hassen, 2016). Most women in Ethiopia (85%) live in deprived rural areas (TEA [Tiruzer Ethiopia for Africa], 2017) with rampant poverty (UN Women, 2023). They are more vulnerable to the effects of climate variability (Ayalew & Mersha, 2019). Moreover, the problem is severe in the study area, i.e., South Gonder of the Amhara region. The area is among the heavily impacted areas by river flooding in East Africa (Gashaw & Legesse, 2011).

Nonetheless, women are the great majority of the population and labour force in the country. They comprise 40 per cent of the agricultural labour force and perform 75 per cent of household food production (Gemechu, 2022; OECD/PSI, 2020; USAID, 2017). They have a great role in natural resource use and management. They are superintendents of biodiversity and household resources (CARE Ethiopia, 2019). Such responsibilities have a connection with climate variability (Gemechu, 2022). This makes women, compared with males, highly vulnerable and more affected by climate shocks (CARE Ethiopia, 2019). Despite women's responsibilities and

[4] Differences in gender expressed in status of health, education, economy and political empowerment. The lowest and highest possible score are 0 and 100, respectively.

vulnerability, the disaster risk management policy and plan of Ethiopia lacks gender sensitivity in considering the impact of climate variability (WaterAid, 2022). Besides, gender-disaggregated empirical studies that assessed the effect of climate variability on women farmers in Ethiopia are very few and yet specific to crop yield (Getachew, 2017), focused mainly on vulnerability to climate variability by women in general (Wossen, 2016), adaptation barriers to climate variability (Mersha & Van Laerhoven, 2016), adaptation practices (Bryan et al., 2009; Cholo et al., 2018; Tsige et al., 2020) and a scoping study on gender policy framework (Ayalew & Mersha, 2019). Getachew (2017) studied the impact of climate variability on crop yield in the South Gonder zone of Ethiopia, but not in a gender-sensitive way. Furthermore, it was based only on 10 years of meteorological data. Methodologically, this study didn't use a deseasonalized trend when, in fact, there are seasonal variations (see Gedefaw et al., 2019; EMI [Ethiopia Meteorology Institute], 2023). Overlooking relevant evidence on rural women can thus lead to ineffective climate mitigation and adaptation processes, and hence, failure to achieve sustainable development (Bäthge, 2010).

In line with this, the study aimed to assess the effect of climate variability on women whose livelihoods depend on agriculture in three districts (Woreda)5 of the Amhara Region in Ethiopia. To this end, the study analysed the data using qualitative and quantitative methods. The qualitative approaches (interviews and focus group discussions) help clarify interwoven interactions and conflicting discussions and enable a deep understanding of social issues (Bercht, 2021; Nyumba et al., 2018). Substantiating this with quantitative analysis using historical meteorological data of three decades, the study enabled a clearer understanding of the gender-differentiated higher negative impacts of climate variability on women, an important section of society in agricultural development and poverty reduction. In doing so, it informs policy-making, planning and implementation in adopting community-based gender-responsive disaster risk management in sustainable rural development.

2. Climate variability and rural women in agriculture

Climate variability is variations of climate parameters, i.e., apart from weather events, from their expected values in different space and time scales (IPCC, 2018). Such variability has a high effect on agricultural production and food security, increasingly affecting the lives and livelihoods of people (Mubenga-Tshitaka et al.,

[5] *Woreda* implies district in Ethiopia

2023). Its effects vary depending on socio-economic development, in which low-income nations and poor people experience the brunt of the negative impacts, given their lack of capacity to prepare for and cope with its adverse effects. Among impoverished communities, women and men may experience these impacts differently, with women being relatively more affected than their male counterparts (Goh, 2012). As women make up 70 % of the world's rural poor (OCHA, 2016), they are expected to be highly vulnerable to the effects of variability and are frequently affected by climate change-induced disasters.

The situation is even worse in Ethiopia, where the economy depends on agriculture, which, in turn, is dominated by rain-fed (less irrigated) crop farming. Given that women have a greater share in agricultural labour participation both globally and in Ethiopia (OECD/PSI, 2020; Team & Doss, 2011), and are affected by climate variability more than men (Belachew & Iqbal Zuberi, 2015; WaterAid, 2022), the effect on the rural economy is paramount. Rural women in agriculture are women in a society residing in rural areas whose livelihood depends mainly on agricultural activity. Their disproportionately higher effect is due to their high dependence on natural resources and their engagement in limited livelihood strategies (CARE Ethiopia, 2019). Apart from women's high reliance on agriculture and natural resources, accompanied by their dominant role in acquiring water and fuel-wood for the household (Ayalew & Mersha, 2019), the disproportionate effect is associated with women's higher vulnerability (Team & Hassen, 2016), sidelined mitigation decisions (Ayalew & Mersha, 2019; Goh, 2012), lower adaptive capacity (Bryan et al., 2009), inadequate access to (Ayalew & Mersha, 2019) and initial level of resources (Wossen, 2016). The Ethiopian rural women constitute the majority of the asset-poor and vulnerable groups (low socioeconomic classes) that are most likely to experience and are already experiencing the disastrous effects of climate change (Team & Hassen, 2016). Projected climate change has the potential to exacerbate the existing inequalities further, worsening women's health and well-being indicators and decreasing their survival rate (Rovin et al., 2013).

3. Materials and Methods

3.1. The Study area

The study was conducted in three disaster-prone Woreda (districts) of the South Gonder Zone of the Amhara Region in Ethiopia: Libo Kemkem (or Kemkem), Fogera and Dera (see Figure 1). The districts are bounded by Lake Tana, the largest

in Ethiopia, and have major rivers, the Arno, Gumara and Ribb Rivers that drain into Lake Tana. The 2020 population projection shows that Kemkem, Fogera and Dera have a population of 246,544, 283,802 and 306,833, respectively. In that order, the districts have a rural population of 88.9%, 93.24%, and 88.89%, and a female population of 48.9%, 45.7%, and 43.5%, respectively. The data, thus, indicate that the people in the districts predominantly live in rural areas and are almost equally disaggregated between females and males (EEU, 2007; Fogera-Woreda, 2009). See further details of the climate characteristics.
of the study Woreda in Table 1.

