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Commercial Feed Value Chain in Central Ethiopia

Aklilu Nigussie[1], Samuel Diro[2], Lemma Zemedu[3]

Abstract

This study examines the commercial cattle feed value chain in central Ethiopia, highlighting key participants, roles, and interactions across the chain. It aims to analyze the processed feed supply chain, identify primary actors, map the value chain, pinpoint leverage points, and explore both challenges and opportunities within cattle feed production and marketing. Additionally, it investigates factors influencing farmers' selection of commercial feed market outlets. This study investigates the commercial cattle feed value chain in central Ethiopia, key participants, roles, and interactions across the chain. It aims to analyze the processed feed supply chain, identify primary actors, map the value chain, pinpoint leverage points, and explore both challenges and opportunities within cattle feed production and marketing. Additionally, it investigates factors influencing farmers' selection of commercial feed market outlets. The study was conducted in Adama, Bisheftu, Welmera, Sululta, Sebeta Hawas, and Chacha districts, known for high milk production and supply to Addis Ababa and surrounding markets. The study employed a two-stage sampling technique to select dairy farmers, with 230 dairy farms interviewed, along with five feed manufacturers, sixteen traders, and other service providers and enabling bodies. The results showed significant differences in dairy production experience among producers, with average experience in years consecutively 9.54 for small scale, 13.81 for medium scale, and 16.18 large scale years in the value chain. The average consumption rate of a single lactating crossbreed cow in the three categories with the feed type of brewery byproduct was 1.5 kg per cow per day, while 9.2kg of roughage was consumed per cow per day. The average dairy producer in the commercial sector feed maize and wheat bran of 2.4kg per cow per day. The study also found that the price of different feed types fluctuates in a year, with most feed types declining from November to March and inflating from April to October. Male-headed households positively related to the choice of wholesale feed market, suggesting that male-headed dairy farms opt to purchase feed from wholesalers.

Keywords: Commercial feed, Value chain, Cross breed, Dairy, Multivariate Probit Model

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1. Background and Justification

Ethiopia's extensive livestock population, particularly its large dairy herd, holds considerable promise for advancing the dairy sector, which supports rural development, generates income, alleviates poverty, and bolsters food security. Cattle accounts for more than 85% of milk production (Brasesco *et al.,* 2019). Adequate feed is essential for milk production, with primary feed sources comprising natural pasture, crop residues, improved forage varieties, agro-industrial by-products, food and vegetable leftovers, and bi-products from local beer production (Alemayehu, 2017; Dawit *et al.,* 2013; Fekede *et al.,* 2014). Among these, natural pasture is the leading feed source for Ethiopian livestock, followed by crop residues, which contribute10-15% (SNV, 2008; Alemayehu, 2017; Brasesco *et al.,* 2019).

According to CSA data, hay, crop residues, and natural grass constitute over 90% of livestock diets across all Ethiopian regions, while improved forages types contribute less than 0.35%. The highest production of crop-based forage occurs in Oromia, Amhara, SNNPR, and Tigray, with stover and straw as key feed sources (CSA, 2019). As human population grows, more grazing lands are being converted to croplands, with 31% of grazing lands in the Amhara undergoing this shift (Tadesse and Solomon, 2014). This transition has amplified the reliance on crop residues and improved forage in livestock diets, with crop residues contributing between 20% and 80% of the feed supply (Africa RISING, 2014).

According to the CSA (2018), a majority of Ethiopian dairy farmers depend on green fodder as their primary feed source, with 56% using stall feeding as their method. Others incorporate open grazing, cut-and-carry systems, or a combination of stall feeding. In some regions, forage seeds such as elephant grass, Rhode's grass, legumes, and certain herbaceous trees are provided to help mitigate feed shortages (Wytze *et al.,* 2012). Despite this, few Ethiopian dairy farmers have adopted forage crops like alfalfa, elephant grass, and sesbania (Dawit *et al.*, 2013).

Agro-industrial by-products from the flour and oil industries, including wheat bran, maize, and wheat middling, serve as sources of energy and protein supplements. However, these products are accessible mainly urban farmers and remain unaffordable for rural farmers. Using concentrates is impractical in rural areas, where smallholder farmers in Ethiopia also face limited access to feed processing facilities. This leads to lower milk and butter production, higher mortality rates, extended calving intervals, and reduced live animal weights (Diriba *et al.,* 2014).

According to Brasesco *et al.* (2019), the high prices of improved feeds like wheat bran and noug cakes make them unaffordable for rural dairy farmers. Additionally, molasses is unavailable due to its use in alcohol production. While alternative feeds such as brewery by-products and pulse hulls are used, challenges like cropland expansion, urbanization, and climate change continue to exacerbate feed shortages.

Ergano and Nurfeta (2006) and Diro *et al.* (2019) indicate that feed expenses constitute over 80% of the variable costs in dairy production. Feeding practices impact not only milk yield but also its composition. Studies regarding feed value chain, particularly for factory-processed feeds, remain limited, though this approach could become essential as natural grazing lands decline, this study aims to address the knowledge gap by investigating the feed value chain in the country’s central dairy hub.

1.1 Objectives

The objective of the study was to investigate factory processed cattle feed value chain in central part of the country. The specific objectives are to: -

- identify the main actors, their functions and relations along the value chain;
- map cattle feed value chain in the study area; identify the leverage points and governor of the chain;
- identify constraints and opportunities of cattle feed production and marketing along the value chain; and
- investigate determinants of consumers (farmers) choice of commercial feed (concentrate) market outlets.

2. Research Method

2.1 Study Area

The study took place in the districts of Adama, Bisheftu, Welmera, Sululta, Sebeta Hawas and Chacha, located in central Ethiopia. These areas are recognized for their high milk production, supplying large quantities to Addis Ababa and nearby markets. This region forms the country's largest milk shed, serving both individual consumers and processors with substantial milk volumes. It is also notable for its high supply of processed feeds, with the majority of feed factories located in these districts.

2.2 Sampling Technique

The study involved interviews with dairy farmers, feed manufacturers, traders, and other service providers. A two-stage sampling technique was used at the first stage we selected the scale producer's category, to select 230 farms, categorized by size: 55% were small-scale, 33% medium-scale, and the remaining 12% were large-scale dairy farms. Dairy farming households were randomly chosen from a list of dairy producers (Table 1).

Table 1: Sample distribution along the study regions based on their farm types

Dairy farming type by dairy caws number	Amhara		Oromia		Overall	
	n	%	n	%	n	%
Small Scale (<4)	44	73	83	49	127	55
Medium Scale (4 to 10)	13	22	62	36	75	33
Large Scale (<10)	3	5	25	15	28	12

Source: Own survey 2021/22

2.3 Data Type and Collections

The study collected both quantitative and qualitative data from dairy farms and various chain actors using structured questionnaires and checklists.

Quantitative data was collected from customers of processed dairy feed, while qualitative data came from various chain actors.

2.4 Data Analysis

To analyze factors influencing dairy farmers' selection of feed market sources, the study applied a multivariate probit (MVP) model. Since farmers often use multiple sources for commercial feed, their choice is naturally multivariate. The MVP model assesses how explanatory variables affect each option while accounting for possible correlations between errors and market sources (Dorfman, 1996). This approach proved more appropriate than bivariate models, such as logit and probit (Belderbos, 2004).

Thus, the observed choice of market source can be modeled using a random utility framework. For the i^{th} *i^{th}*i^{th} farm household (where *i=1,2, 3, Ni = 1, 2, 3, \dots, Ni=1,2, 3,...,N*), the decision involves selecting whether to use a wholesaler (WS), retailer (RT), cooperative (CP), or feed manufacturer (FM) (see Table 2). Accordingly, the observed outcome of market source choice can be modeled following random utility formulation. Consider i^{th} farm household (i= 1, 2, 3, ……N) which is facing a decision on whether to use Wholesaler (WS), Retailer (RT), Cooperative (CP) and Feed Manufacturer (FM) (Table 2).

Table 2: Number of farmers using these market sources

Feed market sources	Sample farmers	Farmers using the source
Wholesalers	230	72
Retailers	230	49
Cooperatives	230	15
Feed manufacturers	230	8

Source: Own survey 2021/22

Let U_0 represents benefits to the farmer from a certain market source and let U_k represent the benefit of using the K^{th} market source (WS, RT, CP, FM) denoting the use of wholesaler, Retailer, Cooperatives and Food Manufacturers.

The farmer decides to use the K^{th} market source if $Y^{*}_{ipk}=U^{*}_{k}-U_0>0$. The net benefit ($Y^{*}_{ipk}$) that the farmer derives from K^{th} market source a latent variable determined by observed household and location characteristics (X_{ip}) and unobserved characteristics (U_{ip}):

$$Y^{*}_{ipk} = X'_{ipk}\beta_j + U_{ipk}, \text{ where } (k=MA, MT, IC, IF, PM) \quad \textbf{(1)}$$

Using the indicator function, the unobserved preferences in equation (1) translate into the observed binary outcome equation for each choice as follows:

$$Y_k = \begin{cases} 1 \; if \; Y^{*}_{ipk} > 0 \\ 0 \; otherwise \end{cases} \qquad (k = WS, RT, CP, FM) \quad \textbf{(2)}$$

The equation (1) assumes that a rational β^{th} farmer has a latent variable Y_{ipk}, which captures unobserved characteristics or demand associated with the kth choice of market source. This variable is a linear combination of observed characteristics, factors affecting the use of the kth market source, and unobserved characteristics captured by the stochastic error term U_{ipk}. Estimations are based on observable binary discrete variables Y_{ipk}.

Equations (1) and (2) are univariate probit models where the use of a specific market source is independent of whether a farmer uses another market. However, if multiple market sources are possible, the error terms in equation (1) jointly follow a multivariate normal distribution with zero conditional mean and variance normalized to unity. In the multivariate model, the error terms jointly follow a multivariate normal distribution with zero conditional mean and variance normalized to unity for parameter identification.

$$\varepsilon = \begin{bmatrix} 1 & \rho_{WSRT} & \rho_{WSCP} & \rho_{WSFM} \\ \rho_{RTWS} & 1 & \rho_{RTCP} & \rho_{RTFM} \\ \rho_{CPWS} & \rho_{CPRT} & 1 & \rho_{CPFM} \\ \rho_{FMWS} & \rho_{FMRT} & \rho_{FMCP} & 1 \end{bmatrix} \quad \textbf{(3)}$$

The correlation coefficient ρ represents the pairwise relationship between error terms in a model's estimated choice equations. It is represented by the off-diagonal elements in the variance-covariance matrix, which can be positive or negative. If these correlations are non-zero, a multivariate probit is applied instead of a univariate probit for each market source, based on the principle of complementarity or negative correlation.

3. Result and Discussion

3.1 Descriptive Analysis

Diary producers in Ethiopia experienced notable variations in distances to markets, cooperatives, and agricultural extension services. Small-scale producers travel an average of 1.67 km to reach to village markets, while medium- and large-scale producers travel 1.60 km and 1.69 km, respectively. Dairy cooperatives are located 2.24 km away on average, and large-scale producers travel 3.01 km to access public agricultural extension services (Table 3).

Table 3: Institutional characteristics of diary feed consumers (Distance to markets in km)

Variables	Small scale		Medium scale		Large scale		Overall		P value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Village market	1.67	1.18	1.60	1.07	1.96	1.34	1.69	1.17	0.37
Main market	5.52	4.24	6.14	4.07	6.09	4.55	5.78	4.22	0.56
Cooperatives	2.28	1.77	1.99	1.58	2.73	2.08	2.24	1.76	0.15
Agricultural extension	2.24	1.67	2.35	1.77	3.01	2.09	2.37	1.77	0.11

Source: Own survey 2021/22

N.B. km = kilometer

The study analyzed the socioeconomic characteristics of dairy producers, revealing significant differences in experience, grassland and forage land holdings, and educational levels. The average daily production experience varied across scales, with small-, medium-, and large-scale producers averaging 9.54, 13.81, and 16.18 years in the value chain, respectively (Table 4).

The study reveals that hybrid cattle breeds, such as bulls, cows, heifers, and calves, are crucial for dairy farmers. A p-value of less than 0.01 demonstrates statistical significance across different categories of dairy farmers, supporting the null hypothesis, as there is less than a 1% chance of it being correct. Additionally, the study identified significant variability in cattle ownership among small-scale, medium-scale, and large-scale dairy farmers, with small-scale producers having averaging 2 cows and medium-scale producers averaging 5 cows (Table 5).

Table 4: Socioeconomic characteristics of diary feed consumers (dairy producers) in Yr. and Ha

Variables	Small scale		Medium scale		Large scale		Overall		P value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Family size	6.16	2.41	6.20	2.17	7.00	2.78	6.27	2.39	0.23
Dairy experience	9.54	6.36	13.81	7.79	16.18	7.96	11.74	7.47	0.00***
Total land owned	1.86	1.72	2.12	1.77	2.46	1.92	2.02	1.77	0.22
Grazing land	0.34	0.35	0.35	0.40	0.35	0.37	0.35	0.37	0.49
Grass land	0.33	0.33	0.46	0.42	0.49	0.41	0.39	0.38	0.02**
Forage land	0.02	0.04	0.03	0.05	0.04	0.06	0.03	0.05	0.09*
Education	4.64	4.17	5.33	4.15	7.11	4.76	5.17	4.29	0.02**

Source: Own survey 2021/22

N.B. Ha= hectare

Yr. = years

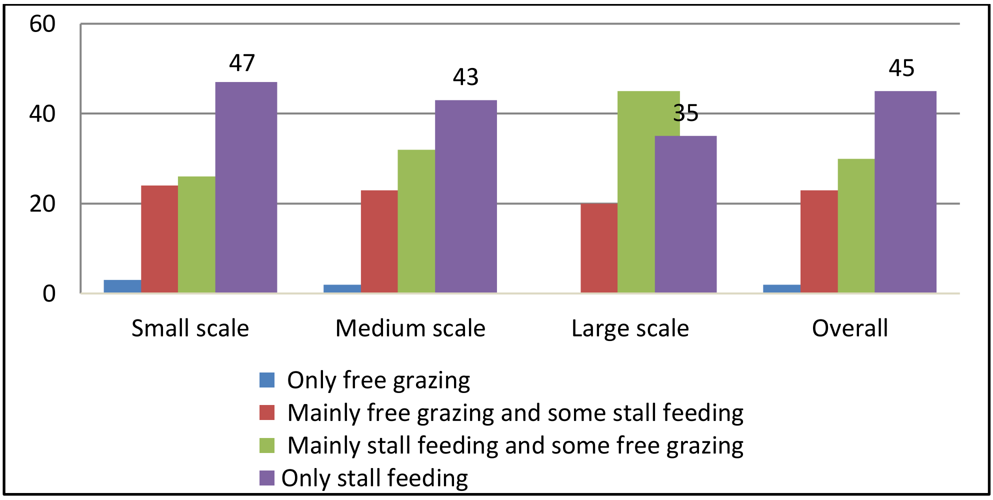
Table 5: Size of dairy farmers' cross breed cattle ownership by cattle type and farmer category

Variables	Small scale		Medium scale		Large scale		Overall		P value
	Mean	SD	Mean	SD	Mean	Mean	SD	Mean	
Ox	0.61	1.13	0.76	1.39	0.99	1.12	0.68	1.29	0.48
Bull	0.31	0.55	0.44	0.79	1.04	0.88	0.42	0.40	0.00***
Cow	1.73	1.16	4.82	3.96	7.10	7.39	4.78	3.98	0.01***
Heifer	0.87	1.05	2.36	2.61	6.20	7.29	2.78	2.45	0.00***
Calve	0.91	1.02	1.57	1.59	5.42	5.09	2.66	2.88	0.00***

Source: Own survey 2021/22

An efficient dairy cow requires a daily dry matter intake of at least 3% of its body weight, with higher-producing cows consuming more than 4%. In Ethiopia, approximately45% of dairy producers use standing feeding systems during the rainy season. Small-scale producers primarily rely on stall feeding, while medium and large-scale producers also adopt stall feeding methods. Large-scale producers combine stall feeding with some free grazing systems. Overall, during rainy season, Ethiopian dairy producers use stall feeding and free grazing systems (Figure 1).

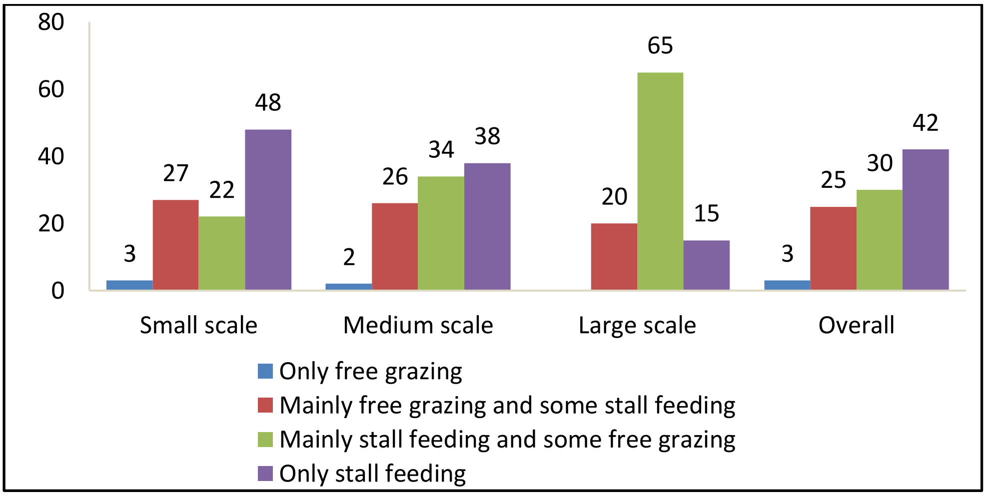
Figure 1: Crossbreed dairy cattle feeding system in rainy season (%)



Source: Own survey 2021/22

In Ethiopia, the dry season is marked by low rainfall, during which 65% of large-scale producers depend on stall feeding and some free grazing. This dry season spans from October to March, while long rain occurs from July to September, and short rain takes place in April and May. Approximately 42% of dairy producers use stall feeding, with 48% of small producers and 38% of medium-scale producers adopting this method. The seasonality of production affects the availability of feed supply, which is prevalent challenge in Ethiopian livestock feeding system. The surplus fodder from the wet season could be used to alleviate the severe feed shortages experienced during the dry season (Figure 2).

Figure 2: Crossbreed dairy cattle feeding system in dry season (%)



Source: Own survey 2021/22

Ethiopia's dairy production systems are encompassing a range of scales, including small, medium, and large-scale producers who utilize improved feed concentrates. Among feed types, maize and wheat bran are the most used, with 71% of producers incorporating them. The proportion of feed usage varies by feed type, with small and medium-scale producers using 37%, 40%, and 36%, respectively. Feed usage also depends on the production level and the cows' genetic potential (Table 6).

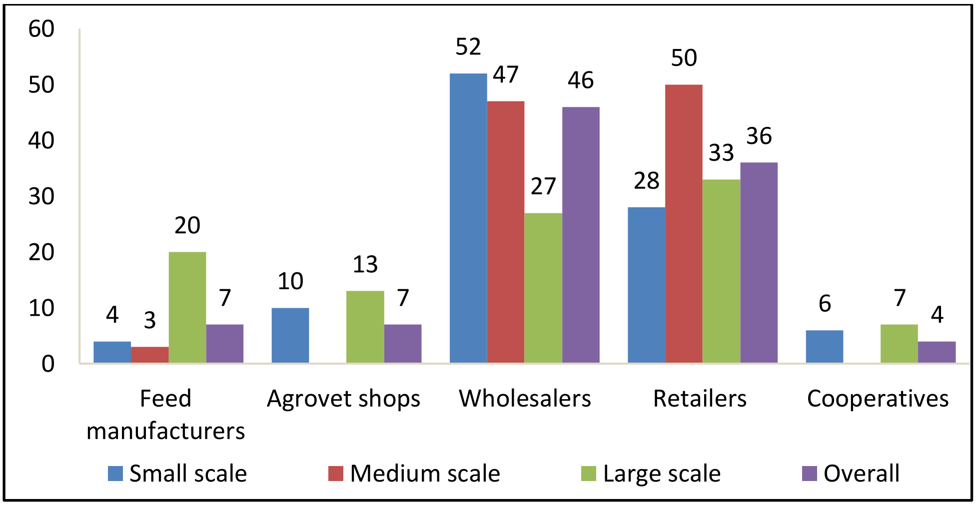
Table 6: Percentage of farmers using improved feed types (%)

Feed type	Small scale	Medium scale	Large scale	Total
Concentrates	37	40	36	38
Maize and wheat bran	72	72	61	71
Oil seed cake	54	43	43	49
Brewery byproduct	31	52	32	38
Molasses	19	21	14	19

Source: Own survey 2021/22

The study reveals that the main sources of feed for dairy animals vary across Ethiopia's diverse production systems. Enhanced dairy production benefits from improved access to input supply and services, including feed, feed sources, market information, extension systems, animal health support, cooperatives, credit, and artificial insemination. To address feed shortages, especially in urban and pre-urban areas, dairy farmers often buy feed from external suppliers. However, the expansion of Ethiopia's dairy sector is hindered by a lack of an organized feed marketing system. Concentrates, which are low in fiber and high in energy, are commonly used to boost energy intake and complement forage deficiencies. Small-scale producers' source concentrated feed from feed manufacturing centers, agro-vet shops, wholesalers, retailers, and cooperatives. For medium-scale dairy producers, 3% of their concentrated feed comes from manufacturers, 47% from wholesalers, and 50% from retailors. The marketing link between these dairy sector participants in the concentrated feed supply chain remains minimal (Figure 3).

Figure 3: Main concentrate market source for dairy farmers (%)



Source: Own survey 2021/22

N.B. Chi2 = 10.13; P=0.04**

Dairy production per cow varies significantly based on the type of dairy producer. High-input, High-productivity systems are common among high-tech producers, whereas small-scale producers using low-tech systems typically have lower productivity. To minimize the impact of dominant cows on the herd, it is recommended all cows feed simultaneously, with feed available around the clock. The average weekly feeding frequency for roughage varies between 1 and 6.5 times. Feeding frequencies for oil seed cake also differ notably across dairy producers, showing a 5% significant level. Small-scale producers exhibit a lower standard deviation of 5.5, while medium and large-scale producers show slightly higher deviations at 5.1 and 5.2, respectively (as indicated in Table 7).