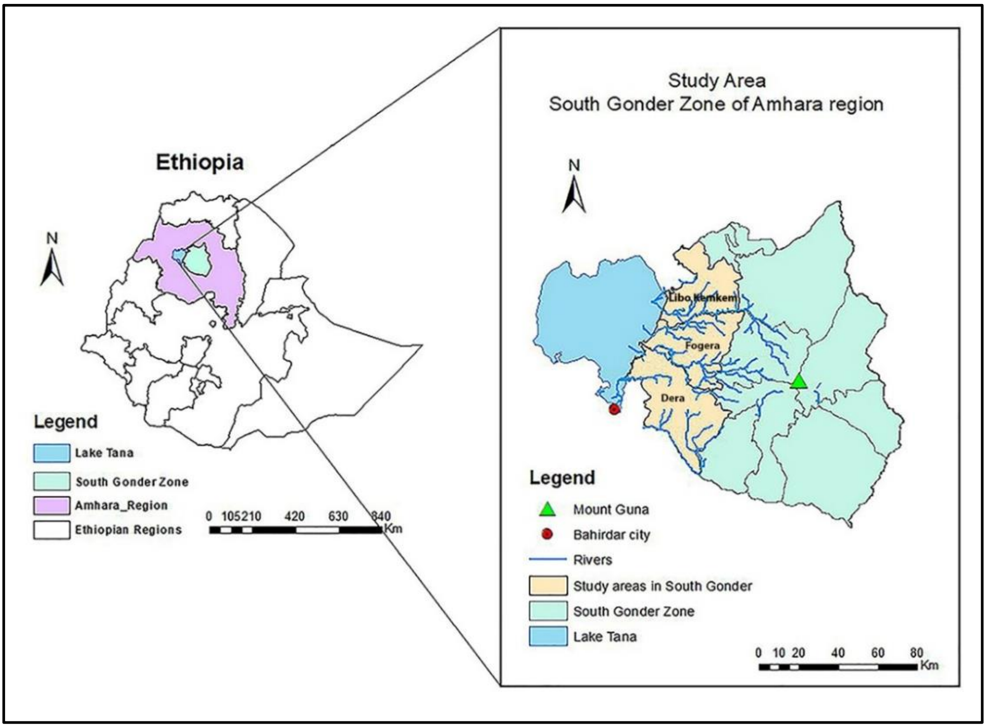

Figure 9: Study area in the Amhara region of Ethiopia. Authors' presentation using ArcGIS 10 software

Table 1: Characteristics of major climate variables in the study Woreda (districts)

Study area (Woreda)	Altitude (m.a.s.l)	Traditional Climate Zones	Annual Temperature (°C)		Annual Rainfall (mm)		
			Average Min	Average Max	Mean	Min	Max
Libo Kemkem (Addis Zemen)	1800-2850	Predominantly Semi-humid (Woinadega) and Cool and Humid (Dega)	3.7	36.2	112.7	0.00	919.9
Fogera (Woreta)	1774-2415	Predominantly Semi-humid (Woinadega)	4.6	33.8	118.7	0.00	1015.4
Dera	1,560-2,600	Cool and humid (Dega) and Semi-humid (Woinadega)	4.8	19.0	104.2	0.00	1500.0

Authors' compilations

3.2. The data

Both primary and secondary data were used for the study. The primary data was collected between December 28, 2021, and February 6, 2022, from three disaster-prone Woredas in the South Gonder Zone of the Amhara Region in Ethiopia. The data consists of text codes from transcripts of interviews, focus group discussions and field observations. The secondary data employed were historical meteorological data on average monthly maximum temperature, minimum temperature and rainfall amount over 31 years (1989-2019). These data were obtained from the two nearest meteorological stations—Woreta and Addis Zemen—EMI [Ethiopia Meteorology Institute], representing Fogera and Kemkem districts, respectively, of the study areas.

3.3. Sample and data collection methods

A sample for the primary data was collected from the rural women and men living in the three Woredas using three qualitative data collection methods: key informant interviews (KII), focus group discussions (FGDs), and direct field observations (FOBs). Since the study aimed to examine the effect of climate variability on rural women, key informants and discussants were selected to be women and men by design and implementation. This is to get first-hand information on gender-sensitive concerns. In the KIIs, 21 key informants were interviewed (of which 13 were women) from diverse groups across the different administrative structures from the federal level down to the Woreda. The sample size for the KII is within the recommended sample size for the data type applied (see Muellmann et al., 2021). The interviews were conducted mainly to incorporate the views of key stakeholders (relevant experts, personnel and organisations) across the administrative structures.

The FGDs were conducted with women and men vegetable and rice producers of various age categories who were selected randomly. Four FGDs (vegetable and rice growers in each sex) were conducted in each Woreda, with a total of 12 FGDs. Each group included 8-11 members. This group size is within the recommended size range for FGD (see Krueger & Casey, 2015). The number of participants in the FGDs was 36, 34 and 36 in Fogera, Kemkem and Derea Woreda, respectively, with a total of 106 participants in the overall study. All participants were treated anonymously except for documentation purposes. Following the guidelines of Krueger & Casey (2015), the group was set up in a quiet environment and guided through a pre-structured outline. The discussions were administered to separate sexes to get detailed and relevant gender-specific information. This is associated with women's group behaviour in which they usually express much less when grouped with males (Stewart & Shamdasani, 2015). The process enabled the consolidation of sex-disaggregated data with participants' views, experiences and challenges in climate variability, adaptation and mitigation and available coping strategies for their agricultural, non-agricultural and gender-based activities.

The FOBs were employed in collaboration with program field staff, community facilitators, development agents, and kebele6 leaders. Through transect walks, the researchers observed the overall vegetable and rice field conditions and the associated socio-economic challenges of rural women in the selected 3 kebeles in each Woreda. The observation was signalled by feedback from KII and FGDs and evidenced by photo documentation. It provided direct insight into the status and conditions of women farmers and complemented the information gained from the other instruments.

3.4. Data analysis

This study is a case study. It employed mixed methods of qualitative and quantitative data analysis. A qualitative approach enables a deep contextual understanding of local perceptions and knowledge of climate variability, thereby extracting values from interlinked social interactions that cannot be revealed by the exclusive

[6] Kebele(s) for village(s) in Ethiopia

application of quantitative analysis (Bercht, 2021). The inherent subjectivity embedded in the qualitative method was, in turn, verified by quantitative analysis of the three-decade time-series meteorological data. The details are indicated in the subsections below.

3.4.1. Qualitative data analysis

Primary data collected through KII, FGDs and FOBs were subjected to data quality management before analysis. This was done for validity and consistency checks by a research supervisor in the field and researchers at the office. At the end of each fieldwork, the researchers and the supervisor discussed and inspected the findings with a critical lens to ensure quality. Then, the audio-recorded data were transcribed. The data obtained were analysed and interpreted against the research objectives following the approach suggested by Saldaña (2016). The analysis accommodated breaking down text data based on a code list (code system) to identify theoretically and practically relevant patterns. The coded segments were then grouped into overarching descriptive themes (see Figure 2). While a code is a word or short text representing a combined feature for text-based data and serving as a basic unit of analysis, a theme is a higher-level abstract that captures meanings across various codes (Clarke & Braun, 2017; Saldaña, 2016). The analysis was conducted in a stage-wise collaborative process that unveiled three main themes: Theme 1: types of climate-induced and indirectly related natural hazards and disasters; Theme 2: effects of climate variability on rural women; and Theme 3: vulnerability and adaptation mechanisms. The research process also involved all the necessary ethical concerns, such as protecting participants' privacy, showing respect for and obtaining full participants' consent.