Table 7: Crossbreed dairy cows' feeding frequency of different feed types per week

Variables	Small scale		Medium scale		Large scale		Overall		P value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Concentrates	4.1	5.7	3.4	5.1	5.4	6.3	4.0	5.6	0.26
Maize and wheat bran	5.4	4.3	4.1	4.0	4.7	5.1	4.9	4.4	0.10
Oil seed cake	5.6	5.5	3.9	5.1	3.6	5.2	4.8	5.4	0.04**
Brewery byproduct	2.5	4.3	3.8	5.2	3.8	5.6	3.1	4.8	0.14
Molasses	1.3	2.6	0.9	1.9	0.5	1.5	1.0	2.3	0.19
Roughage	7.0	4.7	6.3	5.2	4.9	5.5	6.5	5.0	0.11

Source: Own survey 2021/22

The study examines how supplying cows with essential nutrients during early lactation can maximize dairy production. Findings indicate that small, medium, and large-scale producers offered different types concentrate feeds to lactating crossbreed cows, averaging 1.6 kg per cow daily. Providing protein as needed stimulates higher feed intake and optimizes the use of mobilized body fat for milk production. High quality roughage, along with substantial supplementation of concentrates such as noug cake and wheat bran, is essential for achieving high production levels. Notable differences were observed in the consumption of brewery byproducts and roughage, with cows consuming an average of 1.5 kg of brewery byproduct and 9.2 kg of roughage per day (Table 8).

Table 8: Feed provided to lactating crossbreed cows (kg/cow/day)

Variables	Small scale		Medium scale		Large scale		Overall		P value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Concentrates	1.4	2.2	1.6	2.4	1.9	2.8	1.6	2.8	0.55
Maize & wheat bran	4.5	4.7	4.0	4.0	5.7	5.9	4.5	5.8	0.27
Oil seed cake	1.3	1.5	0.9	1.4	1.4	1.7	1.2	1.5	0.15
Brewery byproduct	1.1	1.9	1.9	2.4	1.6	2.5	1.5	2.5	0.03**
Molasses	0.4	1.5	0.2	0.5	0.3	0.9	0.3	1.2	0.65
Roughage	7.7	7.5	10.7	9.1	11.4	9.7	9.2	9.7	0.02**

Source: Own survey 2021/22

The study shows that dairy producers, especially across different scales of production, efficiently use roughage feed compared to other types. Small, medium, and large-scale producers provide varying roughage amounts to their pregnant crossbreed cows, with an overall average of 7.1kg of roughage per cow per day. Pregnant cows require ample grain intake to meet energy demands and support calf development, with common grains like maize, wheat, barley, and oats being used. Small-scale dairy producers feed 2.5 kg of maize and wheat bran per cow daily, medium-scale producers provide 1.9 kg, and large-scale producers offer 3.5 kg. On average, commercial dairy producers supply 2.4 kg of maize and wheat bran per cow each day (Table 9).

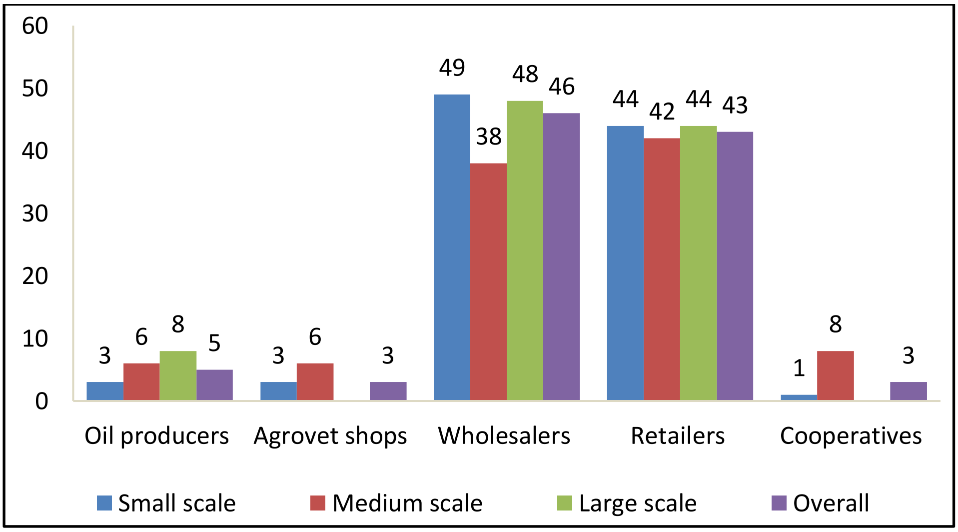
Table 9: Feed provided to pregnant crossbreed cows (kg/cow/day)

Variables	Small scale		Medium scale		Large scale		Overall		P-value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Concentrates	0.5	1.0	0.5	1.0	0.7	1.3	0.5	1.0	0.62
Maize and wheat bran	2.5	3.1	1.9	2.8	3.5	3.7	2.4	3.2	0.06*
Oil seed cake	0.5	0.8	0.3	0.6	0.5	0.8	0.4	0.7	0.16
Brewery byproduct	0.3	0.6	0.5	0.8	0.4	0.8	0.4	0.7	0.09*
Molasses	0.0	0.0	0.0	0.0	0.0	0	0.0	0	-
Roughage	5.9	5.9	7.9	7.3	10.3	8.4	7.1	7.0	0.01***

Source: Own survey 2021/22

Groundnut cake has the highest protein content, ranging from 45-50%, followed by soyabean, cottonseed, rapeseed, sesame, sunflower, palm oil, and olive oilcakes. These protein rich oil cakes can be used to produce protein hydrolysates, protein isolates (with over 90% protein), and protein concentrates (containing 30–80% protein) (FAO Statistics Division, 2010). Small-scale dairy producers obtain their oilseed cake feed primarily from wholesalers (49%) and retail shops (44%), with only 3% coming directly from oil producers and agro-vet shops. Wholesalers and retailers are thus the main sources for their oilseed cake feed (see Figure 4).

Figure 4: Main oil seed cake market source for dairy farmers (%)



Source: Own survey 2021/22

N.B. Chi2 = 3.17; P=0.66

Supplements are vital for pregnant cows, particularly in the later stages of pregnancy, to support the development of a healthy calf. Molasses is commonly used as an additive, supplying energy, iron, and essential vitamins. Commercial dairy feed for cattle also includes various vitamins and minerals to support growth. On average, small-scale dairy producers provide each cow daily with 1.2 kg of concentrated feed, 3.7 kg of maize and wheat bran, 1 kg of oilseed cake, 0.8 kg of brewery byproducts, 0.1 kg of molasses, and 6.8 kg of roughage to sustain production. Medium-scale producers, meanwhile, feed each pregnant and lactating crossbreed cow 9.8 kg of roughage, 0.1 kg of molasses, 1.2 kg of brewery byproducts, 0.7 kg of oilseed cake, 2.8 kg of maize and wheat bran, and 1.5 kg of concentrated feed daily (refer to Table 9).

Supplements are essential for pregnant cows, particularly in the later stages of pregnancy, to support the development of a healthy calf. Molasses is commonly used as an additive, providing energy, iron, and essential vitamins. Commercial dairy feed for cattle also includes a variety of vitamins and minerals to support growth. On average, small-scale dairy producers provide each cow daily with 1.2kg of concentrated, 3.7kg of maize and wheat bran, 1kg of oil seed cake, 0.8kg brewery byproducts, 0.1kg of molasses, and 6.8kg of roughage to sustain production. Medium scale producers, meanwhile, feed each pregnant and lactating crossbreed cow 9.8kg of roughage, 0.1kg molasses, and 1.2kg brewery byproducts, 0.7kg of oil seed cake, 2.8kg maize and wheat bran, and 1.5kg of concentrated feed daily (Table 10).

Table 10: Feed provided to pregnant and lactating crossbreed cows (kg/cow/day)

Variables	Small scale		Medium scale		Large scale		Overall		P value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Concentrates	1.2	2.2	1.5	2.6	2.1	3.3	1.4	2.5	0.245
Maize & wheat bran	3.7	4.0	2.8	3.5	4.8	4.9	3.5	4.0	0.07*
Oil seed cake	1.0	1.4	0.7	1.3	1.1	1.6	0.9	1.4	0.21
Brewery Byproduct	0.8	1.5	1.2	1.8	1.2	2.0	0.9	1.6	0.11
Molasses	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.2	0.75
Roughage	6.8	7.1	9.8	9.4	11.4	9.7	8.4	8.4	0.01***

Source: Own survey 2021/22

The main challenges limiting access to improved feed technologies for small scale dairy producers were high feed costs (51%) limited land for feed production (24%), which represented the largest shares among the identified barriers. For medium scale diary producers, these issues were also significant, with high feed costs at 37% and land shortages at 28%. In contrast, large-scale producers were primarily affected by land shortages (42%) and inadequate extension services (21%) (see Table 11).

Table 11: Factors hindering access to improved feed technologies (%)

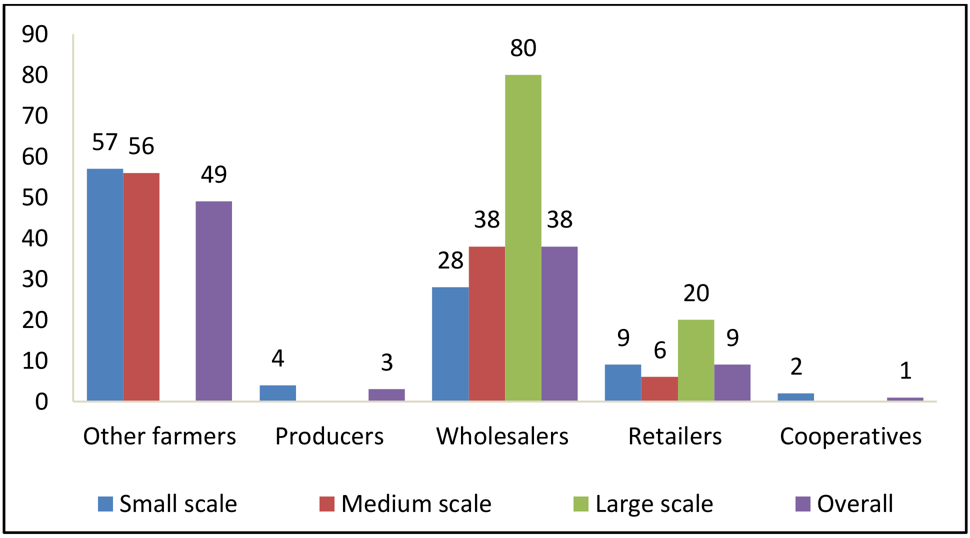
Sources	Small Scale	Medium Scale	Large Scale	Total
High Cost of Feed	51	37	16	43
Land Shortage to Produce Feed	24	28	42	27
Lack of Adequate Extension Services	15	17	21	16
Adaptability Problem of Improved Forage	6	9	13	8
High Cost of Forage	4	9	8	6

Source: Own survey 2021/22

N.B.: Chi2 = 28.98; P = 0.02**

Van Soest (1994) highlighted the importance of roughage feeding lactating cows, as it provides essential fibrous carbohydrates, primarily in the form of neutral detergent fiber (NDF), which includes cellulose, hemicelluloses, and other non-glycolic compounds. In a comprehensive review of research from 1918 to 2017, Hall and Mertens (2017) emphasized the need to deepen the understanding of carbohydrate fermentation in high-yielding dairy cows. In Ethiopia, the primary roughage source for dairy producer is other farmers, cited by 49% of the producers while 36% reported wholesalers as their main source. For large-scale producers, wholesalers are the main suppliers (80%), whereas small and medium scales producers rely predominantly on other farmers, with 57% and 56% respectively sourcing roughage from them (Figure 5).

Figure 5: Main roughage market source for dairy farmers (%)



Chi2 = 23.64; 0.01***

In Ethiopia, agricultural extension services should expand beyond promoting good agricultural practices to also address social practices that create disadvantages, particularly for women. A gender-sensitive approach is needed, including inclusive recruitment and avoiding male-dominated channels. While Ethiopia's agricultural extension programs have shown mixed results, recent expansions have exposed certain weaknesses. A study by Dercon *et al.* (2009) found that receiving at least one visit from a Development Agent (DA) contributed to a 7% increase in consumption growth and a 10% reduction in poverty. The results likely reflect the impacts of technology and knowledge transfers, or DA's influence on input use. Despite establishing one of Africa's largest public extension service systems, quality challenges remain. Berhane *et al.* (2017) examined the role of this system in driving technology adoption, directly improving agricultural productivity, and highlighted the upcoming challenges to further enhance productivity. Their study accounted for diverse factors, such as household wealth and weather variations.

Table 11 shows the participation rates in extension service training for dairy producers of different scaled producers. Small-scale dairy producers received training in dairy management, AI technology, and health and veterinary services, with 44% and 32% of participants engaging in these areas.

The extension service provides non-formal education and learning opportunities to small-, medium-, and large-scale dairy producers nationwide. Data collected reveals that small scale producers received extension services on dairy management (92%), AI technology (92%), feed and nutrition (79%), and on health and veterinary service (91%), Additionally, 86% of these services were provided by the public (governmental extension system (Table 12).

Table 12: Access to training and extension services (%)

Particulars	Small Scale	Medium Scale	Large Scale	Total	Chi2	P-Value
Training						
Dairy Management	44	55	71	51	7.50	0.02**
Ai Technology	32	43	61	39	8.99	0.01***
Feed And Nutrition	29	53	46	39	12.31	0.00***
Health And Veterinary Service	32	57	61	43	16.66	0.00***
Extension Services						
Dairy Management	92	77	79	86	9.69	0.01***
Ai Technology	92	79	82	87	7.85	0.02**
Feed And Nutrition	79	73	57	74	5.67	0.06*
Health And Veterinary Service	91	84	89	89	2.54	0.28
Sources Extension Service						
Government Extension	86	76	65	79		
Private Extension	7	17	21	13		
Research Though Training	7	7	14	8		

Source: Own survey 2021/22

NB. Chi2 = 25.02; P = 0.01***

Ethiopia's dairy industry faces rising demand, making it essential to boost productivity and efficiency. Training in breeding, feeding, housing, management, disease control, and entrepreneurship development can help producers meet these demands. Agricultural extension services aim to equip producers with the knowledge necessary for sustainable farming and modern practices. This study investigates the level of training received by sample producers and the types of information services offered by dairy experts. The study revealed that small and medium-sized dairy producers in Ethiopian receive training on diary production management, AI technologies, feed and nutrition, and health and veterinary services twice annually. In contrast, large-scale producers participate in four training sessions annually, with three specifically focused on feed and nutrition (see Table 13). This finding invalidates the null hypothesis, as the frequency of training sessions per year is significantly higher for dairy producers. No significant relationships or differences were identified across the scales of production.

Table 13: Number of training courses received in the last 12 months

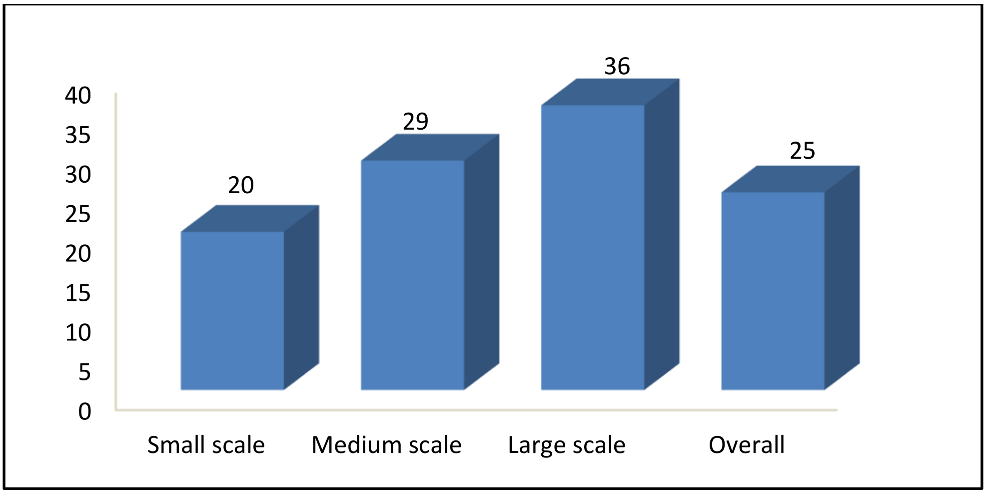
Variables	Small scale		Medium scale		Large scale		Overall		P value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Management	1.58	0.93	2.09	1.18	2.30	1.08	1.89	1.08	0.01***
AI technology	1.63	1.06	1.88	1.09	3.65	3.02	2.10	1.78	0.00***
Feed and nutrition	1.46	1.02	2.15	1.14	2.54	1.19	1.92	1.16	0.00***
Heath and veterinary services	1.53	0.64	2.02	1.14	2.76	1.44	1.95	1.11	0.00***

Source: Own survey 2021/22

Green fodder provides an economical nutrient source for dairy animals, offering high palatability and digestibility. Microorganisms in green fodder enhance the digestibility of crop residues, especially in mixed feeding systems like those in Ethiopia. Additionally, green fodder supports animal health and improves breeding efficiency. Dairy cattle are particularly efficient at converting feed protein and energy into food. Figure 6 indicates that 36% of large-scale dairy producers grow improved fodder and pasture to support commercial dairy production, while 29% of medium-scale and 20% of small-scale producers cultivate improved fodder and pasture for their dairy operations (see Figure 6).

Green fodder provides an economic nutrient source for dairy animals, offering high palatability and digestibility Micro-organisms in green fodder enhance the digestibility of crop residues, especially in mixed feeding systems like those in Ethiopia. Additionally, green fodder supports animal health and improves breeding efficiency. Dairy cattle are particularly efficient at converting feed protein and energy into food. Figure 6 shows that 36% of large-scale dairy producers grow improved fodder and pasture to support commercial dairy production, while 29% of medium-scale and 20% of small-scale producers cultivate improved fodder and pasture for their dairy operations (Figure 6).

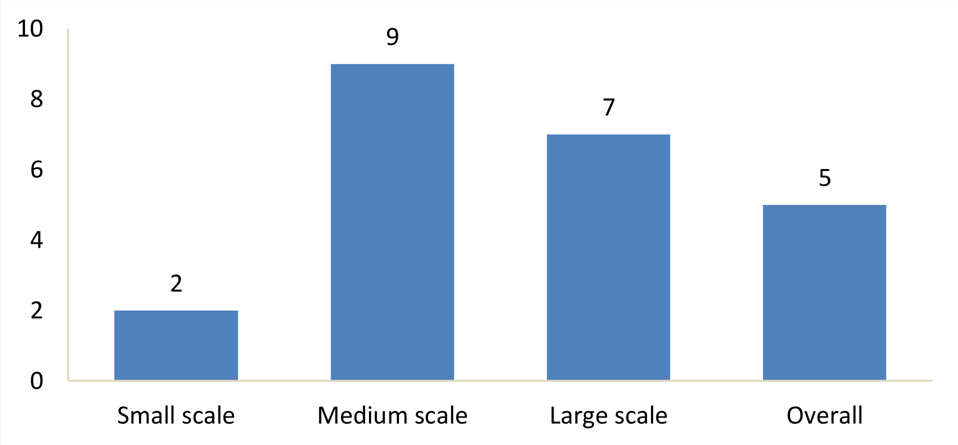
Figure 6: Dairy farmers grow improved fodder and pasture (%)



Chi2 = 4. 39; P = 0.111

Financial markets play a vital role in enhancing the efficiency and growth of the diary economy by mobilizing savings, pooling capital, selecting projects, monitoring contracts, and managing risks. Access to credit, whether from public sources or government subsidies, is crucial for dairy producers to boost production and productivity. However, only 2% of dairy producers in the scale production system can access credit, while medium producers have 9% access and large-scale producers have 7%. In contrast, small-scale producers have significant access to credit, with 98% obtaining it from cooperative sources (Figure 7).

Figure 7: Dairy farmer's access to credit for dairy related activities (%)



Chi2 = 4.87; P = 0.09

3.2 Cattle Feed Marketing Channel and Feeding Price Trends

The study has identified eight feed marketing channels. The sources of all channels are feed processors and pass-through retailers and wholesalers and reach end users (dairy farms).

Main VC actors: Processors, wholesalers, retailers and dairy farms

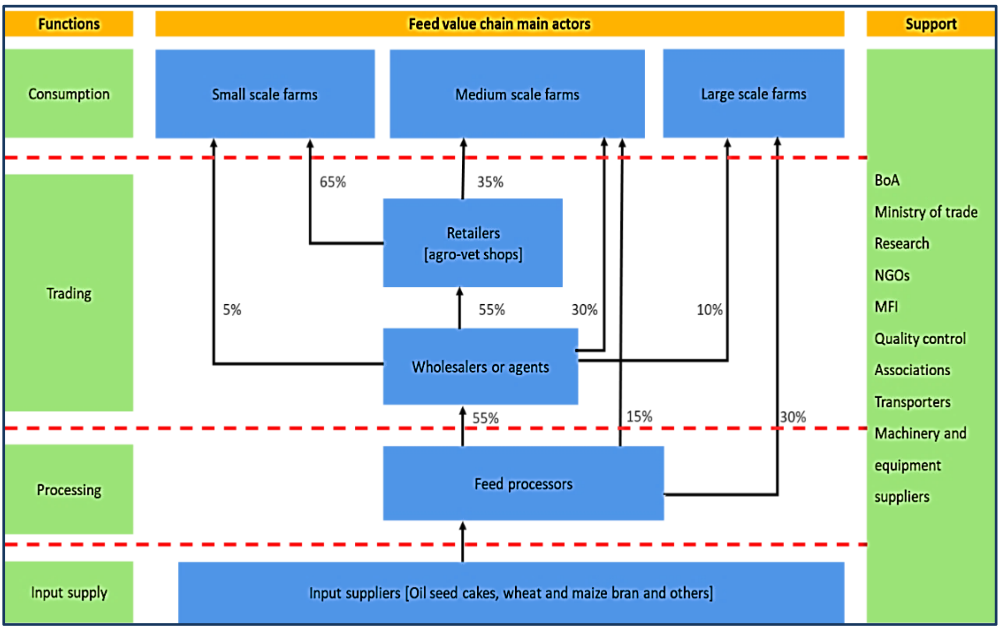
1. Processors → Small scale farms
2. Processors → Large and medium scale farms
3. Processors → Retailers → Small scale farms
4. Processors → Retailers → Large and medium scale farms
5. Processors → Wholesalers → Retailers →Small scale farms
6. Processors → Wholesalers → Retailers → Large and medium scale farms
7. Processors → Wholesalers → Large and medium scale farms
8. Processors → Wholesalers → Small scale farms

3.3 Dairy Feed Value Chain Map

The dairy feed value chain comprises four main functions: input supply, processing, trading, and consumption. Input supply involves sources like farmers' oil factories, flour mills, sugar factories, importers, and breweries. Interviews with GASCO Trading plc, AGP Poultry plc, and Equatorial Business Group plc highlight challenges such as foreign currency shortages, rising premix prices, and fluctuating local demand. Feed processing companies, ranging from small to large-scale, operate with agents across different milk shades, earning fixed margins after covering transportation and feed selling costs. Key challenges here include high production costs, limited input availability, and feed adulteration. Feed traders, including wholesalers and retailers, grapple with high feed prices, deceased demand due to green feed availability, and limited access to credit. Cooperatives also sell processed feed. While large and medium-scale farms rely on processed feed, large farms consume more overall. Farmers face issues like high feed prices and concerns over quality and efficiency.