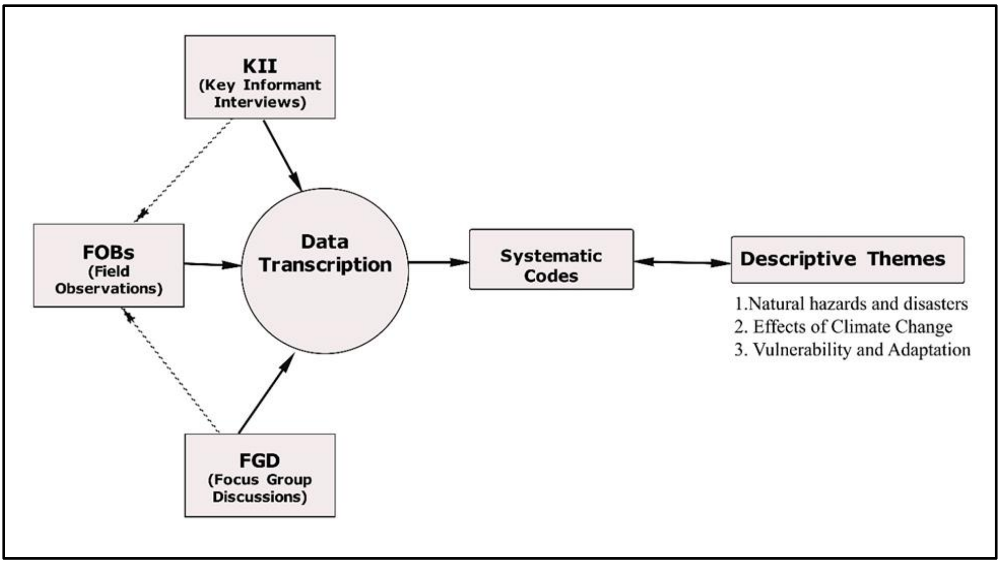

Figure 2: Flow chart of the qualitative data analysis. Authors' representation

3.4.2. Quantitative data analysis

In line with the variability in temperature and rainfall patterns, the common seasons in Ethiopia are Bega, Belg, and Kiremt (EMI, 2023). While Kiremt (June to September) represent a season with the major annual rainfall (50-80%), Belg (February to May) is with lesser annual rainfall, and Bega (October to January) is a dry season. Evidence also indicated that seasonal variability affects rainfall in Ethiopia (Gedefaw et al., 2019). Based on such seasonality verification and the result obtained on the model's accuracy measures (explained in the next paragraph), the analysis of the historical meteorological data was implemented on the seasonally adjusted values using the deseasonalized time series decomposition method. This method deseasonalizes the time series and allows the removal of seasonal effects that have distinct periods and amounts (Dagum & Bianconcini, 2016). As a result, the visualisation of the relationship between climate factors and time is made clear with subsequent best-trend estimates (Anderson et al., 2020).

The analysis was done using Minitab® statistical software (version 18). The climate factors (temperature and rainfall) were checked for normality using the Anderson-Darling test7 and failed to reject the null hypothesis with the default level of significance ($p>0.05$). Following this, the decision to use either the "additive" or "multiplicative" method of the time series decomposition was made based on visual

[7] H_0: The data are normally distributed.

inspection and the result from the model on the accuracy measures of the seasonality variations. Consequently, a multiplicative model with a seasonal length of three (Bega, Belg, and Kiremt) was applied. Accuracy measures are calculated values that measure the accuracy of the fitted model. The commonly used model performance measures include MAPE (Mean Absolute Percentage Error), MAD (Mean Absolute Deviation), and MSD (Mean Squared Deviation). The fitted model is chosen if the obtained performance values are lower (Arslan et al., 2020). The multiplicative model has the lowest accuracy measures and a seasonal variation of increasing magnitude across time. This implies the dependence among the time series components (Dagum & Bianconcini, 2016). Based on Anderson et al. (2020), it is modelled as a product of the trend, seasonal and irregular components:

$$\boldsymbol{Y(t) = T(t) \times S(t) \times \varepsilon(t)} \qquad \textbf{(1)}$$

Where $Y(t)$ is the climate factor (time series)8, $T(t)$ is the trend, S(t) is the seasonal component and $\varepsilon(t)$ is the irregular component (catch-all factor); all at time t (year) = 1,…31. Dividing the estimated time series values by seasonal estimates gives deseasonalized values ($\mathcal{Y}$) that are used in analyzing the trend ($\mathcal{T}$) of the climate variables using the slope coefficient of the trend line β_1. Following Anderson et al. (2020), the resulting trend equation is:

$$\boldsymbol{\mathcal{Y}(t) = \beta_0 + \beta_1 \mathcal{T} + u_t} \qquad \textbf{(2)}$$

Where $\mathcal{Y}(t)$ is a deseasonalized series with multiplicative decomposition $\left(\widehat{Y(t)}\big/\widehat{S(t)}\right)$ and β_0 is the intercept. The serial correlation was checked by using the Durbin-Watson statistic (d). This is the most commonly employed test for detecting serial correlation using least squares residuals when there are sequences in the data and no lagged dependent variable is used in the model (Field, 2018; Greene, 2018). In the limit of the d value (Durbin-Watson statistics), ranging from 0 to 4, the test results for the study were found to be greater than the upper critical value and within the range of the rule of thumb ($1.5 < d < 2.5$). This showed no statistical evidence for a positive correlation (Field, 2018; Schreiber-Gregory, 2018).

Rainfall variability was examined using the statistical tool of the Coefficient of Variation (CV). CV is a relative measure that indicates the variability in rainfall from the mean values of rainfall. According to Anderson et al. (2020), CV% is calculated

[8] Average monthly maximum temperature, minimum temperature and rainfall amount over 31 years

as the ratio of the standard deviation (SD) to the mean rainfall ($\bar{X}$) expressed in percentage.

$$CV = \left[{}^{SD}/_{\bar{X}}\right] \times 100\% \qquad \textbf{(3)}$$

4. Results and Discussion

Almost all participants (KII and FGD) expressed the reality of climate variability, its effect on their agriculture, property and a need for vulnerability support. Based on their responses, the major manifestations of climate variability are raised temperature and high rainfall variability, with the resultant extreme weather events and crop pests. The responses held by participant farmers and key informants are in alignment with the findings of meteorological time series findings on rainfall and temperature variabilities (Sheikh et al., 2024). This is in agreement with evidence that farmers also better comprehend such climate variabilities. The findings are detailed below.

4.1. Raised temperature (heat)

The findings in temperature variability were examined based on KII, FGD and meteorological data. The key informant from the DRM department of Woreta town in Fogera Woreda explained a consistent increase in temperature each year. As stated by the informant, the average annual temperature of the Fogera in 1990, 2000, and 2010 was 28.4, 29.1 and 29.9 degrees Celsius (°C), respectively. This suggested an apparent rise in temperature over time (~MKI-Fogera, aged 41, Woreta Town). Participants also explained the difficulty people in the area faced, animals suffered, and plants failed to withstand the prevailing heat in the area in the recent decade (see 2D in Table 4).

Evidence from the KII and FGDs was confirmed with a deseasonalized time series method by analysing the historical meteorological data from Woreta and Addis Zemen stations (see equations 1 and 2). The data for Woreta station (Fogera Woreda) indicated that there was a statistically significant increase in trend per annum by 0.18°C (1.8 °C every decade) in minimum temperature ($p< 0.001$) (see Figure 3). The minimum temperature usually occurs during night and morning times. The variability can be taken as a serious marker of the changing climate in the area, which could lead to lower agricultural productivity. Evidence, for instance, showed that the increase in minimum temperature could lead to a net loss of photosynthesis that has significant implications for crop yield (Bapuji Rao et al., 2014). Such heat stress also has an effect on livestock production, which may lead to decreased feed intake, milk production, and reproductive efficiency (Cheng et al., 2022).