Approximately 55% of processed feed is directed to feed processors, while large and medium-scale farms receive 30% and 15%, respectively. Retailers receive 55% of the feed, with medium-scale farms getting 30%, large-scale farms 10%, and small-scale farms 5% (see Figure 8).

Figure 8: Dairy feed value chain map



3.3.1 Dairy feed supply challenges and opportunities

The following table (Table 14) showed challenges and opportunities in feed value chain.

Table 14: Challenges and opportunities along feed value chain

Actors	Challenges	Opportunities
Input Supply (Oil, Sugar and Flour Producers, and Breweries)	High Price of Inputs Shortage of Supply of Raw Materials (Oil Seed and Wheat) Demand Fluctuation for Inputs.	High Input Demand Increasing Number of Beers, Oil and Flour Factories
Processors	Shortage of Supply of Inputs (Raw Materials). Low Quality of Supply of Some Inputs Such as Oil Seed Cake (Dry). Adulteration Problem in Inputs Lack of Demand from June to October due to High Supply of Green Feed. Power Interruption. Lack of Foreign Currency for Importing Inputs. Lack of Support from Government and NGO.	High Feed Demand Increasing Number of Commercial Dairy Farms
Traders	High Price of Processed Feed. Lack of Demand from June to October due to High Supply of Green Feed. Lack of Access to Credit.	High Demand though Fluctuating During Summer Increasing Number of Factories Increasing Number of Commercial Dairy Farms
Retailers	High Feed Cost. Shortage of Feed Storage Space which could also affect the Quality of the Feed. Demand Fluctuation. Lack of Access to Credit.	High Demand though Fluctuating During Summer Increasing Number of Commercial Dairy Farms
Consumers (Dairy Farmers)	High Price of Feed. The Quality of The Feed is Declining from Time to Time. Lack of Adequate Extension Services. Lack of Improved Forage Seed.	Increasing Number of Feed Traders High and Increasing Milk Price

Source: Own survey 2021/22

3.4 Factors Affecting the Choice of Feed Market Sources

The multivariate probit model results indicate that farmers' choices to use one market source are influenced by their adoption of other market sources. This is supported by a significant Wald Chi-square statistic (chi2(48) = 668.57, $p < 0.001$) and a marginally significant Chi-square statistic for the log-likelihood ratio test (chi2(6) = 12.33, $P < 0.069$). A positive and significant correlation between wholesalers and retailers suggests these two markets are complementary, allowing farmers to alternate between them. In contrast, the negative and significant correlation between retailers and cooperatives indicates these markets are substitutes, with farmers typically choosing either cooperatives or retailers as their feed source (see Table 15).

Determinants of choice of wholesalers: Male-headed households tend to choose wholesale feed markets for dairy farms, as they often have the resources needed for transporting feed. Households with more exotic cows also prefer wholesale markets due to their need for larger feed quantities. Additionally, proximity to the nearest village market plays a role, as wholesalers are generally located at the woreda level or in towns.

Determinants of choice of retailers: Experience in dairy farming significantly influences the decision to use retail feed markets, as these markets often have limitations such as insufficient storage, high prices, and concerns over feed safety and aflatoxin, promoting seasoned farmers to consider alternative sources. Smallholder dairy farms with a larger number of hybrid cows frequently rely retailers due to the limited availability of wholesalers and cooperatives. However, proximity to cooperatives also significantly influences market choice, with farmers close to cooperatives more likely to buy feed directly from them.

Determinants of choice of food manufacturers: Training in feed and nutrition significantly influences farmers' preference for feed manufacturers as a source for dairy feed. Concerns about feed safety and the availability of sufficient storage make manufacturers appealing. Additionally, proximity to the nearest village market affects this choice, with dairy farms often choosing manufacturers for their competitive pricing.

Determinants of Choice of Cooperatives: The study reveals that cooperative membership and the availability of clean storage significantly affect dairy farmers' choice to use cooperatives as feed a feed source. proximity to village markets also plays a role, with female farmers favoring cooperatives located in villages or kebeles (Table 15).

Table 15: Multivariate Probit Model (MVP) result

Variables	Wholesalers	Retailers	Feed manufacturer	Cooperatives
Cooperative membership [Yes]	-0.31 (0.23)	0.17 (0.23)	0.47 (0.57)	0.69** (0.33)
Household sex [Male]	0.47* (0.27)	0.15 (0.27)	3.79 (0.66)	-0.75** (0.35)
Household education (yrs.)	0.001 (0.01)	-0.003 (0.01)	-0.02 (0.04)	-0.01 (0.01)
Dairy farming experience (yrs.)	-0.002 (0.01)	-0.03** (0.01)	-0.001 (0.04)	0.05** (0.02)
Dairy type	-0.16 (0.18)	-0.04 (0.18)	0.42 (0.40)	-0.05 (0.29)
Total land (ha)	-0.08 (0.06)	0.09 (0.07)	-0.14 (0.19)	-0.06 (0.10)
Grassland (ha)	-0.13 (0.32)	0.21 (0.32)	-0.82 (0.82)	0.39 (0.47)
Number of hybrid cows	0.16*** (0.04)	0.09** (0.03)	0.03 (0.08)	-0.02 (0.07)
Training on dairy feed and nutrition [Yes]	-0.17 (0.21)	-0.26 (0.21)	1.27* (0.67)	-0.13 (0.32)
Access to credit for dairy [Yes]	-0.52 (0.48)	0.28 (0.44)	-4.24 (0.20)	-3.90 (0.55)
Distance to nearest village market (km)	0.42*** (0.08)	0.13 (0.08)	0.48** (0.20)	0.28** (0.13)
Distance to cooperatives (km)	-0.02 (0.05)	0.15*** (0.05)	-0.02 (0.13)	-0.02 (0.09)
Constant	-0.69 (0.46)	-1.16** (0.49)	0.92 (0.78)	-3.71*** (0.80)

Source: Own survey 2021/22
*** (P < 0.01); ** (P < 0.05); * (P < 0.10)
N.B: Numbers in the parenthesis are standard errors
Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0: $chi^2(6) = 12.33$ Prob > chi2 = 0.069

4. Conclusions and Recommendations

In developing economies, the livestock sector is adapting to rising demand driven by population growth, increased wealth, and urbanization. Key challenges include limited feed resources, underdeveloped pastures, and escalating feed costs. Land scarcity limits investment in forage and seed production, and many producers are unaware of methods, such as cultivating natural feed like alpha-alpha, to improve dairy cow productivity.

Scarce forage drives high demand for manufactured feed, pushing prices up, especially in the dry season. The feed and livestock sectors in Ethiopia face major challenges related to the availability, quality, and rising cost of commercial feeds. These feeds are essential for market-driven poultry, dairy, and beef production, often comprising 70-80% of total production costs. The study aimed to investigate the current condition of the commercial feed value chain, along with its challenges and opportunities. Based on the findings, different conclusions and recommendations were made.

- Dairy cooperatives play a vital role in supplying manufactured feed to dairy farmers. However, their weaknesses lead to high milk production costs and low milk prices, highlighting the need to strengthen these cooperatives for the sustainability of the dairy sector, especially in rural areas.
- Training dairy farmers about suitable feed and market sources is crucial for ensuring feed safety and proper nutrition for cattle, which underscores the importance of regular monitoring by relevant authorities in the dairy farming sector.
- Research institutions are working on improved forage technologies and production practices; however, the adoption of improved varieties remains low. To boost adoption rates, it is important to utilize extension services and effective promotion strategies.
- The distribution system for forage and manufactured feed is insufficient, primarily due to an oligopoly among large producers, raising issues related to quality and pricing. Individual producers and cooperatives find it difficult to negotiate reasonable prices, and no there are no subsidies available for farmers with limited resources.

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Optimizing Water Resources Allocation in the Nile Basin: Analyzing Long-Term Changes in Water Footprint and Virtual Water Trade for Sustainability

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Abstract

Achieving sustainable water resource allocation in the Nile Basin is essential in the face of complex climate change and declining freshwater availability. This study aims to optimize water resource allocation by analyzing the long-term changes in water footprint (WF) and virtual water flows of selected crops in the Nile Basin countries. The research reveals significant disparities in green and blue WF among various crops across riparian states. Sudan, South Sudan, and Egypt exhibited the highest average blue WF in crop production. The key findings indicate that in Sudan, maize had a WF of 6046m^3/tonne, rice had 5175m^3/tonne, sorghum had 2644m^3/tonne, and millet had 2160m^3/tonne, Meanwhile Egypt reported a groundnut WF of 3138m^3/tonne. The study also observed that the highest WF occurred during dry years, while the minimum WF was observed during wet years. The WF, as well as the quantity of crops imported and exported, influenced the net virtual water import of crops. Egypt emerged as the primary rice exporter with an average net virtual water export (VWE) of 810 Mm^3 per year, followed by Sudan with 19 Mm^3 and Egypt with 16 Mm^3 for groundnuts. Conversely, Egypt became the highest importer of maize, with a net virtual water import of 4359 Mm^3, while Congo, DR (583 Mm^3) and Sudan (539 Mm^3) were the primary importers of rice and sorghum, respectively. To alleviate pressure on the water resources of riparian states, it is recommended to cultivate crops in countries with significant potential for improvement in terms of water use efficiency. Water-scarce countries in the Basin could benefit from increasing the import of water-intensive crops from countries with relative water abundance. By optimizing water resource allocation based on the analysis of long-term changes in WF and virtual water flows, the Nile Basin can move closer to achieving sustainable water management.

Keywords: water resource allocation, Nile Basin, water footprint, virtual water, sustainability

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1. Introduction

Water is a precious asset for achieving sustainable growth contributing significantly to socio-economic development, hydro-political stability, and environmental sustainability (Sebri, 2016). However, water experts warn that one of the critical challenges of the 21st century is the lack of efficient use of global water resources (Jury & Vaux, 2005). Addressing these emerging global water issues requires a robust scientific approach and the implementation of effective water use efficiency policies (Mekonnen & Hoekstra, 2011). Virtual water trade might stands out as a potential solution for mitigating the water crisis aggravated by climate change and population growth (Qasemipour & Abbasi, 2019). Hence, understanding virtual water can play a vital role in sustainable water management strategies (Hoekstra & Hung, 2002).

Water availability and distribution of water vary significantly across countries and regions as it is not distributed evenly across the world (Rijsberman, 2006; Hoekstra, 2013). The availability and distribution of water vary significantly across regions, necessitating prudent allocation of the world's limited freshwater resources (Rijsberman, 2006; Hoekstra, 2013). Agricultural water use is influenced by location and climate, highlighting the importance of redistributing water through the trade of water-intensive crops from water-rich to water-scarce regions (Neilsen et al., 2018; Tian et al., 2018; Zhang et al., 2018). This approach allows water-scarce areas to import crops rather than relying on limited local water resources (Huang et al., 2019). The Nile River exemplifies the temporal variability of water availability, underscoring the need for effective management strategies.

The concept of virtual water has gained traction in policy development, contributing to improved water management in agriculture (Hoekstra & Hung, 2002; Chai et al., 2014). Virtual water flows facilitate the transfer of water through commodities, potentially reducing water scarcity (Kuiper et al., 2011; Horlemann & Neubert, 2006). Virtual water flows are directly related concepts that have been introduced by Hoekstra for better water management (Hoekstra & Hung, 2002). In the role of water management in agricultural production, VW has helped to reduce water scarcity (Kuiper *et al*., 2011). The virtual transfer of water through water-intensive products may reduce the cost gets due to large disparities (Horlemann & Neubert, 2006). Countries unable to produce food locally can meet demand through virtual water trade, a mechanism that may save global water resources (Molden et al., 2010; Mekonnen & Hoekstra, 2014). Inter-Basin water transfer can be realized either by real water or by VW transfers in the form of commodities trade (Ma et al., 2006).

Horlemann and Neubert (2006) describe virtual water flow as economically unseen, ecologically sustainable, and peaceful methods of water use. Estimating of trade balance at the state level could provide the trade-offs between virtual water trade and physical inter-basin transfers (Verma *et al.*, 2009). Analysis of virtual water flow would help to promote an understanding among the Basin countries. Given the transboundary nature of Nile water, effective water resource management requires close collaboration among all riparian nations in planning and development (Abtew & Dessu, 2019). Despite the potential benefits, the trade-offs between virtual water and physical water transfers present challenges, particularly in the context of the Nile Basin, where water management is contentious due to growing demand, population pressure, and climate change (Aldaya et al., 2010; Sulser et al., 2010). A comprehensive study of virtual water flows in the Nile Basin is crucial for addressing water resource challenges and improving water use efficiency. Unlike previous studies, such as those conducted by Zeitoun et al. (2010), this research utilizes the FAO Nile Basin Dataset to analyze both rainfed and irrigated components of virtual water content.

In most water-scarce regions of arid and semiarid countries, the management of water is a controversial issue (Aldaya *et al.*, 2010), where the Nile River Basin is one example. The Nile Basin is a region that faces water scarcity due to manmade problems and mismanagement of the water resources. According to Sulser *et al.*, (2010), water scarcity is increasingly a critical issue in the Nile Basin due to the pressing need for development, high population growth, and climate change. A virtual water flow study for the Nile Basin is important to address the looming water resource problems. It has opened the door to more productive water use. The current study varies from that of Zeitoun *et al.*, (2010), in that the rainfed and irrigated components of the virtual water content of the presented crops are obtained from the FAO Nile Basin Dataset.

This paper investigates long-term changes in water footprints and virtual water flows for five key crops (rice, maize, millet, sorghum, and groundnuts) in the Nile Basin from 1986 to 2015. These crops were selected based on their extensive irrigated area and production levels within the Basin. The study emphasizes the importance of virtual water trade among Nile riparian states as a strategy to alleviate national water scarcity issues and enhance collaborative water resource management.

2. Methods

The annual water footprint for the selected five crops (rice, maize, sorghum, groundnuts and millet) was estimated in all the eleven Nile Basin countries (Burundi, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania, Uganda, the Democratic Republic of the Congo, and Eritrea) for the years 1986-2015 following the green-blue water accounting standard (Hoekstra *et al.*, 2019). The selection of crops is based on FAO (2019), a database that considers the largest in production and area harvested in the Basin. The AquaCrop model was applied to calculate the water footprint of crops in the Nile Basin countries and simulate current agricultural practices. The model was implemented at 5x5-arc minute grids spatial resolution for all grid cells for all selected dominant crops.

2.1 The Water Footprint Calculation

This study follows the methodology based on the standard the water footprint of water accounting developed by Hoekstra, (2019). Based on the study, daily soil moisture has been separated into green and blue components. Green and Blue water accounting in a soil water balance was calculated following Hoekstra, (2019). The definition of green and blue water footprint is based on the ratio of ET. It has been defined as the green water footprint if the ratio is ET from the green water and yield, while the blue water footprint is the ratio of ET from the blue water to the yield. The green WF measures the volume of rain water stored in soil and used by plants which reflecting water used in rainfed agriculture. Whereas, the blue water footprint quantifies the volume of surface water and ground water consumed during production, particularly through irrigation and the impact of human activities on fresh water resources (Mekonnen & Hoekstra, 2011).

2.2 Virtual Water Trade Estimation

Gross virtual water import and virtual water export could define as the volume of water virtually imported or exported through trade. VW trade has computed by multiplying the volume of trade by its water footprint (m^3/tonne) for each crop in tonnes. VW trades between nations have been calculated by multiplying crop trade, import, and export quantity (tonne) of products by their associated water footprint of the crop in the nation. VW trade is thus calculated as follows (Chapagain & Hoekstra, 2011; Mekonnen& Hoekstra, 2011):

$$VWT[n_{e,}n_{i,}c,t] = CT[n_{e,}n_{i,}c,t]\ x\ SWD[n_{e,}c] \qquad \textbf{(1)}$$

Where *VWT* is the virtual water trade in m^3/yr. CT is the crop trade (tonne /yr). In the exporting nation, SWD reflects the basic water demand (m^3/tonne) of crop c. FAOSTAT (2019) provided the volume of crop trade (CT, tonne /y). The import of gross virtual water to a nation ni is the amount of all imports:

$$GVWI\left[n_{i,}t\right] = \sum\nolimits_{n_e,c} VWT[n_{e,}n_{i,}c,t] \qquad \textbf{(2)}$$

The sum of all exports is the gross virtual water export from a country ne:

$$GVWE\left[n_{e,}t\right] = \sum\nolimits_{n_i,c} VWT[n_{ei,}n_{i,}c,t] \qquad \textbf{(3)}$$

A country's net virtual water import is equal to the difference between the gross virtual water import and gross virtual water export. Therefore, the country x's virtual water trade balance for year t may write as:

$$NVWI[x,t] = GVWI[n_{ei},t] - GVWE[n_{ei},t] \qquad \textbf{(4)}$$

Where *NVWI* is the net virtual water import (m^3/yr) to the country. Net virtual water import to a country has either a positive or a negative sign. To asses import from outside of the country which is the virtual water import, the global averages water footprint of traded crops were obtained from (Mekonnen & Hoekstra, 2011).

While the water footprint (m^3/tonne) of rice estimated for paddy rice, the rice trade was in total milled-rice equivalent. Therefore, the milled equivalent rice was converted to rice paddy equivalent by using the product fraction of 0.64 obtained from Mekonnen and Hoekstra, (2010).

2.3 Data

Different global data sources were used to estimate crop WF. These five crops (rice, maize, millet, sorghum, and groundnuts) were selected based on the FAO (2019) database on both the largest in production and the area harvested. The climate data were obtained from CRU TS-3.20 with a 30 x 30 arc-minute grid spatial resolution (Harris *et al.*, 2014). Soil data with 5x5 arc minute resolution were obtained from the ISRIC-WISE dataset (Batjes, 2014). The MIRCA 2000 dataset was used with a resolution of 5x5 arc minutes for the irrigated and rainfed harvested area for each crop (Portmann *et al.*, 2010) which was made to fit FAO's national level total harvested area. The yearly harvested area at 5x5 arc minute was derived by multiplying the reference MIRCA2000 map by the scaling coefficients. To get the initial soil moisture in the first year, the model was run with initial soil moisture at field capacity for the entire period and then used the average values. The AquaCrop model was used to assess the annual water footprint of the selected crops during the period 1986–2015. The crop trade data were obtained from FAOSTAT, (2019). The global averages of the WF of traded crops were obtained from (Mekonnen & Hoekstra, 2011). To estimate the virtual water import and export the calculation methodology developed by Chapagain and Hoekstra (2003). The AquaCrop model uses several key variables to simulate crop growth and yield based on water availability. These include **ETc** (crop evapotranspiration), **Kc** (crop coefficient), and **ET0** (reference evapotranspiration), which relate to water use; **P** (precipitation) and **I** (irrigation), which indicate water input; **SW** (soil water), and

AWC (available water capacity), which define soil water dynamics; **Y** (yield) to represent expected crop output; and **F** (water stress factor) to assess the impact of water scarcity.

3. Results

3.1 Long Term Change in Green and Blue Water Footprint of Selected Crops

The total green and blue water footprint changed over the study period from 1986 to 2015. The water footprint of crops can increase over the year due to an increase in the cultivated area, which contributes to an increase in crop production. Figure 1 below shows the change in national average green, blue, and total WF of crop consumption in Nile Basin countries. The largest total water footprint of cereals is in Egypt. Among all the crops, groundnuts have the largest national average total crop consumption WF on average of 5500 m^3/tonne in the Nile Basin countries. The results indicated that there is a difference in the average water footprint of crops in (m3/tonne) among countries in terms of water footprint, which ranges from 500 m^3/tonne in Uganda to 14,000 m^3/tonne in Sudan. The consumptive water footprint of crop includes a green (rainfall) and blue (irrigation) component. When comparing the two consumptive water footprints, the green water footprint is a higher proportion than the blue. Similar findings were done in (Zhuo *et al.*, 2016) and (Mekonnen *et al.*, 2015) has been done for the Latin American countries.