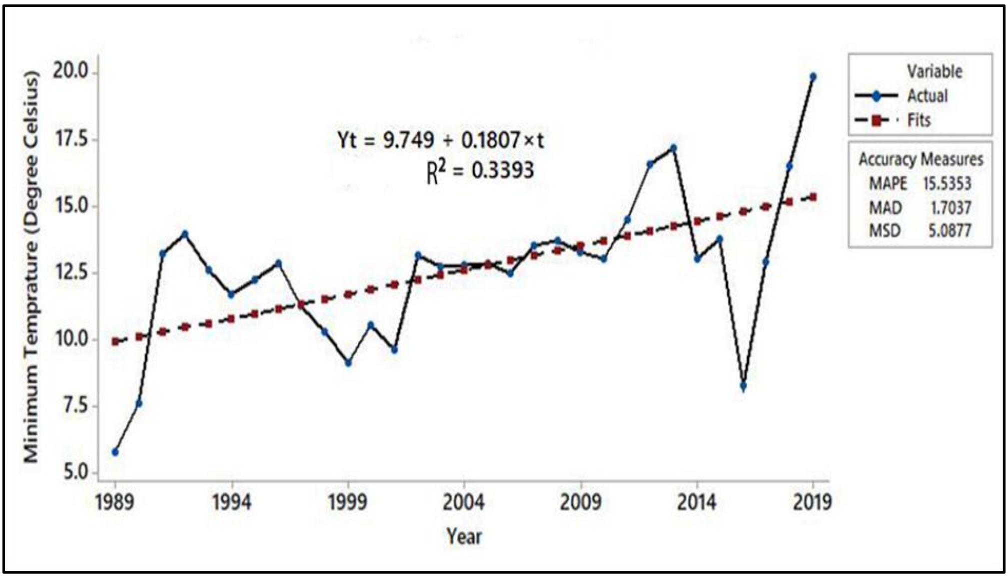

Figure 3: The deseasonalized trend line for average annual temperature (minimum) for Woreta station (1989-2019). Authors' computation

Also in Addis Zemen station (Kemkem Woreda), the maximum temperature showed a statistically significant increase between 1989 and 2019 with an additional 0.076 ℃ every year (0.76 ℃ per decade) ($p<0.001$) (see Figure 4). Given the persistence of climate variability and the coupling effects of environmental degradation and overpopulation, chances are that the variability in magnitude gets high. The finding agrees with the result of Getachew (2018), who conducted a trend analysis on temperature and rainfall in South Gonder for 19 years (1996-2015). His result for Addis Zemen station showed statistically significant increases in annual maximum temperature and mean annual temperature (1.698 ℃ per 20 years). The findings of the rise in temperature in both stations of the present study are within the range of the forecast for global warming in the century of 0.3 and 5°C, which could lead to a reduction in water availability in East Africa (WaterAid, 2022). The findings also agree with a study on Africa that indicated extreme temperatures to be seen more than ever (Bedair et al., 2023). It can be seen from the present findings that the rise in minimum temperature per annum by 0.18 ℃ is higher than the rise in maximum temperature of 0.076 ℃ every year in the study areas. This also agrees with the evidence of a higher rise in the minimum temperature trend rather than the maximum temperature (Gil-Alana, 2018).

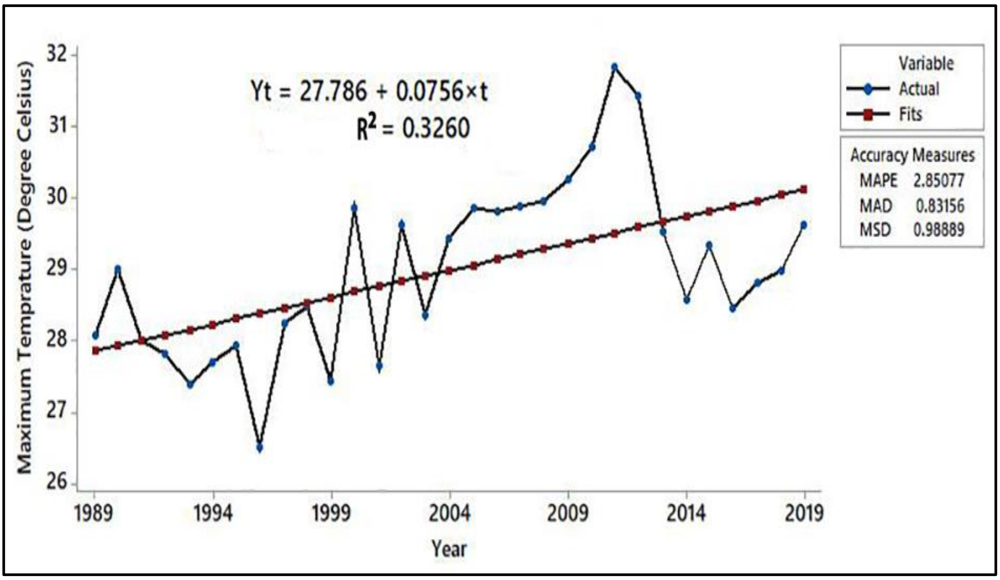

Figure 4: The deseasonalized trend line for average annual temperature (maximum) for Addis Zemen station (1989-2019). Authors' computation

4.2. Rainfall variability (unpredictability)

The perception of the inhabitants about climate variability can be noticed from the opinions of participants from each Woreda. Participants of Fogera and Kemkem were worried about rainfall variability, specifying the unpredictability in the recent decade of rainfall intensity, duration, and falling time (see 1A in Table 4). The result of the annual rainfall analysis in Addis Zemen showed a significantly increasing trend of 1.73 mm per annum (17.3 per decade) ($p<0.05$) (see Figure 5). This shows an increased risk of flooding in Kemkem and its surroundings. The findings also tally with the qualitative evidence of severe flooding (section 3.3.2). On the other hand, in Woreta station, though the annual rainfall was decreasing, it is not statistically significant at a 5% level. This substantiates the participants' evidence of yearly rainfall variability rather than a trend in Fogera.

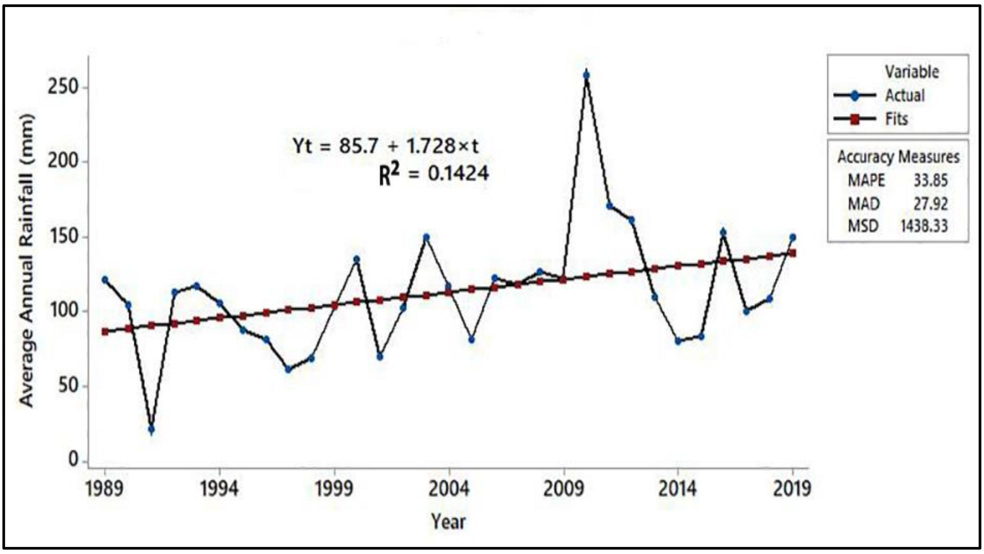

Figure 5: The deseasonalized trend for annual average rainfall at Addis Zemen station (1989-2019). Authors' computation

With participants' remarks on rainfall unpredictability in the study areas, the study objectively examined annual variability using CV (%) (See equation 3). The result indicated a remarkable annual rainfall variability over the years. The yearly rainfall variability in Addis Zemen was 36.7% and that of Woreta was 34.7% (See Table 2). These imply high annual rainfall variability with increasing unpredictability. Such high variability (CV>30) indicates that the areas (Fogera and Kemkem) are vulnerable to drought. The finding agrees with the findings of Wetherald & Manabe (2002) that a high risk of flooding and drought was related to raised heat and climate variability.

Table 2: Coefficient Variation and related descriptive statistics for the annual rainfall (mm) in the two meteorological stations

Stations	Mean	SD	CV (%)	Minimum	Maximum	Range
Addis Zemen	113.36	41.63	36.72	21.16	258.12	236.96
Woreta	116.77	40.52	34.70	0.00	248.32	248.32

Authors' compilations

It is important to note that the areas are experiencing flooding and drought together. This situation is not uncommon in Ethiopia. For instance, flooding is commonly seen along the Shabelle River in the Ethiopian Somali region, which is at risk of drought9 (WFP, 2021). Most climate models predict that the temperature in Ethiopia will rise over the coming years, increasing by 2.1°C in 2050 and 3.4°C by 2080. Over the past five decades, rainfall has shown high variability and is likely to continue with the same pattern (Weldegebriel & Prowse, 2017). The natural variability of the ocean-atmosphere related to El Niño-Southern Oscillation and the increase in anthropogenic activities has greatly contributed to the climate variability and variability in the country (see Rowell et al., 2015).

4.3. Extreme weather events and their effects on rural women

4.3.1. Extreme weather events

Findings showed that the natural disasters resulting from climate variability with the most severe impact in the three Woreda were flooding, drought, snowfall & wind (see Table 3). There were also disasters of crop pests and human and livestock diseases. Among these are an unidentified crop worm, named abekti—አበቅቲ[10] in Amharic, malaria, diarrhea, and a livestock disease called trypanosomiasis (locally called Gendi). The finding agrees with the international discourse that climate variability is a major threat to African agricultural development and public health (Berger & Troost, 2014). The national discourse also agrees with the evidence of high vulnerability to climate variability in Ethiopia concerning the heavy dependence of its economy on rain-fed agriculture (Team & Hassen, 2016).

It can be seen from Table 3 that the very severe natural disasters are flooding in Fogera and Kemkem Woreda and drought in Dera, followed by crop pest (Abekti) in Fogera and Dera, and snowfall in Kemkem. In Dera, drought is the most frequent event compared to flooding. While drought-stricken kebeles are Mecha, Desikua, Degwat, Tik Anibesa, Belabo, and Sanana Digustan, the flood-stricken kebeles were Mtslina Tana, Zarina Jegina and Geregera Gedam Eyesus. In Kemkem, Amena, Mar Tadios, Bilz Wuha, and Darita were drought-hit villages.

[9] Soil becomes so dry that it cannot soak up rain promptly.
[10] Vernacular name

Table 3: Severity rank of extreme weather events and indirectly related disasters in the study Woreda

Woreda	Disaster and Severity Rank				
	1st (Very Severe)	2nd (Severe)	3rd (Mode rate)	4th (Mild)	5th (Very Mild)
Fogera	Flooding	*Crop Pest (Abekti)	Snowfall and Wind	Drought	Malaria (last 2 years)**; Trypanosomiasis; Other crop pests and insects***; misapplication of pesticides, emboch[11] weed.
Dera	Drought	Crop Pest (Abekti)	Snowfall and Wind	Flooding (three kebeles)	Other crop pests, soil degradation, siltation, misapplication of pesticides, and the emboch weed.
Libo Kemkem	Flooding	Snowfall and Wind	Crop Pest (Abekti)	Drought	Malaria (last 2 years); Trypanosomiasis; Other crop pests and insects; misapplication of pesticides, emboch weed.

*Crop pests and diseases are indirectly linked to climate change
**Associated with increased irrigation practices
***Other than Abekti
Authors' compilations

4.3.2. Flooding and its effects

In Kemkem and Fogera Woreda, flooding due to the high rainfall intensity is causing serious damage, especially in the low-lying kebeles. The river water overflows to the banks of the Ribb River, flooding vast areas of croplands with large loads of sediment. It destroyed crops grown in the farmlands. This finding agrees with Gashaw & Legesse (2011), who related flooding in Fogera to rainfall and vegetation removal. To cope with and recover from the effects is beyond the capability of the local inhabitants and administration. In 1987, 2006 and 2019, the most destructive

[11] Invasive species of water hyacinth with its scientific name *Eichhornia crassipes* or locally known as "*Emboch*" appeared around 2011 on Lake Tana. It has been threatening the water and water bodies since then

flooding occurred in Kemkem, during which 5–10 kebeles were submerged. According to the participants, the risk of the disaster was lessened with the support of higher administrative levels (Zonal, Regional and Federal governments). The destruction by flooding of local water sources (springs and wells), besides its economic impact, makes children liable to waterborne diseases.

The participants also revealed that the effects of flooding on local farmers at individual, household or community levels were primarily the result of poverty. The close linkage between the impacts of flooding and the vulnerability situation of the farmers can further intensify the extent of vulnerability and poverty of the local farmers. This can be seen by examining how infrastructure smashed by flooding (e.g. roads) is linked with the underlying farmers' income status. Such a situation was more disruptive when the farmers' engagement in their daily routines became limited. It is thus important to see disaster management as a component of poverty reduction strategies.

The Woredas are prone to flooding due to their topography and proximity to Mount Guna[12] and Lake Tana. The findings indicated that the topography of all the study Woredas are characterised by two distinct slope categories: part of each Woreda (almost one-third) lies in a highland with steep mountains, and the majority (about two-thirds) is a low-lying flood plain. Mount Guna is the only water tower from which all major and smaller rivers in the area originate. The erosion from the highlands and sedimentation on the river path will finally reach Lake Tana. Field observations indicated that at the bridges on the main road from the nearby Bahir Dar city to Addis Zemen town, the depth of the Gumara and Ribb rivers is a meter and a half deep, indicating the chance of easy overflow. Consequently, the lower parts of the study Woreda were flooded during each rainy season.

The other flooding threat to the target Woredas comes from the backflow of Lake Tana. The sedimentation of it led to a decrease in water-carrying capacity and backflowing in the rainy season. The agrochemicals (nitrates and phosphates) from the flooding lead to eutrophication of the lake and exacerbate the problem of dangerous exotic weeds of water hyacinth (locally called emboch) and other weeds. With the backflow, emboch has been invading the farmlands and endangering farmers' livelihoods. It prohibits normal engagements in crop cultivation, fish catching and livestock grazing.