Figure 1: Average national green, blue, and total WF of crops in the Nile Basin countries

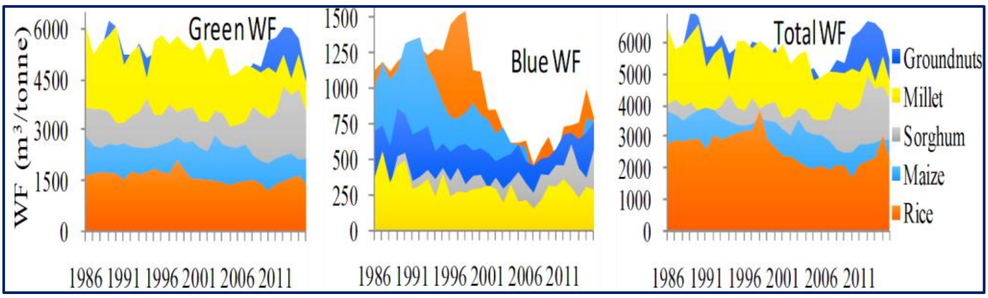


Figure 2: The total green and blue WF of crop production in the Nile Basin countries

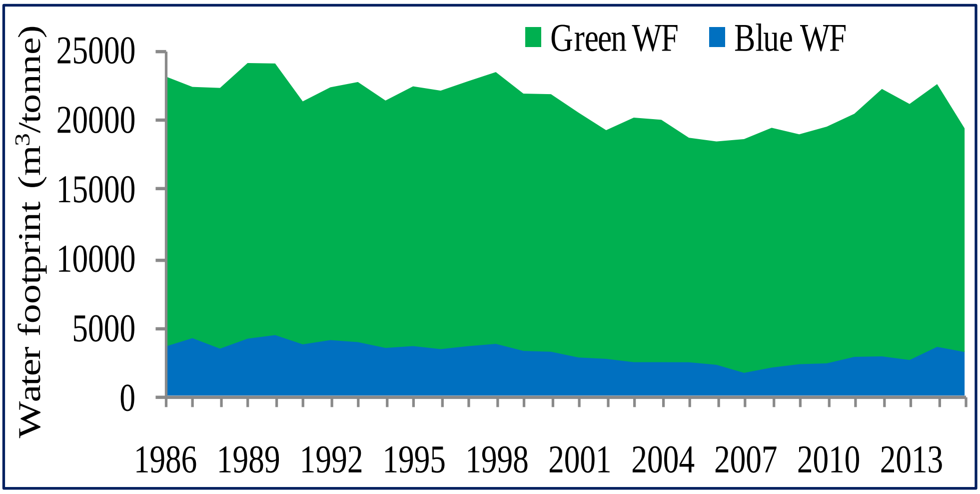
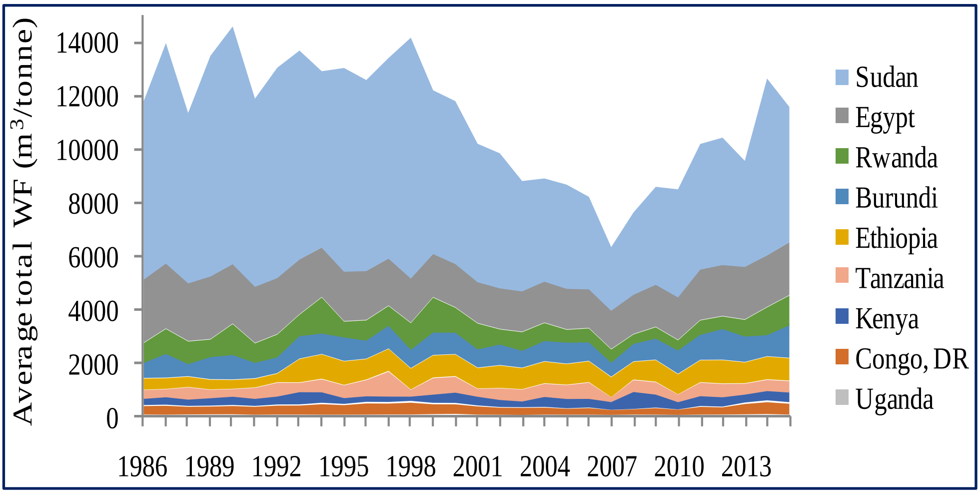
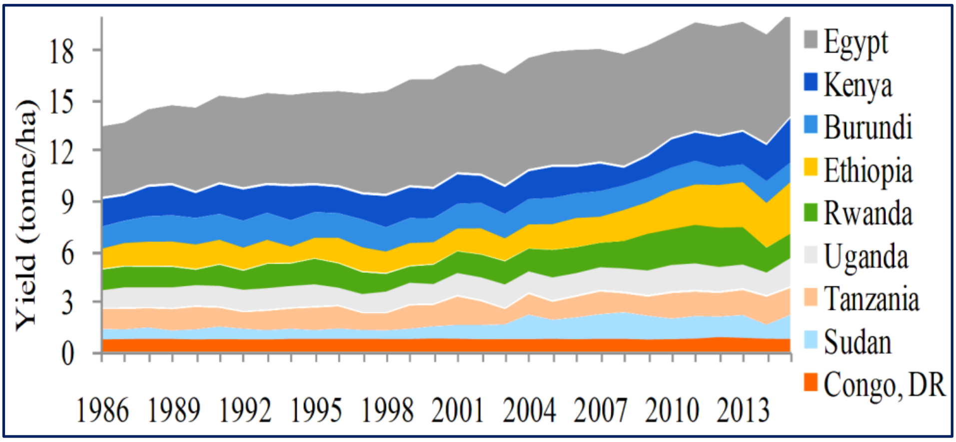


Figure 3: Average total WF of selected crops (m^3/tonne)



The results indicated that Sudan and Egypt have the largest average total water footprint of crop consumption, and the lowest WF is recorded in Uganda and Congo. Figure 3 shows the total green and blue WF of the 5 crops in Nile Basin countries over the study period.

Figure 4: Crop yield (tonne/ha) in the Nile Basin countries



The average annual aggregated green and blue water footprint for the selected crops over the study period 1986–2015 for all the Basin countries was estimated. Upstream countries like Burundi, the Democratic Republic of Congo, Ethiopia, Kenya, and Rwanda were dominated by the green components of the water footprint, whereas the downstream countries Egypt and Sudan were dominated by the blue component. As shown in Figures 5-9, among the listed crops, rice has the highest water footprint, while millet has the lowest. Some crops exhibit a significantly larger water footprint per unit of weight (m^3/tonne), whereas others demonstrate a much smaller footprint within the same country. In the Nile Basin, Egypt and Sudan typically show high water footprints, indicate intensive agricultural practices and high evapotranspiration due to its aridity, while Uganda and Tanzania often show low water footprints, reflecting greater dependence on rainfed agriculture and the climate of the region. A high green water footprint suggests the use of rainfall but vulnerability to drought, whereas a high blue water footprint indicates depend on surface and groundwater, raising concerns about sustainability. On the contrary, a low green water footprint may indicate inadequate rainfall or poor management, necessitating irrigation, while a low blue water footprint reflects efficient water use but may also indicator of limitations in agricultural productivity. Some had the largest blue water footprint, while others had the smallest value. Regarding the green water footprint, certain crops had the largest values in almost all countries.

High green and blue water footprint indicates the amount of water use in agriculture; with high green water footprints suggest effective rainwater use and potential sustainability in well-watered regions. On the other hand, low green footprint reveal reliance on irrigation or poor rainfall management. High blue footprints reveal heavy dependence on surface and groundwater, raising concerns about water scarcity and ecosystem health, while low blue footprints suggest efficient water use and sustainability. At the country level, these footprints provide insights into agricultural practices, resource management, and the balance between productivity and environmental impact.

This study documents the net virtual water trade related to national trade among the Nile Basin countries under current conditions. The net virtual water imported per country in the years 1986-2015 (million m^3/y) has been shown in Figure 6-9. The spatial and seasonal variability of WFs related to the production of all crops in all the Basin countries was presented. The largest contribution to the total water footprint comes from the green water footprint. Substantial inter-annual variability was observed among countries and crops. The variation in the water footprint appears to be driven by inter-annual climatic variability, season, soil, and management practices. The yearly green, blue, and total WF per unit for all selected crops are shown in Figure 5-9. The water footprint of crops is almost all dominated by the green WF. The annual net virtual water trade related to trade in selected crops over time is presented in Figure 5-9. The net virtual water imports related to all the crops are increasing; so are the net virtual water exports related to the crops for most of the countries. Some of the crops show a modest change over the study period. The virtual water trade related to all selected crops has high inter-annual variability.

Figure 5: Green, blue and total WF of rice in Nile Basin countries in the period 1986–2015

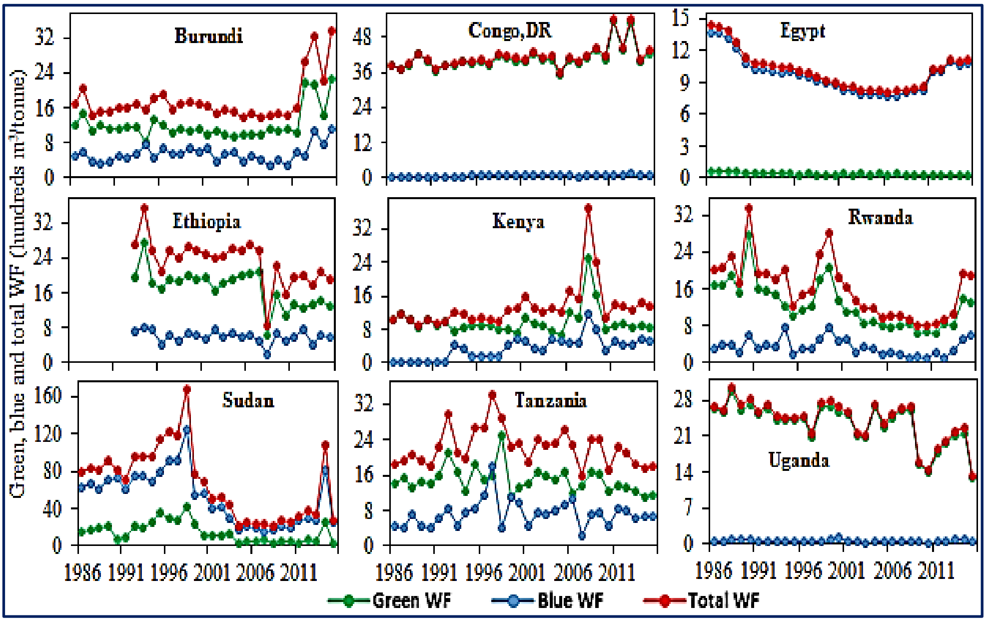


Figure 6: Green, blue and total WF of maize in Nile Basin countries period 1986–2015

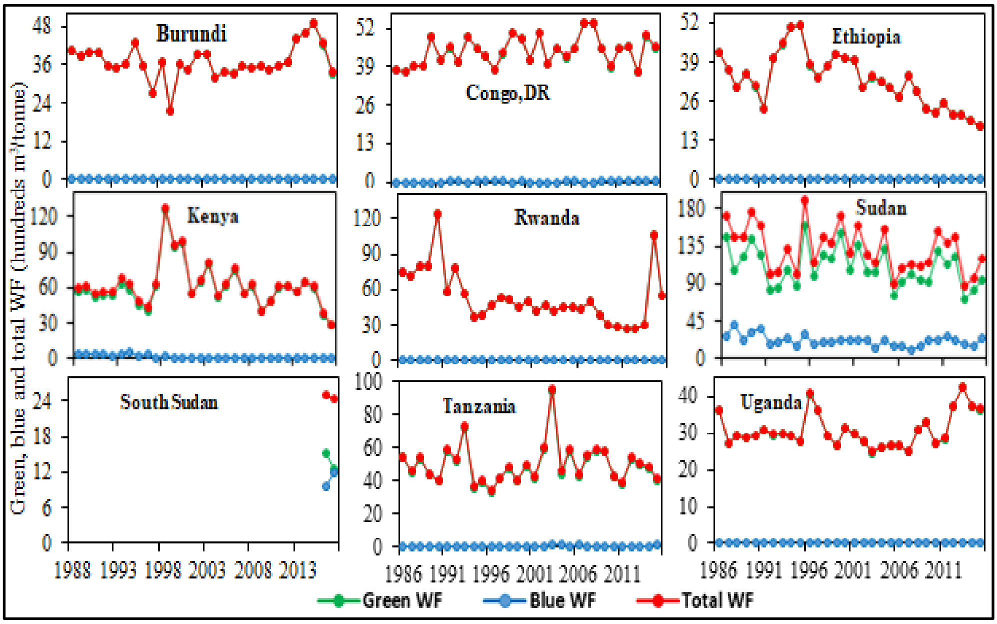


Figure 7: Green, blue and total WF of millet in Nile Basin countries period 1986–2015

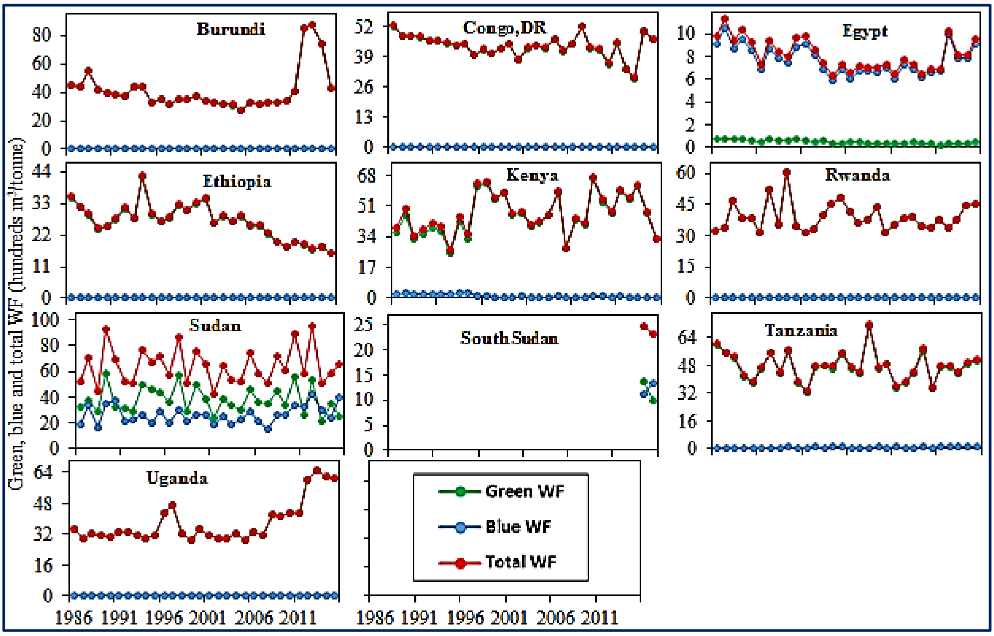


Figure 8: Green, blue & total WF of groundnut in Nile Basin countries in period 1986–2015

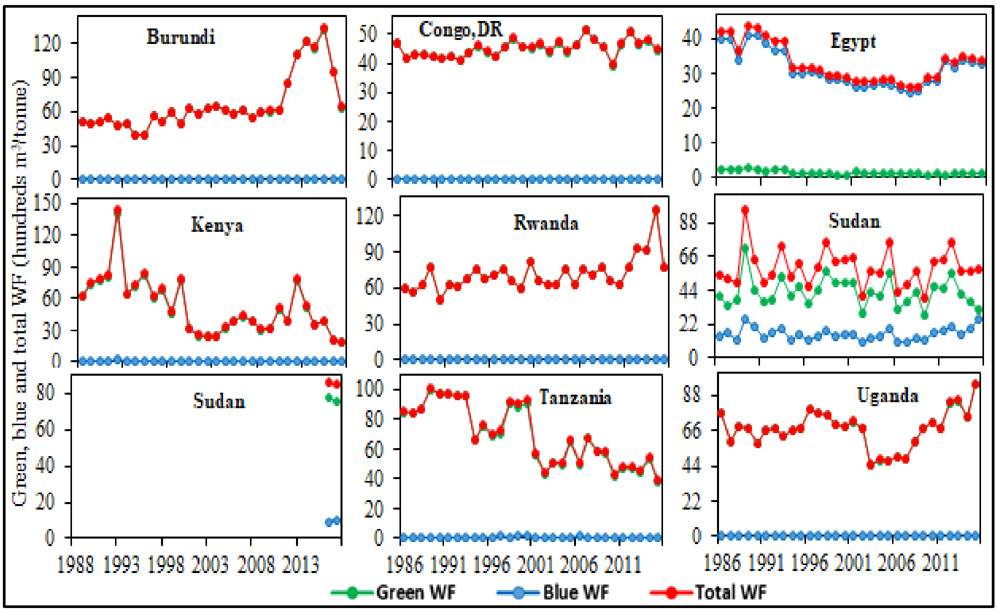
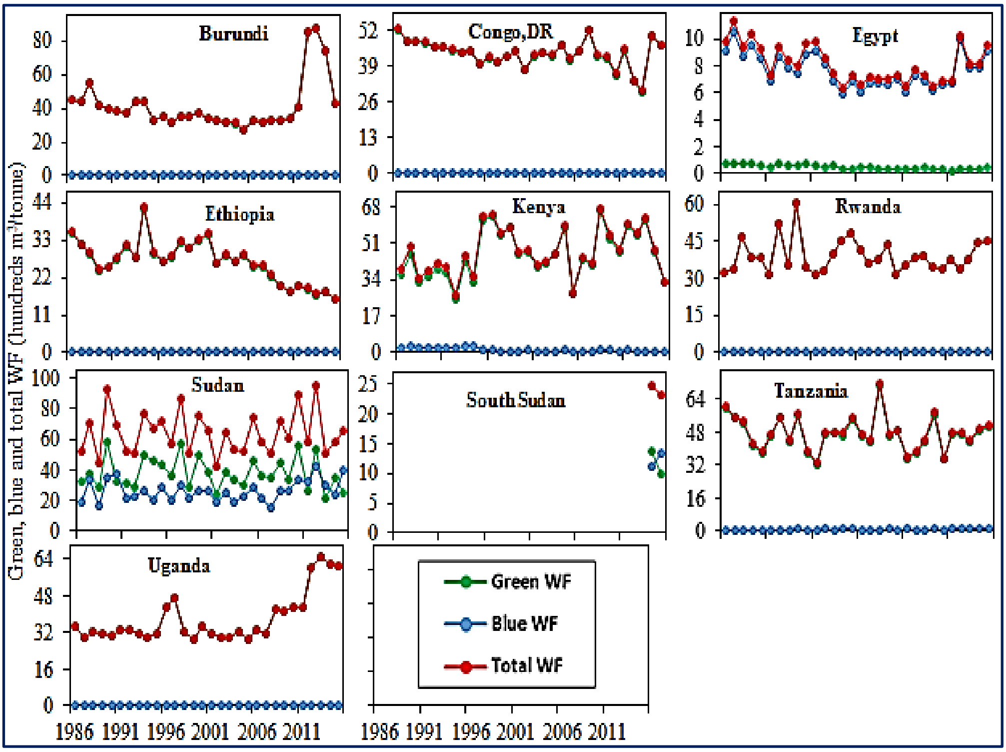


Figure 9: Green, blue & total WF of sorghum in Nile Basin countries period 1986–2015



A comparison of the annual average green, blue and total WF of the five crops in the Nile Basin countries in the period 1986 in the current study has done. In the production of rice, the largest annual average blue water footprint obtained in Sudan that is about 5175 m^3/tonne and Egypt 977 m^3/tonne. Countries like Congo DR, Uganda, Tanzania, Ethiopia, and Burundi have higher green water footprint than blue water footprint in rice production (Figure 5). As indicated in Figure 5 the largest WF has recorded during the dry year and minimum water footprint recorded during the wet year.

For maize production, the largest annual average blue water footprint obtained in Sudan that is about 6046 m^3/tonne and followed by South Sudan 1566 m^3/tonne and Egypt 1111 m^3/tonne . Rwanda, Burundi, and Uganda are the lowest blue WF value. Only three countries Sudan, South Sudan and Egypt are higher blue WF whereas the rest countries are the higher green WF than blue

WF for maize production. For millet production, the largest annual average blue water footprint obtained in Sudan that is about 2160m^3/tonne and followed by South Sudan 1080m^3/tonne. There is no millet production in Egypt. Sudan and South Sudan are higher green and blue WF in millet production whereas the rest of the countries are higher in green WF than blue WF. For groundnuts production, the largest annual average blue water footprint obtained in Egypt that is about 3138m^3/tonne and followed by Sudan 1582m^3/tonne. For sorghum production, the largest annual average blue water footprint obtained in Sudan that is about 2644m^3/tonne and followed by South Sudan 1243m^3/tonne and Egypt 770m^3/tonne. For sorghum production, Sudan and South Sudan are higher in green and blue WF whereas the rest of the countries use only the green WF (Figure 9).

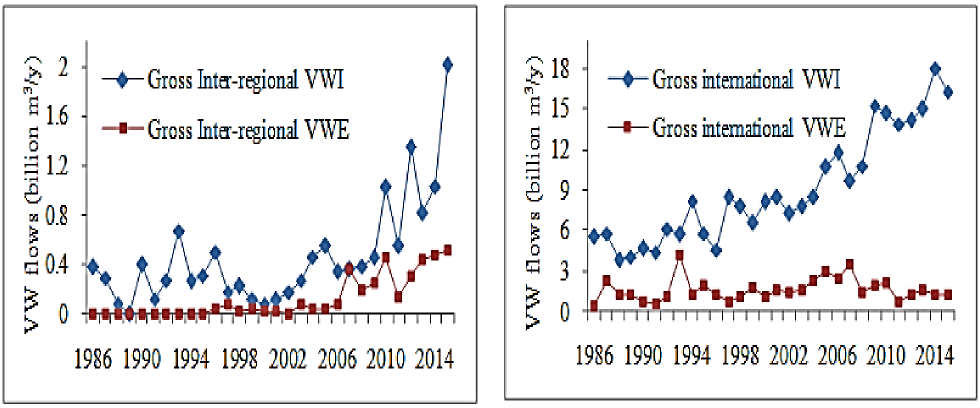
The high blue water footprint for rice in Sudan (5175m^3/tonne) indicates a heavy dependence on irrigation, raising concerns about sustainability and water scarcity. In contrast, countries like Uganda and Burundi, with higher green water footprints, demonstrate effective rainwater utilization, suggesting more sustainable agricultural practices. The variability in water footprints, particularly during dry and wet years, highlights the vulnerability of these systems to climate change. Overall, the findings suggest opportunities for improving water management strategies across the region to enhance food security and resilience.

3.2 Virtual water flows of the Nile Basin countries in the period 1986–2015

The gross virtual water import and export of the Nile Basin countries both the international and inter-regional flows have been done. The result shows that the inter-annual variability of water footprint leads to the variation in the virtual water flows. The annual variation for the virtual water flows has been seen across every basin country. The international flow indicates the flow is within the world countries, and the inter-regional flow indicates the flow within the Basin countries. The virtual water import indicates the flow from abroad whereas the virtual water export the flow is abroad. According to the result, the international flows have larger virtual water flows than inter-regional virtual water flows.

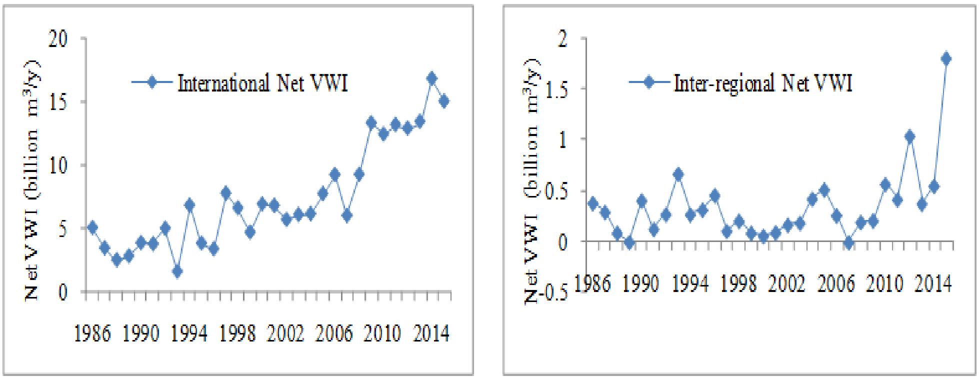
Gross inter-regional virtual water import is higher than gross inter-regional VWE since the import of crop commodities has been greater than exported values. Regarding the international VW flows in Nile Basin countries, the gross international VWE ranges from 0.4 to 1.25 billion m^3/y and gross international virtual water import ranges from 5.5 to16.2 billion m^3/y. The gross inter-regional virtual water export value has been increased from 0.001 to 0.5 billion m^3/y whereas the gross inter-regional virtual water import from 0.4 to 1.2 billion m^3/y. Figure 10 shows that the international and inter-regional virtual water flows within the Nile Basin countries which include from/to other countries.