However, flooding has also unlocked two main opportunities. The Woreda areas,

[12] *Mount Guna* is the highest point in the area (4,231 meters).

with plain topography and large river flows, have exhibited high irrigation potential. Field observations indicated that with irrigation farming, farmers were growing vegetables and even the most common staple food crop in the country, teff (Eragrostis tef). The frequent flooding also made paddy fields available for rice farming. However, only a few farmers have accumulated enough capital and engaged in some form of investment.

4.3.3. Crop pests and their effects

Crop pests[13], insects and the unidentified worm (abekti), in particular, were reported as a serious disaster in all the Woredas. Some pests were reported to be commonly associated with irrigated fields in different agronomic phases. They were more severe during the flowering and fruit-bearing stages. Key informants from Fogera and Dera Woreda explained that crop yield loss was estimated to reach one-fifth and one-tenth, respectively. A statement on the participants' opinions and observations on crop pests and other related disasters is exhibited in Table 4.

4.3.4. Snowfalls and the effects

Participants also indicated that the occurrence of snowfall has been increasing. All the Woredas were increasingly prone to snow across time, but its effect was more severe in Kemkem, particularly in the last ten years. The level of damage was high when the snowfall occurred during the flowering or seed production stages. Three years ago, in Kemkem, for example, snow crystals destroyed most properties and crop yield, resulting in starvation. At the time, the participant explained, they couldn't get straw for animals, let alone harvest crops. The areas on or near the highlands were particularly vulnerable to snow-struck crop failure. When snow falls at the end of the rainy season, crops hit by snow cannot recover, and hence, farmers lose almost half of their expected yield. Field evidence also indicated that crops (sorghum and maize) didn't bear any seed after being stricken by a snowstorm in the earlier month. Even livestock failed to feed on the snow-hit crop residues due to crop infestation by worms (Table 4).

4.3.5. Drought and its effects

A drought is a disaster event occurring when an area experiences below-normal precipitation that can lead to reduced soil moisture or groundwater, diminished stream flow, crop damage, and a general water shortage (Chikabvumbwa et al.,

[13] A crop pest is an insect or small animal which damages crops or food supplies. E.g. insects, mites, nematodes.

2022). The participants (FGD and KII) stressed that drought due to climate variability was a severe challenge. Although all the study areas experienced drought, the event was more severe in Dera Woreda. Because most farmers cannot afford to work with irrigation facilities, coping became practically impossible. During dry seasons (bega), water scarcity occasionally led to conflict.

4.3.6. Diseases (Malaria, Trypanosomiasis, Diarrheal diseases) and their effects

Results also indicated an increased prevalence of human diseases like malaria and livestock diseases, such as Trypanosomiasis, locally called Gendi. The diseases are transmitted by vectors of mosquitoes and tsetse flies, respectively. Climate variability associated with water-logged fields and raised temperatures, just after the end of the rainy season and after the occurrence of flooding, is creating suitable conditions for the breeding and spread of the vectors. There is a high association between flooding and the increasing prevalence of malaria outbreaks in the study areas. With the topography of areas (e.g. flat plain), there is a high predisposition to flooding, particularly during the long rainy season (kiremt ─ June to September) and after October. The Gumara and Ribb rivers also transgress their bank and engulf the farmlands and villages. Following this, malaria outbursts and attack the community, from which children suffer a lot. Deaths due to malaria are also becoming a challenge. The prevalence of the deadly livestock disease Trypanosomiasis was reported to be strongly associated with temperature (Nnko et al., 2017). Research conducted in Africa also showed that extreme flooding increased positive malaria diagnostic tests in the post-flood period by 30% more in villages bordering flooding areas than in villages far from the transgressing river (Boyce et al., 2016).

Table 4: Statement exhibit about the major climate-induced natural disasters and their effects in the study areas by FGDs and KII participants.

Major Disasters				
	Flood	**Crop Pest (Worm Abekti)**	**Snow Fall**	**Heat & Drought**
1	'Rainfall in unusual months and delayed and extended rainfall are becoming unpredictably common. The whole rainfall can precipitate within a few hours or minutes (…) ~MRF-Libo Kem, Aged 50; Shina Tsion Kebele	(…) The worm named – abekti is attacking all crop varieties but is serious on vegetables, particularly tomato and pepper (…).~WVF-Fogera, aged 40; Kuhar Kebele	(…) The frequently falling snow is destroying our crops, but the magnitude of damage is very severe on vegetables** (…). ~MVF-Fogera, aged 47; Kuhar kebele	(…) The most serious climate-related hazard is drought. Those areas which are near highlands and mountain chains are highly & frequently affected (…) ~WKI-Dera, aged 37; Ambesame
2	"I am the victim of the flood. Last summer, my house, together with all possessions inside, was taken away by flooding... only our life was saved with the help of our neighbors (…)" ~WRF-Fogera, aged 45; Kuhar kebele	"In the last 10 years, there has been an occurrence of unknown vegetable pests." ~WKI-Dera, aged 40, Ambe Same Town	"(…) the amount of rainfall seems similar for about the last 20 years, but the intensity, duration and falling time are extremely varied to the level that we cannot predict. The rainfall is frequently accompanied by heavy snowfall, which is damaging our vegetables and other crops substantially. "~MRF-Fog, aged 60; Kuhar kebele	"(…) we are even unable to wear shoes during the bega* season due to the prevailing hot temperature… even animals and plants could not withstand it. … particularly since the last 10 years." ~MRF-Fogera, aged 60; Kuhar Kebele
3	"Flooding is severe in the lower and plain areas, which are below the main road towards Lake Tana… the steep highland areas are affected by soil degradation. The eroded soil is transported and deposited in the lowlands to form siltation…" ~WKI-Libo Kemkem, aged 30, Addis Zemen	"Crop pests are affecting our vegetables seriously (…)" ~WVF-Libo Kemkem, aged 35, Agela Mantogera kebele	"Our houses and community infrastructure were destroyed by the joint occurrence of snow and strong wind (…)" ~MRF-Dera, aged 45; Jigna Kidane-Mihret kebele	(…) The temperature now is similar to that of hot areas in the country, like Humera and Metema. Unlike the usual time, Tikimt and Hidar [October and November] are also unusually hot". ~WRF-Libo Kemkem, aged 45, Shina Tsion Kebele

*bega- dry months; **common vegetables suffering from snow are tomato, pepper, cabbage and onion
Authors' compilation

4.4. Effect of climate variability specific to rural women

4.4.1. Effects on agricultural productivity and loss of income

It was found that the major effects of the natural and indirectly related disaster in the Woreda were associated with agricultural production, such as crop damage, crop yield reduction and loss of livestock. The effect on agriculture was a decline in productivity and loss of income. The findings also showed that the rural women in the target areas, compared to men, are more vulnerable to climate variability. Women's vulnerability was explained mostly in terms of their lower physical vigour, biological role, resource ownership, different cultural influences and gender inequalities in exist in the study area. The result of the study showed that vulnerability to the effects of climate variability is more intense and significant for rural women in agriculture. With such gender inequality, the situation led rural women into a trap of vulnerability. The effects varied with the type of disaster and the extent of vulnerability as indicated below.