Figure 10: Inter-regional and international virtual water flow in Nile Basin countries.



The international net virtual water import ranges from 5.5 billion m^3/y to 16.2 billion m^3/y whereas the inter-regional net virtual water import ranges from 5.1 billion m^3/y to 15 billion m^3/y. The international and inter-regional net virtual water import of crops has increased from the initial study period to the final study period. The virtual water import and virtual water export of crops per country has shown the incremental changes.

Figure 11: Net virtual water imports from international and inter-regional trade in Basin countries



The highest international NVW has shown for maize crops estimate about 3507 Mm^3 in the year 1986 and increased with 10890 Mm^3 in the year 2015 followed by rice from 1485 Mm^3 to 2502 Mm^3 in 1986 and 2015 respectively. Regarding the inter-regional NVW of crop trade, the highest value has estimated for maize 381 Mm^3 to 240 Mm^3 by the year 1986 and 2015. The following Table 1 shows the international and inter-regional NVW (Mm^3) of crop trade in Nile Basin countries.

Table 1: International and inter-regional NVW (Mm^3) of crop trade in Nile Basin countries

Crops	International NVW (Mm^3)		Inter-Regional NVW (Mm^3)	
	1986	2015	1986	2015
Groundnuts	-4	28	0	-4
Maize	3507	10890	381	240
Millet	-5	-26	0	-18
Rice	1485	2502	0	1581
Sorghum	112	1626	0	0
Total	5095	15021	382	1799

3.3 Net Virtual Water Import and Regional Trade in Nile Basin Countries

The current study assessed the net virtual water import of the selected crops for the current conditions in the Basin countries as a whole. To show virtual water trade in the Basin countries with the whole basin regions, a list of countries for import and export of those selected crop products were selected from FAOSTAT along with the world region that presented in the figures. The gross virtual water trade between and within regions of the country have been analyzed. The Figures 12-13 show the trends of net virtual water import for rice and maize crops in the Nile Basin countries for the period 1986–2015. In the analysis, Eritrea was excluded from the study because the selected crops were not produced in that region.

Figure 12: Net virtual water import for rice in Nile Basin countries the period 1986–2015

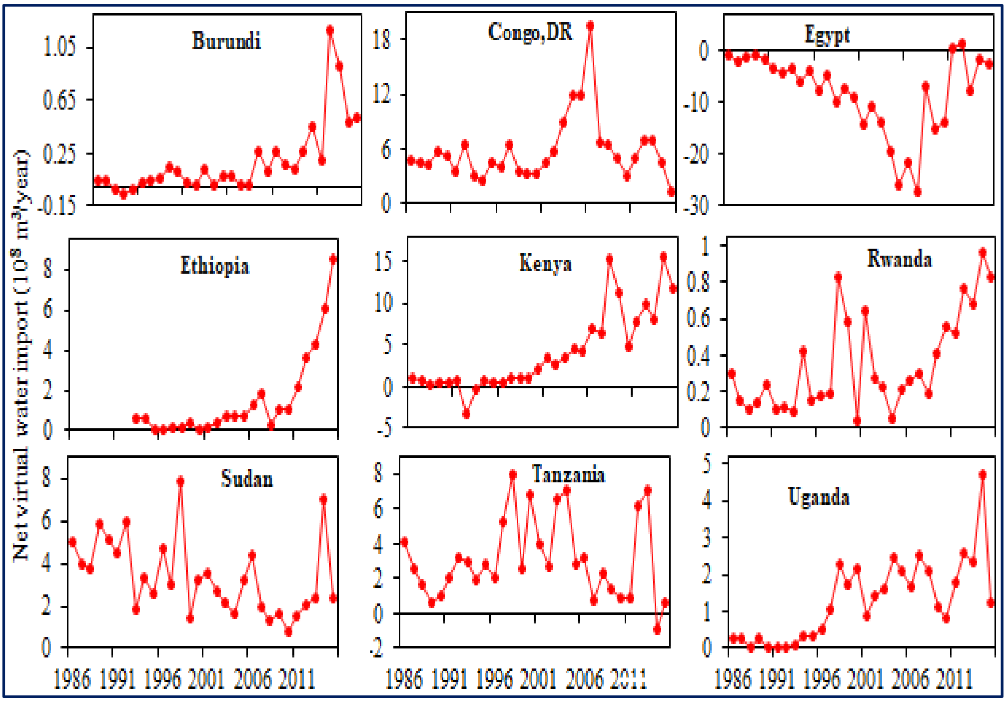
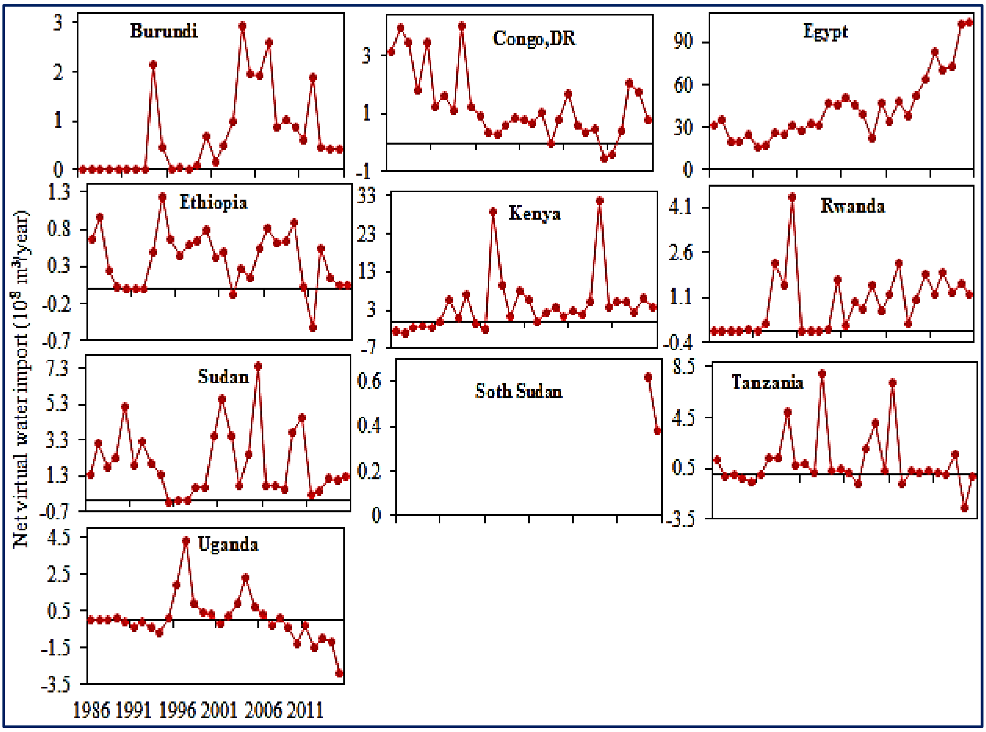


Figure13: Net virtual water imports for maize in Nile Basin countries in the period 1986–2015



A comparison of the average values for the period 1986-2015 with the current study and reported values in Mekonnen and Hoekstra, (2011) has provided useful insights on virtual water import and export crop products in the Nile riparian states.

Rice and maize are the most traded products in the region among the selected crops in all the Basin countries. The highest Net VWE in Mm^3 is in Egypt and Sudan for rice and sorghum, respectively. A large variation was observed among the Nile Basin countries in terms of net virtual water import and export of crop products. The majority of the Basin countries are importers for the selected crops. Generally, the highest Net virtual water import in Mm3 was in Egypt and Sudan for maize and sorghum, respectively. Egypt, Congo, Sudan, and Kenya were the highest importers of maize ($4359Mm^3$), rice ($583Mm^3$), sorghum ($539Mm^3$), and maize ($437Mm^3$) respectively with the annual average value for the study period. Some of the Basin countries such as Egypt, Sudan, Uganda, and Tanzania export some commodities items like rice, groundnut millet, and sorghum respectively. Figure 12-13 present the results of the net virtual water import long-term patterns of the Nile Basin countries from the period of 1986 to 2015.

Virtual water trade can play a significant role in addressing regional water shortages. For instance, Egypt and Sudan are net virtual water exporters of rice and sorghum in the Nile Basin countries. As a severe water-scarce region, these countries export more water in the form of crops to other areas through trade. Meanwhile, these countries could greatly benefit from importing water-intensive crops from the relatively water-abundant countries and exporting less water to consume crops. At the same time, it is more economical to produce such water-intensive goods in the region from areas that are relatively water-abundant region and export large quantities of virtual water to other regions by transferring agricultural products. Feng *et al.*, (2011), studies in China suggest that in most water-scarce regions it should increase the import of water-intensive goods from other more water-abundant regions.

Water is an important resource urgently needed for regional development and should be used in a manner that promotes productivity and thus sustainability. WF of crop products can be useful for sustainable use, by creating awareness of producers who provide sustainable products. Since WF is a measure of water consumption, the management of water consumption has policy implications. Although the Nile Basin countries may implement different water policies for their water management, effective riparian cooperation and careful consideration of WF and Virtual water trade are needed to develop policies. Virtual water trade could be a very effective alternative to physical water transfers in alleviating water scarcity. Since water is an important component of sustainable regional development and thus it is very important to use water efficiently.

This finding revealed that the majority of the Nile Basin countries are mainly net virtual water importers through agricultural trade. It is difficult to compare previous findings with this particular study due to variations in methodologies employed by the researchers in the different studies. Consequently, the green water footprint of the current study for the Basin countries is in agreement with the results of (Mekonnen & Hoekstra, 2011).

However, the results were different from other studies Zeitoun *et al.*, (2010) due to many reasons mentioned previously: variations in the methods applied, the type of crop variety, the study period, the models, and the data used. Zeitoun *et al.*, (2010) reported about 14,000 Mm^3 exported mainly rainfed-derived virtual water annually and roughly 41,000 Mm^3/y imported between the years 1998 to 2004. The current study benefited from the latest available national data and improved methodologies compared with previous studies.

4. Conclusions

In this paper, the long-term change in water footprint and virtual water trade in the Nile Basin countries estimated the current water footprint. The analysis shows that there are large differences in water footprint within the nation and the net virtual water import variation. There is a significant variation between WF and virtual water trade among the upstream and downstream countries. Countries like Egypt and Sudan have higher water consumption for crop production. The net virtual water trade balance of Egypt drawn in the current study suggests that this country has a high net import of virtual water due to the large import of crops. This study was limited to only a few selected crops of the Basin countries to virtual water trade between nations. To develop a comprehensive picture of the total virtual water trade, a comprehensive study that could involve many crop products is required. Domestic virtual water trade is important in countries like the Nile Basin, which is relatively dry in the lower part and wet in the upper part. This study indicates that Nile riparian states should seriously consider the potential of virtual water trade in alleviating nagging water scarcity concerns locally. Policymakers of the Basin countries can use the current national virtual water trade within the country to develop a sound national policy through a trade agreement to achieve higher regional water use efficiency. Hence, this finding is a very important addition to our understanding of water resource management, highlights the role of virtual water trade in water policy development and provides policy-relevant information.

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Valuation of Urban Ecosystem Services in Addis Ababa: A Benefit Transfer Approach

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Abstract

Maintaining urban ecosystems could contribute positively to social inclusion, health, sustainability, and urban renewals. Valuing multiple urban ecosystem services is important for potential improvements to urban green spaces. Using the year 2011 and 2022 land use and land cover classification (LULC) data, this study applied a benefit transfer or value transfer approach to value the stock and flow value of urban ecosystem services by taking Addis Ababa as an example The finding indicated that the stock value of ecosystem services in Addis Ababa for the year 2022 was about $270.8 million, which is equivalent to 0.08 percent of Ethiopia's GDP. the stock value is dominated by provisioning ecosystem services accounting about 44 percent which is $120.4 million. Regulating ecosystem services account for about three percent with value about $12.7 million. Approximately 5.13 percent which is close to $13.9 million attributed to supporting ecosystem services. Cultural ecosystem services ranked as the second highest taking 46 percent of the total ecosystem services value, amounting to about $ 123.7 million. Even if the city's ecosystem services stock value is higher, the flow value is reduced by about $4.63 million per year for the period between 2013 and 2022. A continuous loss of ecosystem services in the city may involve high long-term economic costs and severe

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impact associated with urban green space and ecosystem services. Therefore, conducting economic valuation of urban ecosystem services is vital for better understanding of sustainable cities and to inform green infrastructure planning and development interventions.

Keywords: Urban Ecosystem Services, valuation, Benefit Transfer, Addis Ababa

1. Introduction

Sustainable Development Goal (SDG) 11 intends to “make cities and human settlements inclusive, safe, resilient and sustainable”. Healthy urban ecosystems are the foundation for sustainable cities (Brendan Fisher, 2011). Maintaining urban ecosystems can contribute positively to social inclusion, health, sustainability, and urban renewals (Swanwick et al., 2003). In recent years, a mounting body of literature advanced our understanding of urban ecosystem services in their biophysical, ecological, economic, and socio-cultural dimensions. However, the attention given to the value of urban ecosystem services has yet been relatively modest as compared to other ecosystem services (Bar et al., 2014). Urban green spaces and ecosystems play an important role for a number of different ecosystem services including the ecological infrastructures in cities that regulate local temperature (Mcphearson, 2011) and maintaining water flow regulation (rainfall interception and runoff reduction (Xiao, Q. and McPherson, 2002); cooling and heating energy use(Simpson, 1988); air purification (Escobedo and Nowak, 2009); carbon sequestration (Jim and Chen, 2009; Sander et al., 2010); and maintain neighborhood ties and provide opportunities for social interactions (Kaz´mierczak, 2013).

Urban ecosystems can lessen noise pollution through absorption, deviation, reflection, and refraction (Gómez-Baggethun et al., 2013). It contributes to reduce air pollution, which is a major challenge for human health and environmental quality in urban environments particularly from transportation, industry, domestic heating, and solid urban waste incineration that leads to increases in respiratory and cardiovascular diseases (Dzierzanowski et al., 2011) . The recreational aspect or the cultural ecosystem services is the major urban ecosystem services, thereby enhancing human health and well-being (Maas et al., 2006; Rall and Haase, 2011). Likewise, the aesthetic benefits from urban ecosystems have been associated with stress reduction (van den Berg et al., 2010). Cities in coastal areas are also benefited from ecosystems and improving urban ecosystem services significantly reduces the damage caused to coastal cities by means of extreme climate events and hazards, including storms, heat waves, floods, hurricanes, and tsunamis (Depietri et al., 2012). Urban ecosystems also provide suitable alternative habitats for diverse species (Jansson and Polasky, 2010). Pollination, pest regulation, and seed dispersal are important processes in the functional diversity of urban ecosystems and can play a significant role in maintaining their long-term stability (E. Andersson and Ahrné, 2016)

Urban ecosystems contributed to provisioning ecosystem services, especially for long-term food security (Barthel and Isendahl, 2013; Reid et al., 2005) and supported urban agricultural practices to enhance urban livelihoods, food security, and enable to integrate multiple functions in densely populated areas (Moustier, 2007). Urban areas vegetation and forest cover improvement influence water-related ecosystem services in terms of water availability and quality in cities (Wagner et al., 2007); to mitigate storm-water runoff (Pataki et al., 2011); to improve storm-water management (Oberndorfer et al., 2007). The loss of ecosystems in cities may involve high long-term economic costs and severe impacts on social, cultural, and economic values associated with urban green spaces and ecosystem services. However, valuation of urban green space ecosystem services remains one of the most difficult tasks in ecosystem services research (Mulatu, 2019). Valuing these multiple urban ecosystem services is important for potential improvements to urban green spaces in a given city. In recent decades, there has been significant expansion in the scientific understanding of how urban ecosystems benefit people in cities. These ecosystems provide a wide range of benefits, including social, environmental, ecological, and economic advantages (Nordman and Wolff, 2009). Urban ecosystems play a pivotal role in providing essential ecosystem services that contribute to human well-being and the overall welfare of urban populations (Reid et al., 2005).

It is important to note that per-capital green space serves as a measure of the quality of life in cities: it represents the area (m^2) of accessible green spaces available per city inhabitant. The minimum standard per-capital green space recommended by WHO is that cities should provide 9 m^2 per capital green space within 15 minutes of walking distance from their home place. However, in 2017, Addis Ababa per-capital green space estimated about 1.52 m^2 per capital which is far below the African average 7m^2 per capita green space (Kahsay, 2016), thus, investment on urban green infrastructure is vital to make cities livable and sustainable. However, studies on urban ecosystem services valuation are limited in developing countries. Therefore, conducting economic valuation of urban ecosystem services to inform green infrastructure planning and development interventions is vital for better understanding of sustainable cities. This study applied a benefit transfer or value transfer approach to value the urban ecosystem services by taking Addis Ababa as an experiment.

1.1 Addis Ababa

The current rate of urbanization in Ethiopia is high. According to (WB 2015), urbanization in Ethiopia increases by 5.4 percent per a year that puts the country among the top ten fast urbanizing countries in the world. This is both an opportunity to transform economic activities and a challenge to manage negative impacts of urban expansion. However, rapid urbanization demands balanced investments in basic infrastructure such as health, education, road facilities, clean water supply, sewerage services, housing and recreational facilities. The provision of such facilities is challenging in urban areas of Ethiopia including the capital city. Addis Ababa is the largest urban area in Ethiopia serving as a capital city for the country as well as the headquarters for African Union (AU) and other international institutions including the United Nation Economic Commission for Africa (UNECA) Mulatu (2019)

The city has very low public park coverage, corresponding to 0.7m^2/person. Recently, there are several initiatives to create open spaces and green areas in the city. However, in 2010, there are about 11 public parks with a total area of 122 ha and additional 342 ha of land was planned to be allocated for public parks ~5120 hectares (ha) of land potentially suitable for urban agricultural practices, to improve the life of the urban poor, as a source for biomass fuel, and to absorb CO_2 emission. At present, only ~300 ha of land is used for urban agriculture (CLUVA, 2012). Recently the city urban green areas and parks have improved with interventions through various programs, for example urban park development, urban open space development, river and river side rehabilitation, and urban green area development programs. The city has a total of seven big rivers, with six medium-sized and 75 small rivers forming a network in the city. These have the potential to provide irrigation for urban agriculture. However, the presence of illegal settlement, urban population growth, and pollution from different sources is threatening the biodiversity and ecosystem of these rivers. In addition, Addis Ababa's city land use plan has identified close to forty percent of the total land has a potential for green area facilities and development (CLUVA, 2012). The plan reflected in the decision to construct 15-meter buffer zones for environment and climate consideration that is intended to protect residents from flooding, and to access clean river and river sides.

The current growth trajectory of Addis Ababa is unsustainable due to extensive urban poverty, inadequate housing, severe overcrowding and congestion, and undeveloped physical infrastructure (Mulatu and Ginbo, 2018). These factors have placed green areas under extreme pressure; consumed the natural and scenic beauty of the landscape; and altered the attractiveness of the city, thereby threatening the ability of urban green areas to perform their basic ecological, social and economic functions (Mpofu, 2013). The continuing growth of Addis Ababa has shrunk urban green areas to the extent that there is evidence of rising temperature and hot conditions in many neighborhoods (Abebe and Megento, 2016).

The city is expanding with unbalanced expansion of infrastructures and services. These create a burden on the provision of adequate housing to residents, business areas, and green amenities.

The successful implementation of the structural plan and protection of green amenities in Addis Ababa requires support from the private sector including real estate developers, city administration, individual house builders and buyers. In addition, the economic value assigned to urban green amenities such as green spaces, parks, street trees and other related urban ecosystem services is also vital to implement the plan (Mulatu and Ginbo, 2018). The economic value assigned to urban green amenities and other related urban ecosystem services is vital to implement plans that are focused on greening the city. Therefore, understanding and valuing the ecosystem services of the city can provide important insight about urban sustainability in a context of rapid urbanization and industrialization for urban planners and decision-makers to develop green infrastructures in the city.

2. Methodology

2.1 Ecosystem Services Valuation Approach

This study applied benefit transfer method ("value transfer") to estimate economic values for urban ecosystem services by transferring available information from relevant documents, empirical works, ecosystem services valuation database, and studies. The ecosystem unit help us to define the components of the environment (ecosystem) and the economy (socioeconomic conditions) in more detail. In this case, the recent Addis Ababa city boundary is considered as the spatial scale or ecosystem unit of analysis.

This study complements the economic valuation methodological framework presented in the Economics of Ecosystems and Biodiversity (TEEB) for cities; global and regional initiatives focused on highlighting the economic benefits of biodiversity and ecosystem services (UNDP, 2020). Ethiopia's national ecosystem service valuation guideline has been used to indicate how the value of ecosystem services can be estimated and incorporated in decision making (UNDP, 2018). To compute the total economic value the urban ecosystem services, different approaches were applied depending on the availability of information pertinent to each urban ecosystem services. Value/benefit transfer approach (Troy and Wilson, 2006) were applied since field measurement and primary data collection were not possible to estimate the economic value of the city's ecosystem services. In value transfer, we employ the adjusted unit value transfer approach because it allows the possibility of capturing the differences in income, exchange rate, inflation rate and price between the policy and the study sites. The TEEB global database is considered for the value transfer exercises, it further broadening the global experience in applying benefit transfer approach to conduct valuation of different ecosystem services in a given study area (Rudolf et al., 2020). Based on (Troy and Wilson, 2006), the following core steps have been applied in this study as a framework for valuing the ecosystem services:

1. Study area delineation: Spatial designation of the study area extent. It have a significant impact on the results when estimating the economic value of ecosystem services.
2. Typology development: establishment of a land use and land cover (LULC) or ecosystem account/asset typology. This step starts with a preliminary survey of available Geographically Information Systems (GIS) data at the site/study area to determine the current LULC or ecosystem asset of the city. Remote Sensing (RS) data and Geographical Information System (GIS) techniques were used for extraction of the study area, preprocessing, analysis and spatiotemporal assessment of the LULC analysis for the city. The LULC classification of GIS methodology helped in the identifying, delineating, and mapping of the land use/land cover into several classes. The Supplemented online available land use and land cover as well as the LULC developed for the city are used for validation of multi-temporal land use / land cover mapping and change detection which was performed using digital datasets of for the year 2011 and 2022. The analysis has been done using ARCGIS software and some graphs have been done by R programming language and excel. The details of the LULC analysis have been presented in the LULC analysis part of this paper.
3. Meta-analysis of peer-reviewed valuation literature to link per unit (area) coefficients to available LULC types: Preliminary review of economic valuation studies to determine whether the ecosystem service coefficients valued documented for the LULC types in a relatively similar context and available global and regional database. For this study, we used the Ecosystem Services Valuation Database for TEEB (ESVD-TEEB) global database due to the limited case and valuation studies in Ethiopia and in the region to drive coefficients.
4. Mapping: Map creation involves GIS overlay analysis and geo-processing conducted to combine input layers from diverse sources to derive the LULC map of the city. We combined available remote-sense data and GIS approach, and available ecosystem account (land use land cover)

models to be considered as analytical methods to map the LULC of Addis Ababa.