4.4.2. Effects on material and financial resources

According to the male and female participants, women, compared with men, are financially and physically weaker in withstanding the challenges posed by climate variability. All participants indicated that the destruction and loss of properties and live animals, demolished houses, and loss of personal belongings, with the required long recovery period, led to the loss of income and a huge financial burden (see participants' exhibit 2A and 3A in Table 4). Key informants from South Gondar indicated that flooding usually blocks roads and makes transportation inaccessible. The defective roads made accessing physical infrastructure and facilities (markets, clinics, schools, water points, etc.) difficult for people's daily needs. Such events made females more susceptible than males. Male farmers do have more capability (physical and financial) to water their vegetables by fetching water from distant areas during dry seasons. Rural women also experienced low access to different resources. The key informant of the zone (~WKI-South Gonder, aged 29, Woreta Town) elaborated that, though access to essential resources is common regardless of gender differences, rural women were among the lowest groups in terms of accessing or controlling basic resources (e.g. land, oxen, farm tools). For instance, the majority of motor pumps in irrigation farming were still owned by male farmers. Rural women were capable enough to purchase neither pesticides nor fertilisers. As a result, their agricultural productivity and yield became lower than men's, leading to a vulnerability trap. Eventually, rural women became more vulnerable and less resilient to cope with or recover from climate-induced effects.

4.4.3. Effects on women's health and their productivity

Participants (KII and FGD) expressed the psychological trauma and damage they faced from the flooding and the recovery period they went through. Apart from the huge loss of crop yield, the community suffered from malaria. Women, particularly pregnant and breastfeeding, were more susceptible to malaria, for which there are death records. The effect of climate variability is daunting on vulnerable groups. Studies show that, in areas with high transmission, such as Africa, people with little immunity against malaria are the most vulnerable groups. These include pregnant women whose immunity is decreased by pregnancy and children who have not yet developed partial immunity to malaria (Takem & D'Alessandro, 2013; Tamir et al., 2023). Research showed that malaria contributes significantly to worker absenteeism (Lukwa et al., 2019). This is also evident in the study areas where women and men indicated absenteeism from their routine farms. This, in turn, could contribute to their financial weakness.

4.5. Coping and adaptation mechanisms

There is important local knowledge and practices in coping with and recovering from the effects of climate variability in the study areas, as mentioned below.

4.5.1. Social capital

The findings indicated a high level of social capital in the areas. Villagers live in a system functioning as a single entity. They were networked with various social, cultural and religious bondages. Participants explained that whatever disaster might occur in a village, the community members, including those living in neighbouring villages within a Woreda, assist each other with knowledge, skill, labour, money, material and time. In a relatively lesser disaster impact, the community members cooperate initially to solve it independently using their long-standing social network. The rich in the village would also support the poor and women. The participants believe that the social association in those target rural areas are stronger than in the nearby urban centres. What happens with a member in a village is also a concern for other villagers with a strong sense of cooperation.

4.5.2. Changes in farming practices

The usual farming practices in the study areas were shifted to unusual crop types. According to participants in Fogera Woreda, due to the catastrophic effects of pests on crops, farmers shifted from their usual farming (wheat and barley) to producing disease-resistant crops such as sorghum, millet, and rice. Furthermore, when the river becomes drained in the dry season, farmers dig down and extract underground water for irrigation and try to compensate for the lost income from crop damage (MKI-Fogera, Woreta).

4.5.3. Support from Governmental (GOs) and Non-Governmental Organisations (NGOs)

Depending on the extent of damage and urgency, farmers get support to deal with it from different GOs and NGOs in the form of food aid and materials. When rice-growing women focus-group participants were asked about their recovery from those hard disasters, a woman farmer indicated that though the support allowed them to sustain their lives, it was so limited (WRF-Libo Kemkem, aged 43; Shina Tsion kebele).

4.5.4. Livelihood diversification

Although primarily dependent on farming, rural men and women tend to diversify their livelihoods in the face of disasters in their agricultural production. The major traditional coping and adaptation mechanisms at an individual level to diversify, earn or save income were engaging in casual work, selling farm products, and participating in petty trades, some of which are linked with financial and social capital (see Table 5).

Table 5: Major livelihood diversifications as coping strategies for the effects of climate change

	Traditional diversification options for coping with climate change	Remarks
1	Engaging in casual work	They move to urban areas as daily labourers (particularly the youth).
2	Selling farm products in the nearby towns (Bahir Dar and Debre Tabor)	This happens when the extent of the damage is severe.
3	Engaging in petty trades around their homestead and urban centres	Young women were engaged in selling tea and coffee; Similarly, adult women farmers sell local alcoholic drinks (areki and tella). While the young men were engaged in barber and shoe-shining services, the adult men were involved in crop and livestock trading.
4	Grain storage and reduction of consumption levels	Financial capital
5	Inter-household transfers and loans	Social capital
6	Sale of assets (livestock, tools),	Financial Capital
7	Credit from merchants and moneylenders	Social capital

Authors' compilation

4.6. Institutional support and limitations

Several stakeholders are working on addressing disaster risks in these areas. They gave support in various ways, such as awareness creation and offering training on crop production and protection, soil and water conservation, disaster prevention, and technology transfer. The major institutional challenges and weaknesses are listed below.

4.6.1. Limited institutional capacity

Participants believed that DRM responses were not sustainably or holistically addressed. Key informants from Fogera Woreda explained that such efforts have been disorganised and underutilised in terms of the institutional capacity that existed at the higher administrative level and are highly dependent on the limited local capacity (WRF-Libo Kemkem, aged 43; Shina Tsion kebele; MKI-Fogera, aged 32;

Woreta). These indicate that the institutional capacity is much weaker at the grassroots level compared to the higher administrative levels. The participants illustrated that while the disaster challenge is at the grassroots level, the physical, human, and financial resources are piled up at the higher administrative levels.

4.6.2. Inadequate, delayed and not all-inclusive support

Participants confirmed the presence of support by the GOs and NGOs when affected by natural disasters. However, the support offered was, in participants' elaboration, very limited and incomparable with what the farmers were anticipating. The support, they believe, was reached after the disaster had already inflicted severe damage. Furthermore, non-urgent natural hazards, such as drought, have no support at all.

4.6.3. Lack of coordination

Participants noted that coordination between different stakeholders working in DRM is very weak. Most stakeholders made themselves available during active disaster occurrences, in which case, most stakeholders put their resources (time, energy, capital, technique) into reducing the effects. Moreover, such effort is exerted in isolation with a neglect of duplication of efforts.

4.7. Pesticide uses, application and effects

The participants indicated that the cost of pesticides is beyond their purchasing power, and the situation is even graver for rural women. They revealed that crop worms have frequently attacked their vegetables and pulse crops, especially in the last ten years. Tomatoes are the most affected among the vegetables. One related challenge growing in the area was the problem of pesticide resistance. Due to similar pesticide applications over a long period, pests gradually develop chemical resistance. Participants believed that there was a knowledge gap in using the right doses. The situation also conveyed negative externalities polluting the environment and affecting the health of vegetable consumers (WKI-Fogera, aged 35; Kuhar kebele).

4.8. Agricultural insurance

The findings showed that there was no agricultural insurance in the Woredas. However, a key informant from South Gonder Zone indicated the presence of some discussions and preliminary (pilot) actions made about the issue in Kemkem Woreda by a not-for-profit organisation working in the area. Preparations to undertake discussions in the other disaster-prone Woreda of Dera and Forgera were also underway (~MKI-Libo Kemkem, aged 37, Debre-Tabor Town). However, participants showed their willingness to participate if insurance were to exist related to climate variability (WRF-Fogera, aged 39; Kuhar kebele). The issue of agricultural insurance is no more than the pilot stage and is also almost non-existent at the country level.