5. Ecosystem Services Valuation: Calculation of the Ecosystem Services Values (ESVs) and breakdown by LULC types were analyzed.
6. Geographic summaries: Tabulation and summary of ESVs by relevant ecosystem services were developed.

2.2 Land Use/Cover Classification Processes

2.2.1 General Description

Image classification is the process of assigning pixels to classes (Jensen, 1996). Each pixel is treated as an individual unit composed of values in several spectral bands. There are two types of satellite image classification methods: supervised and unsupervised classification. In our case we used supervised classification method to determine the LULC change of our capital city Addis Ababa. Supervised classification is the process of using a known identity of specific sites in remotely sensed data, which represent homogeneous examples of land cover types to classify the remainder of the image. These areas are commonly referred as training sites (Jensen, 1996). The maximum likelihood classifier is one of the methods of classification in remote sensing. This classifier assigns a pixel with maximum likelihood into a corresponding class. Selecting the appropriate bands to use in the color image on the other hand does have a huge impact on which features can be seen in a particular image during classification.

2.2.2 Source of Data and Analysis Techniques of LULC

Two Landsat images were used to get a complete coverage of the city. The images were obtained from the data portal (earthexplorer.usgs.gov) of the USGS and Google Earth Engine. The path and row of these images were 168, and 54 for the dry seasons of (December to February) respectively, with 15m & 10m spatial resolution for the spectral bands. We employed multispectral satellite data (Landsat 7 with sensors OLI and sentinel 1 Landsat) for 2011 and 2022, respectively, to identify and evaluate images. Besides, the LULC classifications were interpreted using additional data sets following previous researchers CLUVA (Climate change and Urban Vulnerability in Africa; cluva.eu) and Structural Plan of Addis Ababa 2017. Remote sensing and GIS tools, including ERDAS Imagine version 14, QGIS 3.2 and ArcGIS 10.5, were used to process the imagery and data analysis, respectively. At first, images were converted to UTM and geo-referenced using a datum selected by WGS-84 for Ethiopia. We digitized the demarcated study area in Arc GIS 10.5 to overlay the view on the spatial databases generated by the satellite image. We used ERDAS software to enhance the quality of the image, different mosaicking, sub-setting and radiometric enhancement techniques (Haze reduction and Histogram equalization) were applied to the raw data following after the image was processed, signatures were distributed per pixel by identifying the land into twelve classes of 2011 and 2022. Image cataloging was totally based on the reflectance characteristics (false-color composite) of the specific land cover classes and supplemented by using Google earth observation. Each class was given a unique identification and assigned a selected color to differentiate one from another. For each of the predetermined LULC categories, training samples had been selected via delimiting polygon around representative sites. The conversion matrices were created and each land cover value was analyzed to indicate the source, and destination of different land cover categories we calculated the LULC area cover in hectares, kilometer square and percentage.

3. Results and Discussion

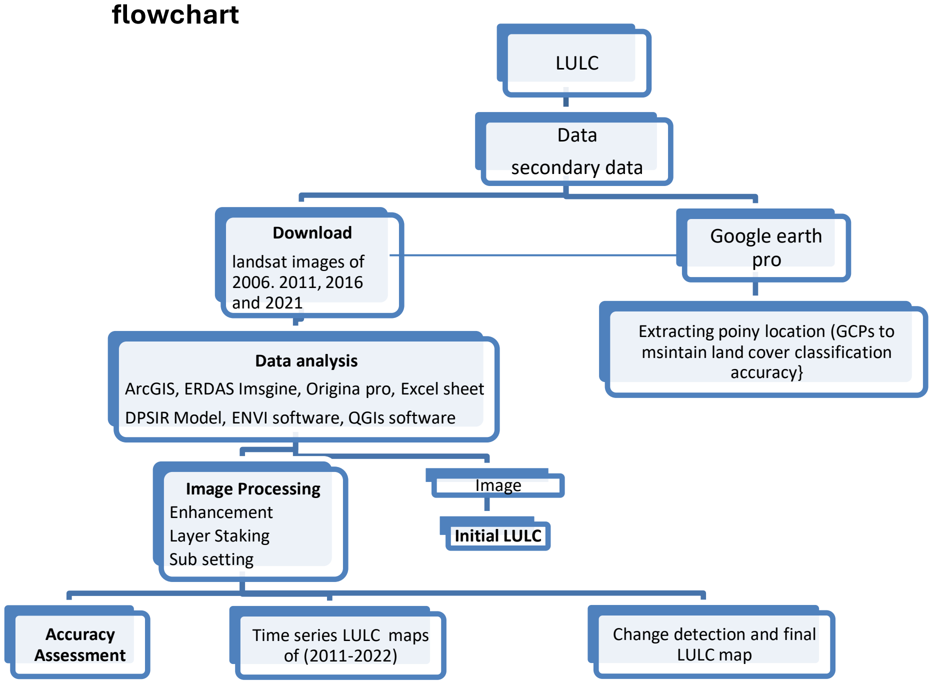
3.1 Addis Ababa City Land Use/Cover Analysis

The city's land use and land cover (LULC) types were categorized into twelve classes: Bare, Land, River Corridor, Field Crop, Forest, Grassland, Commercial Land, Shrub land, Residential, Mineral Extraction & Quarries, Woodland, Vegetable Farm, and Urban Green & Parks.

The areas of each land use class were calculated for the year 2011 and 2022 (Table 2). The spatial distribution and trends of LULC changes in Addis Ababa over the last decade is presented in Figure 1. During the study period, the area of cultivated land declined by 54 percent, decreasing annually by 4.86 percent (Table 2). Shrubland was also significantly converted into other land-use categories, experiencing a 60 percent reduction, with an annual rate of 5.48

percent. Even though the government strongly advocates the plantation of trees, especially urban forest cover declined by 1.15 percent per year, going from 2390 ha in 2011 to 2097 ha in 2022. This might because new planted trees were not at the stage of forest cover or not considered as urban forest since their plantation age is less than four years and their canopy is still space. The decline in Addis Ababa's Forest area was also confirmed by a previous study by (Degefu, 2021), which found that from 1990 to 2020, the size of Addis Ababa's urban forest and green ecosystems reduced by 1496.9 ha (2.8%). The area of bare land also decreased by 40 percent, from 7219 ha to 4362 ha. Unlike other LULC types, there was no change in the area coverage of water bodies.

Figure 1: Land use/Land cover classification and change detection flowchart

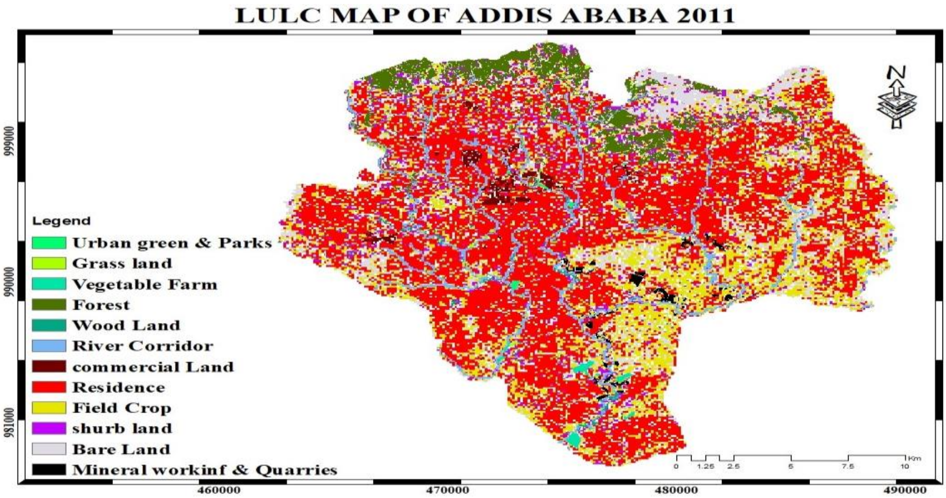


According to the city planning office, the city is mandated to allocate 30 percent of its area to green infrastructure projects. However, presently, only 26 percent of the city's land is covered by vegetation, with 10 percent of this being dedicated to cropland, a percentage lower than what the city administration aims for. In 2011, the residential land use was 189.82 km2 (44%), and it expanded to 286.92 km2 (67%) in 2022. By 2022, residential and built-up areas of the city indicated more than 50% of the city area. This growth can be attributed to expansion of residential areas, business areas, booming construction activities within the center and periphery areas of the city, as well as illegal construction activities on the city's outskirts. Unplanned urbanization is a major issue facing developing countries, leading to significant environmental consequences. (Degefu, 2021) also showed that over the past three decades, the built-up landscapes of Addis Ababa increased by 17,341.0 ha (32.2%). Similarly, the study of (Mulugeta et al., 2017) as compared to 1986 in 2016 the built up area coverage of Koye Fecha area, Addis Ababa increased by 1124.6% . Likewise, the area coverage of urban green spaces increased, with an annual increment of 25.41 percent, from 44 ha in 2011 to 167 ha in 2022. Additionally, the area of mineral extraction and quarries increased by 19 percent, from 408 ha in 2011 to 486 ha in 2022. Finally, grassland area increased from 335 ha in 2011 to 670 ha in 2022 Figure 2b (as indicated in Table 1).

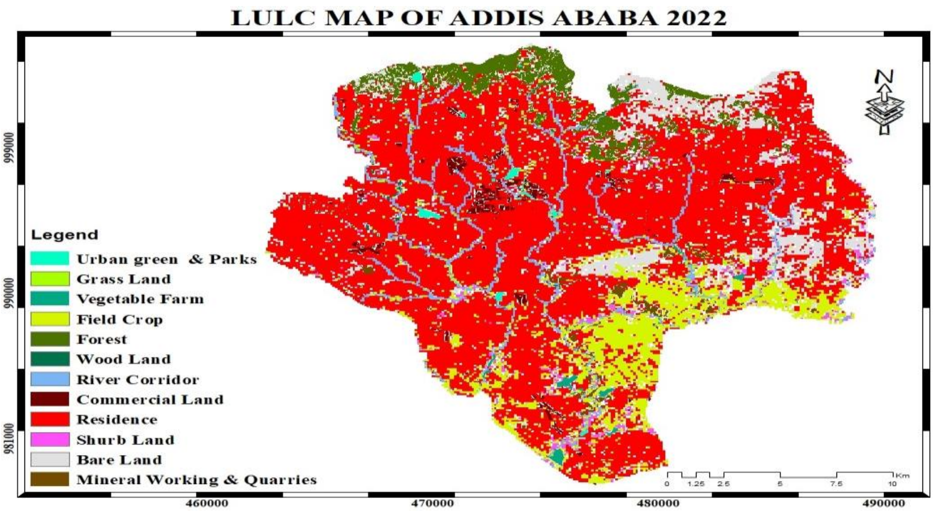
3.2 Ecosystem Service Valuation Analysis

The economic valuation of urban ecosystem services was computed for the major selected ecosystem services of the city, including provisioning services, cultural services, regulating services, and supporting services. Note that the capacity of the urban ecosystem to provide ecosystem services depends on the city's LULC or the ecosystem asset of the city and the analysis related to ecosystem condition and ecosystem extent of the city were not done in this study. The economic value of each ecosystem service was calculated by multiplying the value of each ecosystem service per hectare that is generated by the ecosystem asset by the area of each ecosystem asset (i.e. LULC area). To capture the value of different currencies across countries, the standardized equivalent dollar value, as international standardized measurement, is used to apply for per hectare value of a given LULC or ecosystem asset. To determine the stock value of the ecosystem services in 2022, the net present value was considered using an average discount rate of 10 percent by taking one year as time t. Since the LULC of Addis Ababa city within 11 years, the 11 years period was taken as time (t) for the computation of flow value. Note that the minimum recommended period to conduct a LULC change analysis is a five-year period. Thus, the ecosystem services flow value can be done for multiple periods, with different time intervals. However, for this study we only consider two period intervals as opening and closing periods. Further study can be conducted with multiple periods. The ecosystem services stock value of each service across the categories was presented in Table 2 that summarizes the economic values of the ecosystem services.

Figure 2: Land use land cover change of Addis Ababa from 2011 to 2021



(a) 2011



(b) 2022

Table 2: Land use land cover change

Land cover class	2011/ha	2022/ha	Change in ha per year	Percentage change
Shrub land	3931	1560	-216	-5.48
Woodland	213	67	-13	-6.23
Grassland	335	670	30	9.09
Forest	2390	2097	-27	-1.15
Water body (River and River Corridors)	114	114	0	0
Urban Green	44	167	11	25.41
Cultivated Area (Veg+Crop)	8882	4129	-432	-4.87
Mineral working & Quarries	408	486	7	1.74
Residence	18982	28692	883	4.65
Bare land	7219	4362	-260	-3.6
Commercial Land	471	644	16	3.34
Total	42989	42988		

Table 3: The 2022 stock value urban ecosystem services in Addis Ababa

LULC	Provisioning services	Regulating services	Supporting services	Cultural services	Total ESS value
Shrubland	12764	236836		536073	785673
Woodland	2254	130833	7126	187295	327508
Grassland	190645	75527		145573	411745
Forest	114782155	3860386	1811045	06287398	226740985
Waterbody (River and River Corridors)	1199902	5724044	2520229	1692900	11137075
Urban Green		1785078		1785230	3570308
Cultivated Area (Veg+Crop)	4204073	938409	9564265	13122713	27829460
Total Ecosystem Service	120391792	12751114	13902666	123757182	270802754

The result indicated that in 2022 the total stock value of ecosystem services of Addis Ababa is about $270.8 million, which is equivalent to 0.08 percent of Ethiopia's GDP in 2022. The highest value of ecosystem services is derived from urban forest cover ($226.74 million), urban cultivated land ($27.8 million), and water bodies ($ 11.13million). In contrast, shrub land, woodland, and grassland have the lowest ecosystem services values, which are $785,673, $327,508, and $411,745, respectively. Similarly, other studies in Ethiopia estimated the stock value of different ecosystems. For instance: Tesfay et al. (2023) estimated the ecosystem service of Chacha Watershed, and (Kindu et al., 2016) estimated Munessa – Shashemene landscape ecosystem service value. The city total ecosystem services values is presented in Table 3.

The detail of the Ecosystem Services Values (ESVs) for the flow value for the period between 2011-2022 are presented in Table 4. Due to changes in the LULC or the ecosystem asset of the city, for the specified period between 2011 and 2022, the flow ecosystem value of the urban ecosystem services of Addis Ababa is reduced by about $5.63 million. Specifically, the flow of the ecosystem services economic value that indicated a decline is about $1.87 million, $81,758 million, $ -1.01 million and 2.6 million for provisioning, regulating, supporting, and cultural services, respectively Table 4. Likewise, the ecosystem services of Wuhan were reduced from 74.554 billion yuan ($521.85 million) in 1990 to 68.548 billion yuan ($479.84 million) in 2021, resulting in a yearly decrease of $1.35 million, which is lower than Addis Ababa's annual loss of ecosystem services (Yan Zhang, Yanfang Liu, Yang Zhang, Yi Liu, Guangxia Zhang, 2018). (Kindu et al., 2016) also confirmed the reduction of ecosystem service by 14.86 percent. On contrary, the study by (Tesfay et al., 2023) showed a fluctuation in the total ecosystem value of Chacha water shade ecosystem service. As the study showed, the ecosystem service value increased by $2.86 million from 1997 to 2006 while it reduced by about $1.02 million from 2006 to 2011.

Table 4: The 2011-2022 the flow value urban ecosystem services in Addis Ababa

LULC	Provisioning services	Regulating services	Supporting services	Cultural services	Total ESS value
Shrubland	-1739	-32264		-73029	-107032
Woodland	-440	-25554	-1392	-36582	-63968
Grassland	8544	3385		6524	18453
Forest	-1437502	-48346	-22681	·1331116	2839645
Water body (River and River Corridors) Urban Green		117845		117855	235700
Cultivated Area (Veg+Crop)	-433769	-96823	-986823	·1353977	2871393
Total Ecosystem Service	-1864905	-81758	-1010896	-2670326	-5627886

The urban forest area in the city only 5 percent of its land cover. Within the city forest, there are a total of 37 woody species, comprising 13 trees and 24 shrubs. The most abundant species is Eucalyptus, accounting for 43.94% of the total, followed by Juniperus procera at 13.15%. The least abundant species is Buddleja polystachya, constituting only 0.17% of the total. The density of woody species varies, ranging from 21 individuals/ha for Olea europea subsp cuspidata to 5513 individual trees/ha for Eucalyptus. Eucalyptus globulus and Juniperus procera are the two densest species in the urban forest of Addis Ababa, with a density of 5513 individual trees/ha and 1650 individual trees/ha, respectively (Woldegerima et al., 2017).

As shown in Table 2 , the urban forest has an estimated annual value of $ 226.74 million. It provides the highest value for provisioning services ($ 114.78 million or 50.6 percent) followed by cultural services ($106.29 million or 46.9 percent). The value for supporting services from the forest is approximately $1.81 million, and regulation services account for $3.86 million. Similarly, the ecosystem service of Chacha forest is $7.74 million in 2016 (Tesfay et al., 2023). Despite providing these ecosystem services, the area coverage of Addis

Ababa's urban forest has decreased by 27 ha per year. Consequently, the city might lose close to $2.83 million per year, particularly $1.44 million, $1.33 million, $22,681, and $48,346 for provisioning, cultural, supporting, and regulation services, respectively Table 2. On similar study, the ecosystem service Munessa – Shashemene natural forest shirked through time (Kindu et al., 2016). But Chacha river basin forest ecosystem service increases through time (Tesfay et al., 2023).

Cultivated areas take about 10 percent of the city's ecosystem services value and provide the second-highest ecosystem services, valued at approximately $27.83 million in 2022, which is lower than Chacha river basin cultivated land ecosystem service that covers 40.34 percent total ecosystem service (Tesfay et al., 2023). While, only 10.2 percent of Munessa – Shashemene landscape ecosystem service emitted from cultivated area which is comparable with Addis Ababa(Kindu et al., 2016). In terms of the ecosystem services value, cultural service ($13.1 million 47 percent) and supporting service ($9.56 million or 35 percent) dominated the share of cultivated land ecosystem services (Table 3). However, Addis Ababa cultivated land area has declined by 4.87 ha per year, leading to a 3.2 percent reduction in ecosystem services annually, amounting to $2.87 million. In a similar study, the reduction of agricultural land in southwestern coastal Bangladesh resulted in a decrease in ecosystem service value (ESV) by US$ 1.41 billion during the period 1980–2016, or a reduction of $39.17 million per annum, which is much higher than the reduction of Addis Ababa's ecosystem service due to cultivated land reduction.

The water bodies, including both rivers and riverbanks, covered about 114 hectares of the city land cover, offering a wide range of ecosystem services. The estimated total value of ecosystem services provided by the water bodies is about $11.14 million. Among the ecosystem services, $5.7 million attributed to regulating ecosystem services, $2.5 million to supporting services, $1.7 million to cultural services, and $1.2 million to provisioning ecosystem services Table 2. The urban green area cover and space in Addis Ababa was approximately 167 hectares, accounting for 0.39 percent of the cities total area. The total value of ecosystem services provided by urban green area estimated about $3.57 million. Out of this, $1.78 million attributed to regulating services, while $ 1.78 million was attributed to cultural services. A similar study conducted by (Xu and Zhao, 2021) in 2021 on Urban Green Infrastructure Ecosystem Services in Beijing estimated the value of ecosystem services to be $240 million, which is approximately $33,895.65 per hectare. By multiplying this per hectare estimation by the urban green area of Addis Ababa, the total value of ecosystem services provided by the cities green cover was found to be $5.66 million per year. This value is relatively higher than that of Addis Ababa's current green cover ecosystem services estimation, possibly due to differences in vegetation cover as observed in the study. Unlike other land uses, the land cover of Addis Ababa's urban green area increased by 11 hectares (25.24 percent) per year, resulting in an increase of $235,700 in ecosystem services value annually. About $117,845 value attributed to regulating services, and $117,855 attributed to cultural services.

Shrub land, woodland, and grassland together accounted for 5.33 percent of the total land cover in Addis Ababa, with individual percentages of 3.63percent, 0.16 percent, and 1.56 percent of the total urban ecosystem services value, respectively. Combined, they make up 1 percent of the city's ecosystem services value. In terms of ecosystem services value, shrub land, woodland, and grassland were estimated to be worth $785.6 thousand, $327.5 thousand and $411.75 thousand respectively. Shrubland and woodland were found to provide higher value for cultural services, followed by regulation services. In contrast, grassland provided higher provisioning services, followed by cultural services. Within 11 years of the study period from 2011 to 2022, the area coverage of shrub land and woodland has decreased by 216 hectares and 13 hectares per year, respectively, leading to a reduction in their respective ecosystem service values by $107 thousand and $63.9 thousand per year Table 2 However, the area coverage of grassland has increased by 30 hectares per year, resulting in an increase in its ecosystem service value by $ 18,453 per year (Table 3).

3.3 Addis Ababa Urban Ecosystem Services

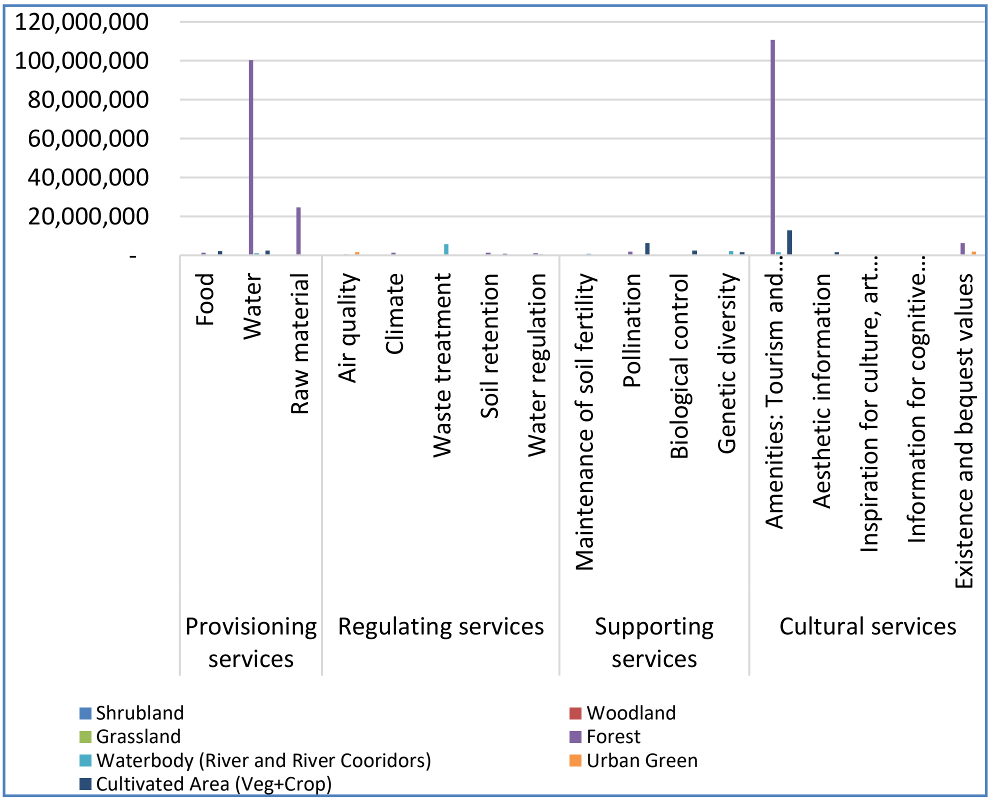
In terms of ecosystem services, provisioning services dominated the city's ecosystem services potential, accounting for about 44 percent which is $120.4 million. Forest areas contribute the majority share to provision services (95.3 percent), followed by cultivated lands (3.5 percent). The main provisioning services derived from the urban ecosystem are food, water, and raw materials. Water provision services value constitutes the highest proportion among the provisioning ecosystem services which is $94.67 million (78.63 percent). Followed by raw materials $22.41million (18.61 percent) and food $3.31 million (2.74 percent) respectively. The highest share of food service comes from cultivated land ($1.91 million) followed by forest ($1.15 million) and water body ($237,120). The highest proportion of water and raw material service gained from forest followed by cultivated land area and water bodies. However, the flow value of the urban ecosystem service for provisioning service declined by 1.45 percent ($1.86 million) per year (Figure 3). Specifically, the urban ecosystems contribution for water, food, and raw material reduced by $1.36 million, $213 thousand, and $283.17 thousand per year respectively. This is due to the case area reduction of forest, cultivated land, woodland, and shrub land, their provision's service dropped to by $1.43 million, $433.76 thousand, $440, and $1739 respectively because of their area coverage reduction. The study done by (Kindu et al., 2016; Tesfay et al., 2023) confirmed the reduction of provision service of urban ecosystem.

Regulation services[8] account for about 5 percent of the urban ecosystem service in Addis Ababa which is about $12.7 million Table 3. Water bodies contribute the highest percentage of regulation services which is 44.8 percent ($ 5.7 million). While, 30.27 percent which is $3.86 million of emitted from forest. Water treatment, air quality, climate regulation, waste treatment, and soil retention considered in this analysis for regulating ecosystem services of the city of the city. Waste treatment accounts the largest value of regulation services at 43 percent ($ 5.43 million), followed by air quality at 17 percent ($2.16 million), climate services at 13.93 percent (1.77 million), water regulation at 12 percent ($ 1.57 million) and soil retention at 14.12 (1.8 million) Table 2 . On contrary, regulation service takes about 63.8 percent of Munessa–Shashemene landscape ecosystem service (Kindu et al., 2016). According to the Addis Ababa Water and Sewerage Authority, rivers and streams in Addis Ababa are challenged with various interventions: Despite the government has made remarkable progress in the riverside project, there are numerous challenges. There are illegal buildings and sometimes used as a tunnel for waste disposal and dumping site for excavated soil. As a result, the river

[8] In this study, air quality and climate regulation ecosystem services reflect issues related to urban pollution. However, the contribution of green infrastructure to reduce pollution require further detail research is needed by installing pollution monitoring instruments (to collect city pollution data from different economic activities) in different parts of the city.

ecosystem service provision for irrigation, drinking, swimming, and cattle drinking services is challenged. Currently the rivers are used as a tunnel for removing the town waste.

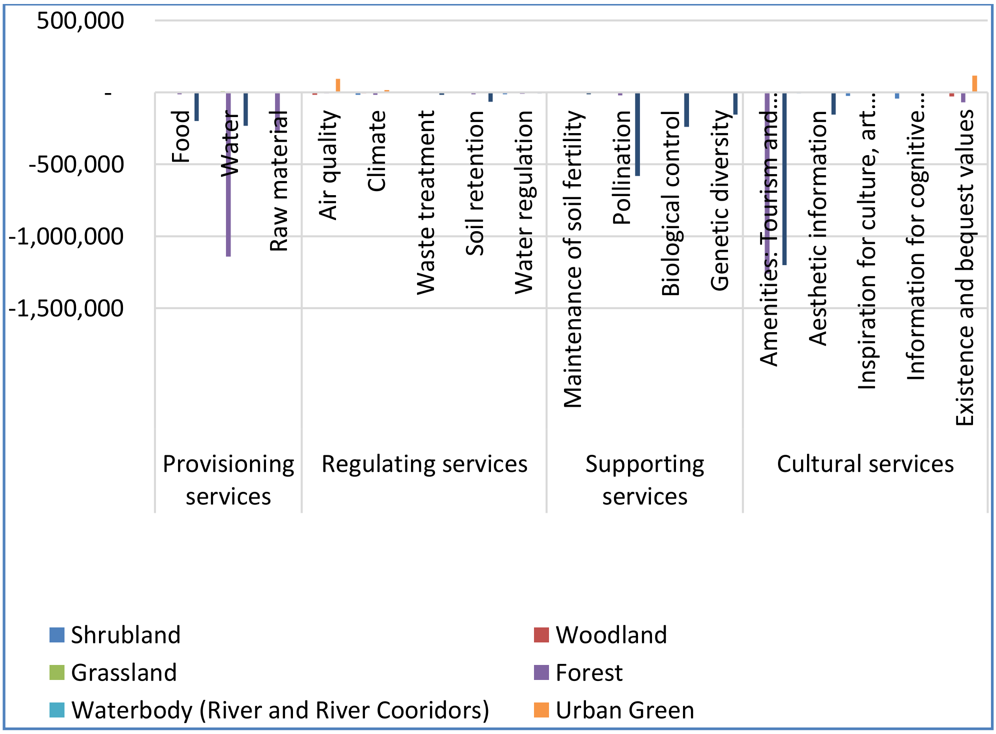
Figure 3: Stock value of Addis Ababa ecosystem services by LULC in 2022



Based on LULC classification of the city, about 70 percent, 64 percent, and 54 percent of climate, soil retention and water regulation service respectively emitted from the forest ecosystem service. While, about 66 percent of air quality emanate from urban green. About 36.07 percent of soil retention gained from cultivated land. Similar study in Adam forests, Ethiopia (Koricho et al., 2022) an estimated air purification value of Adam forest, estimated about $ 686.5 million per year value for air purification service. (Tesfay et al., 2023) estimated Chacha river basin as of water regulation, erosion control, and climate regulation as $2.23 million, $2.99 million and $1.75 million respectively.

Fortunately, the regulation service of urban ecosystem annually increased by 3 percent ($431 thousand) because of LULC. Specifically, ecosystem air purification increased by $63,036 per year. While the ecosystems soil retention and climate change service reduced by $81,494 and $23,248 per year respectively The flow values of the regulating services from urban forest area ($48,334) and woodlands' reduced ($25,554 or 20 percent) followed by the regulating services from shrub land ($32,264 or 14 percent) and cultivated ($96,823 or 10 percent) Figure 4. However, the regulating ecosystem services of urban green areas increased by 7 percent. The finding on regulating ecosystem services value is in line with this (Tesfay et al., 2023) that revealed the variation of Chacha River basin for regulation service and showed an increment of regulation service from 1997 to 2006. But it indicated a reduction from 2006-2011. On contrary, (Kindu et al., 2016) revealed the increment of Munessa–Shashemene landscape regulating ecosystem services.

Figure 4: Addis Ababa City Ecosystem Services (ES) Flow per ES and per LULC from 2011-2022.



In terms of supporting services, they account for approximately 5.13 percent of the total ecosystem services of the city's ecosystem assets, amounting to $13.9 million. The major contributors to this ecosystem service are cultivated areas, contributing $9.56 million (69 percent), and forests, contributing $1.81million (13 percent). Shrub land and woodland have a negligible contribution to supporting services. Among the supporting services, biological control takes the highest share with $2.37 million, followed by genetic diversity with $3.36 million. The estimate value of Addis Ababa ecosystem service is higher than Chacha river basin estimate which is $3.55 (Tesfay et al., 2023) and Munessa – Shashemene which is $3.9.

Based on land use and land cover (LULC), around 74 percent of the maintenance of soil fertility service is attributed from water bodies, while cultivated land contributes to about 15 percent and pollination took about 77 percent. A significant portion of biological control (98.25 percent) and genetic diversity (44.12 percent) are emanated from urban cultivated land areas. Unfortunately, the contribution of urban ecosystems to supporting services has declined by 6 percent annually due to LULC changes. Specifically, the supporting services of cultivated urban land and forest areas contribution have reduced by a value close to $986,823 and $22,681 per year, respectively, this is due to the decline in the land cover area coverage of these two classes for the specified period Table 3. Among the specific supporting services, due to a change in the urban ecosystem assets or the LULC, the value of pollination is declined by about $601,342, followed by biological control ($239,524) and genetic diversity ($153,148).

Urban ecosystems make a significant contribution to cultural ecosystem services, ranking second highest ecosystem services of the urban environment. It is approximately 46 percent, amounting to about $123.7million. Within this contribution, the majority is attributed to urban forest cover, accounting for 85 percent ($106.3 million), followed by cultivated land area at 10 percent ($13.12 million). Other land cover collectively contribute close to 5 percent. Regarding cultural services, tourism and recreation services play a dominant role, constituting around 92 percent ($113.76 million), followed by existence value at about 6.12 percent ($7.58 million), with the remaining services collectively contributing about 1.95 percent. In a similar study, (Nthiiri,

2016) estimated the ecosystem service of Nairobi parks using the travel cost method and found a total parks' recreation value of about $70.9 million per annum. Additionally, (Tensaye, 2017) found the recreation value of Hamel 19 Park to be about $18.24 million per year. Munessa – Shashemene ecosystem and Chacha river basin provides about $0.8 million, and $0.11 million respectively (Kindu et al., 2016; Tesfay et al., 2023).

However, the ecosystem service of cultural services has been declined by 2 percent as a result of LULC change. Specifically, the urban ecosystem's cultural service contribution reduced by $1.35 million, $1.33 million, $73 thousand, and $36.58 thousand from cultivated land, forest land, shrub land and wood land respectively 4. Regarding cultural services, the ecosystem service for tourism and recreation has mostly reduced by $2.46 million, followed by aesthetic information, which decreased by $160.79 thousand and information for cognitive development, declined by $39.01 thousand per year. Meanwhile, the ecosystem's existence contribution has increased by $18 thousand per year Figure 4.

4. Conclusion

Healthy urban ecosystems are the foundation for sustainable cities. Maintaining urban ecosystems could contribute positively to social inclusion, health, sustainability, and urban renewals. Valuing these multiple urban ecosystem services is important for potential improvements to urban green spaces in a given city. Therefore, conducting the economic valuation of urban ecosystem services to inform green infrastructure planning and development interventions is vital for better understanding of sustainable cities. This study applied a benefit transfer or value transfer approach based on the Land Use/Land Cover (LULC) classification to value the urban ecosystem services by taking Addis Ababa as an experiment. The 2011 and 2022, LULC classification has been used to estimate the flow and stock value of ecosystem services in Addis Ababa. The finding indicated that the total stock value of ecosystem services in Addis Ababa for the year 2022 is about $270.8 million, which is equivalent to 0.08 percent of Ethiopia's GDP in 2022.

In terms of the stock value of the ecosystem services, the provisioning ecosystem services dominated the city's ecosystem services accounting for about 44 percent which is $120.4 million. Regulating ecosystem services account for about three percent of the urban ecosystem service in the city which accounts for about $12.7 million. Supporting ecosystem services account for approximately 5.13 percent of the total ecosystem services, about $13.9 million ecosystem services value. In addition, urban ecosystems significantly contribute to cultural ecosystem services, it is reflected in Addis Ababa and ranked as the second highest at approximately 46 percent of the total ecosystem services value, amounting to about $123.7 million. Even if the total ecosystem services value of the city shows a higher value, due to changes in the LULC or the ecosystem asset of the city, for the period between 2011 and 2022, the flow value of the city's ecosystem is reduced by about $4.63 million. A continuous loss of ecosystem services in the city may involve high long-term economic costs and severe impacts associated with urban green space ecosystem services.

To maintain the city ecosystem services value, it requires regularly maintaining and expanding the urban ecosystems like green areas, parks and rivers; as well as implementing effective institutional coordination mechanisms are important. However, institutions in Addis Ababa have duplicative efforts in green spaces development and management, including Addis Ababa Environmental Protection Authority, Beautification and Green Development Bureau, Public Recreational Places Administration Corporation, and the Office for Urban Agriculture. Thus, consideration of the stock and flow value of the city ecosystem services is vital to support the planning and management efforts of the city's urban green infrastructure as well as urban green areas. As the city land use and land cover are the major source of urban ecosystem services, the findings underline the importance of sustainable urban land management practices to maintain and enhance the Addis Ababa ecosystems.

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Industrialization and Deindustrialization in Ethiopia

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Abstract

Despite the government's policy orientation emphasizing industrialization, Ethiopia's economy has recently shifted directly to a service-based economy, bypassing the industrialization phase. This unconditioned shift towards services, while the manufacturing sector remains stagnant, signals a risk of premature deindustrialization. In light of these developments, this study examines industrialization and deindustrialization in Ethiopia using historically linked newly constructed Economic Transformational Database (ETD) for the period 1961-2018 and by employing fractional logit regression, OLS estimation, and the Lind and Mehlum exact U-curve test as an empirical strategy. The results, derived from both linear and nonlinear estimators and various data sources, do not conclusively show that Ethiopia is undergoing premature deindustrialization. Instead, the result suggests that the persistently weak performance of Ethiopia's manufacturing points to stalled industrialization. An extended analysis using firm-level data gathered from industrial surveys from 1990-2015 shows that employment industrialization is driven by the expansion of small, often informal firms, which, despite low productivity and survival rate, contributes significantly to manufacturing jobs. Conversely, output industrialization is led by large, more productive firms, albeit creating fewer jobs. The policy implication is that industrial policies aimed at enhancing the productivity and growth of small, often informal firms, along with promoting job creation by large firms can significantly contribute to materializing Ethiopia's industrialization potential.

Keywords: Premature Deindustrialization, Stalled Industrialization, Manufacturing, small, often informal firms, large firms, Industrial Policy, Ethiopia

JEL Classification Codes: O11, O14, O17

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1. Introduction

Over the past two centuries, industrialization has been regarded as the primary avenue for countries to grow and develop, particularly for developing nations seeking to climb the ladder of prosperity. Economic history demonstrates that the developed world we see today largely emerged through industrialization. According to Szirmai (2009), most instances of significant, rapid, and sustained economic growth in modern economies have been closely linked to industrialization, particularly manufacturing growth. However, recent empirical studies question the ongoing importance of manufacturing as the single route to development, noting deindustrialization trends in many developing nations over recent decades (e.g., Palma, 2005; Tregenna, 2015; Rodrik, 2016; Felipe et al., 2019; Atolia et al., 2020; Taguchi and Tsukada, 2022).

In contrast to the traditional pattern of structural change in which economies evolve from agriculture to manufacturing and then to services, many developing economies are bypassing the industrialization phase and moving directly to a service-oriented economy. This phenomenon is documented in the literature as premature deindustrialization, referring to an early decline in the manufacturing sector's share of total employment or output, occurring at lower levels of income per capita than seen internationally (e.g., see Dasgupta and Singh, 2007; Rodrik, 2016; Nguimkeu and Zeufack, 2019). As a result, these countries miss out on the potential benefits of high productivity and sustained economic growth that industrialization typically provides. Rodrik (2016) highlights that several Sub-Saharan African countries, which were expected to excel in labor-intensive manufacturing, are unexpectedly undergoing deindustrialization prematurely.

Ethiopia's economy exemplifies this trend, with the service sector having recently surpassed the historically dominant agriculture, while the industrial structure and performance of the manufacturing sector remain stagnant. Although a shift to a service-based economy is not inherently problematic, Ethiopia's service sector is primarily driven by traditional, non-marketable, and informal services like distribution, public, and personal services. These subsectors have limited potential to improve overall productivity or absorb the growing unskilled labor force. Thus, without a structural change in the economy and long-lasting productivity gains in the manufacturing sector, moving towards less dynamic informal services poses significant risks, threatening long-term economic growth and sustainability.

Despite the government's policy orientation emphasizing industrialization and considerable efforts to stimulate manufacturing growth through a comprehensive industrial policy, the persistently weak performance of Ethiopia's manufacturing sector remains puzzling. For decades, this sector has not surpassed 7% of GDP, 8% of total employment, and 13% of total merchandise exports, all well below the Sub-Saharan Africa average. This disappointing performance, combined with an unconditional shift of the economy towards traditional services, raises concerns about the risk of premature deindustrialization in Ethiopia. If it holds premature deindustrialization is not good news for Ethiopia's economy found at an early stage of development. It has a far going negative consequence on long-run economic growth, thereby on the fate of the economy unless identified and addressed with appropriate policy intervention to the best of soon.

In light of this concern, this paper examines industrialization and deindustrialization in Ethiopia using historically linked the newly constructed Economic Transformational Database (ETD) for the period 1961-2018, and by employing a more appropriate empirical strategy (i.e., fractional logit regression model) that accommodates a fractional response variable taking value between 0 and 1, in addition to applying the Lind & Mehlum exact U curve test.

Why this research? First, despite there is concerns and claims among policymakers and researchers about whether Ethiopia's economy is undergoing deindustrialization prematurely due to the stagnation of the manufacturing sector, empirical studies thoroughly investigating this phenomenon are very scanty. This gap underscores the need for this study and its practical relevance. Thus, this research bridges that gap, contributing to the specific context of Ethiopia and the tiny deindustrialization literature at large. Furthermore, this study, which is one among the few, if not the first, to empirically explore premature deindustrialization risk in Ethiopia contributes by presenting fresh evidence into whether Ethiopia's economy is indeed at risk of premature deindustrialization or not, thereby providing valuable insight to inform policymaking.

Second, most previous empirical works done in the broader deindustrialization literature suffer from methodological limitations in two key ways (see, e.g., Rodrik, 2016; Tregenna, 2016; Kruse et al., 2022; Andreoni and Tregenna, 2019; Prasad, 2023; and Palma, 2005, among others). First, many earlier studies, including Rodrik's (2016) seminal work, used linear estimators (i.e., pooled OLS, linear fixed effect model, and OLS) to estimate the famous econometric specification widely used in the deindustrialization research in which manufacturing share of output or employment is regressed on GDP per capita, GDP per capita square, population and its squared term. However, as the manufacturing share of output or employment is a bounded fractional response variable, applying linear models to such fractional outcome variable leads to a model misspecification problem, thereby making inferences and conclusions drawn from such model invalid and misleading. As a result, appropriate functional form specification tailored to fractional response variables is necessary. In this study, we address this issue by employing more suitable estimation techniques, such as the fractional logit regression model and the beta regression model, which are designed to handle fractional response variables effectively. Second, traditionally the presence of an inversed U-shape manufacturing-income relationship is confirmed, once the coefficient on GDP per capita is positive and significant and the coefficient of its squared term is negative and significant, in addition to the estimated turning point needs to be within the data range. However, this approach is too weak. Lind and Mehlum (2010) argue that to identify a true inverted U-shape manufacturing-income relationship over relevant data values, the test must identify whether the relationship is increasing at low values within the interval and decreasing at high values within the interval. They suggest a new test based on prior work by Sasabuchi (1980). Accordingly, in this study, we applied the Lind and Mehlum exact U test to examine the existence of a true inverted U-shape relationship between manufacturing activities and GDP per capita. In summary, this study contributes by addressing the methodological shortcomings of prior research by employing estimation techniques suitable for fractional response variables and by applying the Lind and Mehlum exact U-shape test to provide more robust insights.

Third, previous deindustrialization research has primarily focused on its macro aspects, with empirical studies offering both macro and meso evidence being almost nonexistent. Therefore, this study contributes to the existing literature by examining industrialization and deindustrialization trends using both sectoral aggregate data and firm-level data gathered from industrial surveys, thus providing both macro and meso evidence.

Fourth, unlike previous studies, this study attempted to explore premature deindustrialization risk by applying two empirical approaches one proposed by Rodrik (2016) and the other by Taguchi and Tsukada (2021). Specifically, this study is the first of its kind in the case of African countries to investigate the occurrence of premature deindustrialization by adopting the latecomer's index closely following Taguchi and Tsukada (2021). Thus, this study contributes to the existing literature by making a comparison between the two competing approaches.

Fifth, while there is a growing discourse suggesting that developing nations, especially those in Sub-Saharan Africa, are undergoing premature deindustrialization, the empirical evidence remains mixed and inconclusive. Therefore, the current paper contributes to the ongoing deindustrialization debate by taking Ethiopia as a special case study of developing countries.

2. Literature Review

The foundational studies on premature deindustrialization are Dasgupta and Singh (2007) and Rodrik (2016). Dasgupta and Singh (2007) explored the roles of the manufacturing and service sectors in developing countries, highlighting manufacturing's continued importance for growth in developing countries, per Kaldor's law. They defined "premature deindustrialization" as a decline in manufacturing output and employment share, with a rise in services at lower income levels. They also distinguished between technology-driven deindustrialization, seen in India, and pathological deindustrialization, common in Latin American and African countries facing balance-of-payment issues under import-substitution industrialization strategies.

Rodrik (2016) further refined the concept, developing a two-sector model to show that developing countries opening to trade often become price-takers in global manufacturing markets. Without a strong comparative advantage in manufacturing, these countries become net importers as manufacturing prices fall and China's influence grows, leading to deindustrialization in employment and output. Rodrik's empirical analysis from the late 1940s to post-2010 showed that Latin American and African nations experienced deindustrialization due to resource discovery and rising commodity prices, while Asian countries with stronger manufacturing sectors avoided this trend. He also found that late industrializers reached peak industrialization at lower income levels, about 40% of what early industrializers achieved. Fujiwara and Matsuyama (2020) expanded Rodrik's model by adding "technology gaps" to illustrate varying abilities to adopt advanced technologies, providing additional insight into premature deindustrialization.