A key informant from the Ethiopian Insurance Company (a governmental organisation) in Addis Ababa, the capital city, also asserted this, explaining the existence of pre-conditions rather than actual implementation. The key informant further expounded on the importance of infrastructure development and system establishments needed before executing an insurance policy. Pre-assessment of the farmers' engagement in agricultural activities and climate variability, information on the Weather Index, road transport, and technological compatibility, such as mobile phone usage at the farmers' level, is needed to function before implementing crop insurance. The situation, the key informant explained, is too costly to benefit the company. In this regard, it is clear that some technological, infrastructure and human capacity, along with a regulatory system, are to be built before applying any such insurance.

5. Conclusions and Practical Implications

The insight into climate variability held by participants in the study areas coincides with the findings from the meteorological data. Prolonged climate variability existed in the form of a rising trend in temperature and annual rainfall. The variability was associated with extreme weather events of flooding, drought, snowfall, crop pests and diseases. The disasters have occurred concurrently, which aggravated the challenges of and affected the livelihood of women in agriculture more than men. Women were also found to be more vulnerable to disasters owing to their lopsided situation in poverty and gender inequality. Concerning constraints on livelihood assets, it was found that women, more than men, were disadvantaged in physical capital (particularly producers' goods such as farm equipment, tools, pumps etc.), human capital (physically weak, lack adequate labour skill and knowledge, suffered more by malaria and diarrheal diseases), and faced low financial capital (low income). There were gender-based mobility restrictions where women are socially not free to move to nearby towns for better wage opportunities. Such inequality in gender usually makes women more vulnerable to the effects of climate-induced disasters. With such status, the effects on agriculture ultimately led to a decline in productivity and a loss of income, which led them to a vulnerability trap. As opposed to constraints, however, some opportunities have also prevailed in terms of social capital (a strong network of relationships and cohesion) and natural capital (irrigation with floodplain on a suitable landscape). Yet the rural women in the area remained vulnerable and failed to be resilient enough. All along, the current institutional capacities and procedures on the ground have not been adequate in addressing the needs and empowering the capabilities of rural women.

The prolonged climate variability, women's higher vulnerability to disaster, and the disproportionately higher effect of extreme weather events on women in agriculture eventually led women to a vulnerability trap. Breaking such a cycle necessitates suitable extra-local interventions, along with internal (local) effort. Besides, the major coping strategies upheld by the rural inhabitants in the area were greatly related to their socio-economic conditions, age structure and the intensity and persistence of the effects of climate variability. Thus, adopting a gender-responsive, community-based approach to disaster risk management that addresses the needs and capabilities of poor rural women could enhance sustainable rural development.

In assessing the effects of climate variability, the qualitative analysis could have been extended to a rigorous quantitative study to estimate the impact and obtain more evidence. This was not conducted due to constraints in the required objective data. However, the study applied different qualitative methods (KII, FGDs and direct observations) and combined these with historical climate data to extract as much relevant and in-depth information as needed.

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Supplementary data

Table A.1: Number of participants in the Key Informant Interview (KII)

No.	Town/City	Key Informant Interviewed
Fogera woreda		
1		DRM Office: Disaster Risk Management Expert
2	Woreta	WCYA Office: Women, Children and Youth Affairs Expert
3		Agriculture Office: Development Agent (DA)
4		Agriculture and Natural Resource Offices: Agronomy Team Leader
Dera woreda		
5		WCYA Office: Project M&E Expert
6	Ambe Same	Water Resource and Irrigation (Natural Resource) Expert
7		Agriculture Office: Irrigation Agronomy Expert
8		DRM Office: Early Warning Expert
Libo Kemkem woreda		
9		DRM Office: Disaster Risk Management Expert
10	Addis Zemen	Natural Resource Expert
11		Women, Children and Youth Office: Women and Children Expert
12		Agriculture Office: Extension Service Expert
South Gonder Zone		
13		Agronomy Expert, Zonal Agriculture Office
14	Debre-Tabor	Disaster Response and Rehabilitation Expert
15		Environment Protection Authority (EPA): Environmental Team Leader
Amhara Region		
16	Bahir Dar	Environmental Forest and Wildlife Protection and Development Authority: Environmental law enforcement monitoring and auditing expert
Federal Level		
17		Ministry of Agriculture: Senior Agronomy Expert
18	Addis Ababa	Ministry of Women, Children and Youth Affairs: Women Expert
19		National Meteorology Agency: Meteorological Data Expert
20		Ethiopian Insurance Company (Medihin): Senior Insurance Expert
21	Woreta	Debre Tabor University: Rice Researcher

Source: Authors' compilation

Table A.2: Number of participants on FGD by study woredas

No.	Woreda (District)	Kebele	Number of Participants		
			Male	**Female**	**Total**
Focus Group Discussion (FGD)					
1	Fogera	Kuhar- Male Vegetable Growers	11	-	11
		Kuhar- Female Rice Growers	-	9	9
		Bahar Mikael-Male Rice Growers	8	-	8
		Bahar Mikael-Female Vegetable producer	-	8	8
Sub-total per Fogera					36
2	Libo-Kemkem	Shina Tsion-Male Rice Producers	8	-	8
		Agela Mantogera-Female Vegetable Growers	-	10	10
		Hagola Mentogala-Male Vegetable Producers	8	-	8
		Shina Tsion Female Rice Producers	-	8	8
		Sub-total per Libo Kemkem			34
3	Dera	Jigna Kidane-Mihret-Male Vegetable Producers	8	-	8
		Jigna Kidane-Mihret-Male Rice Producers	11	-	11
		Dera - Female Vegetable Growers	-	9	9
		Dera - Female Rice Growers	-	8	8
Sub-total per Dera					36
Total FGD participants for the study			54	52	106

Source: Authors' compilation

Table A.3: Code construction for the anonymity of all participants in the study

Gender	Farming Practice	Data Collection Methods		Administrative Structure	Final Code	The key to the codes
W= Women	V= Vegetable Growers	F= FGD	KI= KII	Fogera Woreda	WVF-Fogera	Women Vegetable Growing Focus Group Discussion in Fogera Woreda
					MRF-Fogera	Men Rice Growing Focus Group Discussion in Fogera Woreda
M= Men	R=Rice Growers				WKI-Fogera	Women Key Informant from Fogera Woreda
					WVF-Dera	Women Vegetable Growing Focus Group Discussion in Dera Woreda
				Dera Woreda	WRF-Dera	Women Rice Growing Focus Group Discussion in Dera Woreda
					MKI-Fogera	Male Key Informant from Dera Woreda
					MKI-Dera	Male Key Informant from Dera Woreda
				Libo Kemkem Woreda	WVF-Libo Kemkem	Women Vegetable Growing Focus Group Discussion in Libo Kemkem Woreda
				Federal Organization	WKI-Fed	Women Key Informant from Federal Organisation
				Regional Organization	MKI-Reg	Male Key Informant from Amhara Regional Organisation
				Zonal Organization	MKI-Zon	Male Key Informant from South Gonder Zonal Organisation

Source: Authors' presentation