Since Rodrik's groundbreaking research in 2016, numerous empirical studies have endeavored to identify premature deindustrialization, both in advanced and developing countries, at both regional and individual country levels. These investigations include studies conducted by Sato and Kuwamori (2019) in non-OECD nations, Nayyar et al. (2021) in lower-income developing countries, Daymard (2020) in Latin American and African nations, Caldentey and Vernengo (2021) in Latin American countries, Ssozi and Howard (2018) in Sub-Saharan African countries, Taguchi and Tsukada (2022) in Asian latecomer economies, Lee (2020) in Malaysia, and Hamid and Khan (2015) in Pakistan.

While there is broad consensus regarding deindustrialization in developed economies, the situation is less unequivocal for developing nations, notably those in sub-Saharan Africa, where a debate persists concerning premature deindustrialization. On one hand, research conducted by Rodrik (2016), Atolia et al. (2019), and Felipe et al. (2019) posits that manufacturing output and employment have decreased in sub-Saharan African countries at lower GDP per capita levels compared to global trends. Conversely, recent studies by Nguimkeu and Zeufack (2019), Mensah (2020), and Kruse et al. (2022) contest this notion, suggesting that contrary to expectations, the share of manufacturing employment has been on the rise in many African nations. This highlights the ongoing empirical dispute regarding whether developing countries, particularly those in sub-Saharan Africa, are undergoing premature deindustrialization. Additionally, there is a notable scarcity of single-country case studies focused on sub-Saharan African nations, a research gap that this study aims to address.

3. Methodology

3.1 Data Source and Measurement

The data for this study come from a variety of sources. The sectoral data for the measurement of manufacturing share of employment or output come from two main sources: the newly constructed Economic Transformation Database which is extrapolated backward using the GGDC 10-sector database (De Vries et al. 2021) and the Expanded Africa Sector Database (Mensah et al., 2018). Three measures of de (industrialization) are commonly employed in the literature, namely the share of manufacturing value added in GDP at constant prices, the share of manufacturing value added in GDP at current prices, and the share of manufacturing employment in economy-wide employment. We focus on real measures and accordingly use the share of manufacturing real value added in GDP at constant price and manufacturing employment share in total employment as a dependent variable to capture the degree of de (industrialization).

For the income and population data, we use the 2023 release of the Maddison Project Database (Bolt, Inklaar, de Jong & van Zanden, 2018). The database includes information on GDP per capita (in 2011 USD) and population size.

In an extended analysis, we examined industrialization trends based on the size of firms using manufacturing firm-level data. To achieve this, we utilized the United Nations Industrial Development Organization (UNIDO) Industrial Statistical Database (INDSTAT 2, 2020), which draws from national industrial surveys on manufacturing industries, and combined it with the Economic Transformational Database (ETD). The ETD primarily relies on population census data, encompassing both formal and informal manufacturing sectors (Timmer and de Vries, 2015). In contrast, INDSTAT 2 only includes data for formal sector firms in manufacturing (UNIDO, 2020). Generally, industrial surveys focus on firms that meet certain registration criteria or exceed an employment size threshold. Therefore, we refer to the firms included in these surveys as registered (large) firms. Thus, the manufacturing employment and output data from the INDSTAT 2 database represent those of registered (large) firms. Conversely, to determine the manufacturing employment and output data of unregistered (small and informal) firms, following an approach by Diao et al. (2019), we subtract the manufacturing employment or output data of registered firms in the INDSTAT 2 dataset from the corresponding figures in the ETD for each year. The difference represents the employment or total manufacturing value added of unregistered (small and informal) firms. This approach allowed us to break down the aggregate data into manufacturing employment and output figures for registered firms and unregistered firms.

3.2 Empirical Model

The theoretical explanation for the existence of an inverted U-shape relationship between manufacturing activities and GDP per capita forms the foundation to formulate the empirical models estimated in this study. Throughout the development process as income and population increase, the share of manufacturing in GDP or total employment rises to a certain income threshold. Beyond this threshold, further income increases are accompanied by a decline in manufacturing output or employment share due to non-homothetic consumer preferences.

To determine if this inverted U-shape manufacturing-income relationship exists, the practice is to regress manufacturing share of output or employment as an indicator of the degree of industrialization against GDP per capita, GDP per capita square, population, and its squared term, all variables are log-transformed. Thus, this basic econometric model can be stated as:

$$ManShare_t = \alpha_0 + \alpha_1 \ln POP_t + \alpha_2 (\ln POP_t)^2 + \alpha_3 \ln GDPPC_t + \alpha_4 (\ln GDPPC_t)^2 + \epsilon_t \qquad \textbf{(1)}$$

Where $ManShare_t$ is manufacturing output or employment share at time t, α_0 is the constant term, $\ln GDPPC_t$ and $\ln(GDPPC_t)^2$ are the natural logarithm of GDP per capita and its squared value, $\ln POP_t$ and $\ln\ (POP_t)^2$ are the natural logarithm of population and its squared value, and $\in_t$ denotes the error term.

The starting point of our analysis involves estimating the econometric model stated above and examining whether manufacturing share of output or employment follows the theoretically predicted inverted U-shape relationship with GDP per capita. However, there are two econometric challenges to investigating whether manufacturing follows an inverted U-shape or not in equation (1). The first challenge concerns the appropriate approach for testing the presence of an inverted U-shape manufacturing-income relationship. Traditionally, the presence of an inversed U-shaped manufacturing-income relationship is confirmed, once the coefficient on GDP per capita is positive and significant (α_1 >0), and the coefficient of its squared term is negative and significant (α_2<0), in addition to the estimated turning point needs to be within the data range. However, Lind and Mehlum (2010) argued that the aforementioned procedure is a weak and deeply flawed test for an inverted U-shaped relationship. According to Lind and Mehlum (2010) to identify a true inverted U-shape manufacturing-income relationship over relevant data values, the test must identify whether the relationship is increasing at low values within the interval and decreasing at high values within the interval. They suggest a new test based on prior work by Sasabuchi (1980) which is available in STATA software as a community-contributed add-in package. Accordingly, in this study, we applied the Lind and Mehlum exact U test to examine the existence of a true inverted U-shape relationship between manufacturing activities and GDP per capita.

The second challenge in estimating the parameters of Equation (1) is that the dependent variable (i.e., manufacturing share of output or employment) is a bounded fractional response variable, thus, requiring an appropriate functional form specification. Using linear models for fractional outcomes is subject to the same drawbacks and pitfalls as those related to linear probability models (LPM) for binary outcomes. Papke and Wooldridge (1996) have identified several methodological issues that arise from using a standard linear model on this type of dependent variable. Firstly, the effect of an independent variable on the dependent variable is not constant throughout the possible range of values of the independent variable. Secondly, the predicted values of the dependent variable are not guaranteed to fit within the unit interval. As a result, appropriate functional form specification is required that addresses these two issues. Therefore, we tackled this issue by employing more appropriate estimation techniques (i.e., fractional logit regression model and beta regression model) that accommodate a fractional response variable.

Once the existence of a hump-shaped relationship between manufacturing activities and GDP per capita is confirmed, the next step involves calculating the level of GDP per capita at the turning point at which deindustrialization commenced. The point at which deindustrialization begins is crucial to understanding its nature and likely effects. Simply, using the estimated coefficients of our empirical model in Equation (1), we can calculate the level of GDP per capita at which the predicted curve reaches its maximum and starts to decrease. This means using simple algebra, we can then calculate this peak by taking the first derivative of the estimated equation and then equating it to zero, which is expressed as follows:

$$\frac{dManShare_t}{dGDPPC_t} = 0 = -\frac{\alpha_3}{2\alpha_4} \qquad \textbf{(2)}$$

The second and third objective of the study aims to examine industrialization or deindustrialization trends at the sector level and in an extension by the size of manufacturing firms using firm-level data gathered from industrial surveys respectively. To achieve these objectives, we estimate a regression model similar to our basic econometric model presented in Equation (1) which simultaneously controls for income and demographic effects. Specifically, to capture the patterns of industrialization or deindustrialization over time, now we follow Rodrik (2016) and include a period dummy variable in terms of decades dummy to baseline model states in Equation (1). The inclusion of a decade dummy allows us to examine whether manufacturing share of output or employment increases or decreases over time, beyond what can be explained by income and demographic trends.

Thus, the empirical model estimated for the purpose can be expressed as:

$$ManShare_t = \alpha_0 + \alpha_1 \ln POP_t + \alpha_2(\ln POP_t)^2 + \alpha_3 \ln GDPPC_t + \alpha_4(\ln GDPPC_t)^2 + \sum_T \gamma_T \, PER_T + u_t \qquad \textbf{(3)}$$

Where all variables are as defined in Equation (1). The only variable added is PER_T which stands for decades dummy for capturing different decades (i.e., 1970s, 1980s, 1990s, 2000s, and 2010s). Here the main variables of interest are the estimated coefficients on the decade dummies (γ_T) which measures the manufacturing share of each decade relative to the excluded 1960s decade.

In case they significantly differ from zero, they allow the identification of an upward shift (γ_T> 0) or downward shift (γ_T< 0) in the observed hump-shaped curve over time.

The fourth objective of the study sought to investigate the occurrence (risk) of premature deindustrialization in Ethiopia. For this purpose, in this study, two different empirical methods are applied one proposed by Rodrik (2016) and another by Taguchi and Tsukada (2021).

One approach to identifying deindustrialization episodes as premature or not is to see whether the hump-shaped manufacturing-income curve has shifted closer to its origin in recent periods. To examine the horizontal shift of the hump-shaped manufacturing-income curve in recent periods, which would indicate if the deindustrialization is premature or not, we follow Rodrik (2016) and estimate a regression similar to the one we used above for examining deindustrialization trends in the Equation (3). However, the difference here is that we drop the decade dummies and interact the natural log of GDP per capita and its squared term with post-1980s, post-1990s, and post-2000s dummies which are used to capture the horizontal shift of the curve in post-1980s, 1990s, and 2000s periods. These interaction period regressions specifically trace the change over time of the hump-shaped effect of GDP per capita on the manufacturing share. Thus, the interaction period regressions estimated for identifying whether the deindustrialization is premature or not based on the horizontal shift of the curve in the recent period, can be expressed as follows:

$$ManShare_t = \alpha_0 + \alpha_1 \ln POP_t + \alpha_2(\ln POP_t)^2 + \alpha_3 \ln GDPPC_t + \alpha_4(\ln GDPPC_t)^2 + \sum_T \varphi_{1T}\,[PostDum_T * \ln GDPPC_t] + \sum_T \varphi_{2T}[PostDum_T * \ln(GDPPC_t)^2] + v_t \qquad \textbf{\textit{(4)}}$$

Where all variables are as defined in Equation (1). The only variable added here is $PostDum_T$ which stands for post-1980s, post-1990s and for post-2000s dummy. The main variables of interest in this case are the magnitude and significance of the coefficient of the interaction terms. The coefficients of log GDP per capita and its squared term for both with and without interaction terms should be significant and display their expected positive and negative signs respectively. In addition, the magnitude of the coefficient of the interaction terms φ_{1T} and φ_{2T} has to be lower than the corresponding coefficient of log GDP per capita and its squared term without interaction terms α_3 and α_4.

However, the limitation of the above method is that it relies entirely on the assumption of the presence of an inverted U-shape manufacturing-income relationship. However, during the initial stages of industrialization, identifying clear inverted U-shaped relationships may be difficult. In such cases, the empirical approach stated in Equation (4) is not applicable.

To address this limitation and investigate the risk of premature deindustrialization regardless of the existence of the typical hump-shaped manufacturing-income relationship, our second empirical approach follows Taguchi and Tsukada (2021) and incorporates the latecomer index to the basic econometric model stated in equation (1). The latecomer index represents the development lateness of the latecomer's developing country (Ethiopia) and is calculated as the ratio of a latecomer country's GDP per capita (Ethiopia) to that of GDP per capita of a benchmark country (China) in a specific year. In this study, China is chosen as a benchmark country because it has become a global manufacturing hub and a top runner among late industrializers in terms of manufacturing value-added share in GDP or manufacturing employment share in total employment. Hence, the latecomer index is calculated as the ratio of the GDP per capita of Ethiopia to that of China in a specific year. The advantage of this approach is that the latecomer index facilitates the identification of downward shifts in the manufacturing-income relationship of latecomer economies, irrespective of the existence of a peak in the manufacturing ratio. For economies that have not yet reached their peak, a downward shift suggests an imminent peak at a lower manufacturing ratio and income stage, indicating the symptom and risk of premature deindustrialization. Thus, the empirical model estimated for the purpose which is formulated by including the latecomer index to the baseline model in Equation (1) can be expressed as:

$$ManShare_t = \alpha_0 + \alpha_1 \ln POP_t + \alpha_2 (\ln POP_t)^2 + \alpha_3 \ln GDPPC_t + \alpha_4 \ln(GDPPC_t)^2 + \gamma_1 LAC_t + \gamma_2 LAC_t * d90 + \gamma_3 LAC_t * d00 + \varepsilon_t \quad (5)$$

Where all variables are as defined in Equation (1). The only variables added here are LAC denotes the latecomer index, d90, and d00 which stands for post-1990 and post-2000 period dummies incorporated for capturing the effect of globalization. Here the key variable of interest for identifying premature deindustrialization risk is the latecomer index. The significance and sign of the coefficient of the latecomer's index (γ) is critical for identifying premature deindustrialization risk. Specifically, a significantly positive value of the latecomer index ($\gamma > 0$), a linkage of a later development of a country with a lower manufacturing ratio (a downward shift of manufacturing-income relationship) could be proof of the existence of premature deindustrialization risk. It is because under its downward shift of a latecomer, the latecomer would face a lower manufacturing share than that of the benchmark country when it reaches the same GDP per capita as that of the benchmark country, and it suggests that the manufacturing ratio of the latecomer would pick out at the lower level than that of the benchmark country.

3.3 Empirical Strategy

This study to achieve its objective employed a fractional logit regression, beta regression, OLS estimation, and the Lind and Mehlum exact U-curve test as part of its empirical strategy.

Justification for choosing the fractional logit/beta regression model: since our dependent variable is manufacturing output or employment share across all empirical models estimated, fractional logit regression/beta regression is an ideal estimation technique that accommodates a fractional response dependent variable. Thus, we utilized fractional logit regression/beta regression for estimating all empirical equations. For making a comparison we also estimated the empirical equations using a linear estimator (i.e., OLS).

4. Result and Discussion

This section focuses on presenting and elaborating on the results obtained from estimating the econometric model discussed earlier. This section is divided into four parts for presenting and discussing the study's results.

The first part presents and discusses the result obtained from examining industrialization or deindustrialization trends at the sector level using the share of manufacturing in national output and employment data. The second part details the regression results obtained from analyzing the patterns of industrialization or deindustrialization at the firms' level based on the size of manufacturing firms by distinguishing manufacturing firms into registered (large) and unregistered (small and often informal) firms. The third part is devoted to presenting and analyzing the result derived from the regression exercise aimed at investigating the occurrence of premature deindustrialization in Ethiopia, providing evidence on whether the stagnation of Ethiopia's manufacturing sector is due to premature deindustrialization or stalled industrialization. The last section discusses the results derived from investigating the determinants of manufacturing performance. To set the context for our analysis, we first examine the historical evolution of manufacturing share in national output and employment and its relationship with GDP per capita using simple distributive statistics tools.

4.1 Historical Trend of Industrialization

The first step toward understanding the patterns and trends of industrialization or deindustrialization is to map the share of manufacturing in the economic-wide GDP or employment. Table 1 presents the manufacturing output and employment share for selected years: 1961, 1970, 1980, 1990, 2000, 2010, and 2018. These years provide useful decadal demarcations that help relate the descriptive result to the regression analysis discussed later in this section. Additionally, Figures 1 and 2 illustrate the historical evolution of manufacturing share in national employment and output respectively, covering the period from 1961 to 2018.

Table 1: Trend of Manufacturing Share in GDP and Total Employment

Year	Manufacturing Employment Share in Total Employment	Real Manufacturing Value-Added Share in GDP
1961	1.47	1.35
1970	2.15	2.18
1980	1.92	2.67
1990	2.04	3.20
2000	3.60	4.05
2010	7.32	3.74
2018	9.55	5.69

Source: own computation using Groningen Growth and Development Center (GGDC) database

Figure 1 illustrates the historical evolution of the manufacturing employment share in total employment from 1961 to 2018. The manufacturing sector's employment share exhibits two distinct patterns over these periods (see Figure 1). For about closer to four decades (until the late 1990s), there was a phase of stagnation, with the manufacturing employment share not exceeding 3 percent. However, from the early 2000s onwards, manufacturing employment significantly increased, tripling its share in total employment. During the whole period under consideration (1961-2018) manufacturing employment share increased by 8.08% which raised from its share of 1.47% in 1961 to 9.55% in 2018. Although the manufacturing employment share saw substantial growth in the later decade, it remained largely stagnant for most of the period. Therefore, the historical trends show that the manufacturing employment share exhibits an overall increasing trend without a historical peak, but it does not show a clear sign of significant employment expansion since Ethiopia's manufacturing employment share, falls short of the average for Sub-Saharan African countries.

Figure 1: Trend of Manufacturing Employment Share in Total Employment (1961-2018)

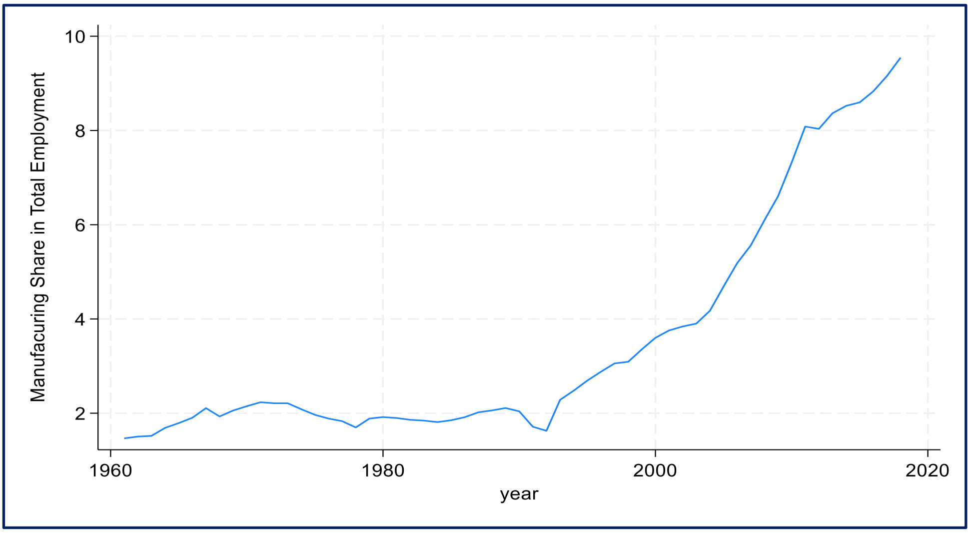
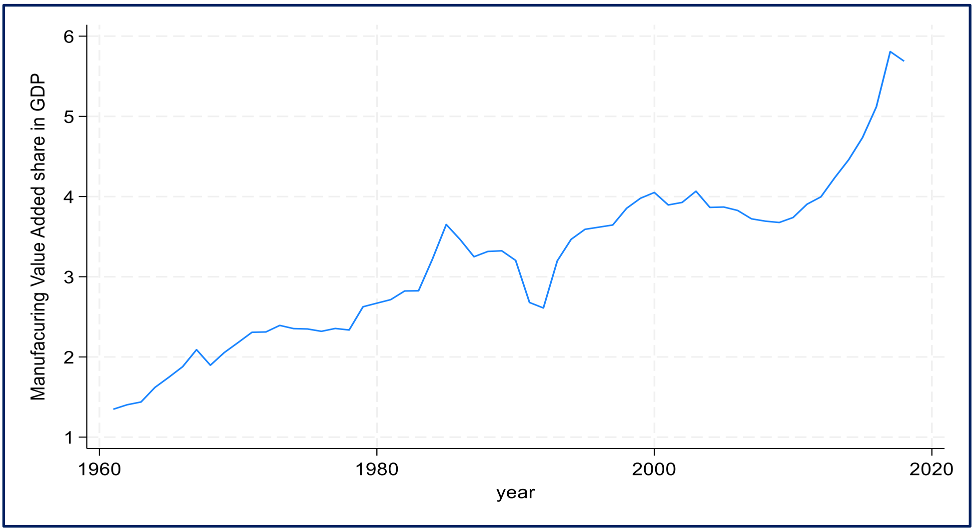


Figure 2 illustrates the historical trends of manufacturing real value-added share in GDP. Except during two periods (1985-1994 and 2001-2009) where the real manufacturing value-added share of GDP exhibited declining trends, the overall trend from 1961 to 2018 shows an upward trend. Over the entire period, the share of real manufacturing value added to GDP rose by 5.42%, climbing from 1.99% in 1961 to 7.41% in 2018. Notably, Figure 2 indicates that this share saw a sharp increase during the 2010s (2010-2017), characterized by a steeper positive slope compared to previous decades. Despite Ethiopia's manufacturing output share having grown and showing an upward trend, it remains significantly below the average for Sub-Saharan African countries, indicating no substantial evidence of expansion or contraction.

To sum up, the descriptive analysis reveals that both manufacturing employment and output share follow an increasing trend and have not reached a historical peak. However, despite the evolution of manufacturing share exhibits an increasing trend, especially during the recent decades, it remains below 12% for real manufacturing value added as a percentage of GDP and 8% manufacturing employment as a percentage of total employment, which are the averages for Sub-Saharan African countries. Thus, the result indicates neither significant industrialization nor significant deindustrialization patterns while measured in terms of both manufacturing share in total employment and output.

Figure 2: Trend of Manufacturing Real Value-Added Share in GDP (1961-2018)



Figures 3 and 4 display scatter plots of the shares of manufacturing in total employment and output respectively, as functions of GDP per capita with fitted quadratic trends. The fitted quadratic trend in Figure 3 highlights an inverted U-shaped relationship between manufacturing employment share and GDP per capita. Conversely, the scatter plot for manufacturing output shares in Figure 4 is suggestive of a rather U-shaped relationship between manufacturing real value-added share and GDP per capita.

Figure 3: Manufacturing Employment share versus GDP per capita

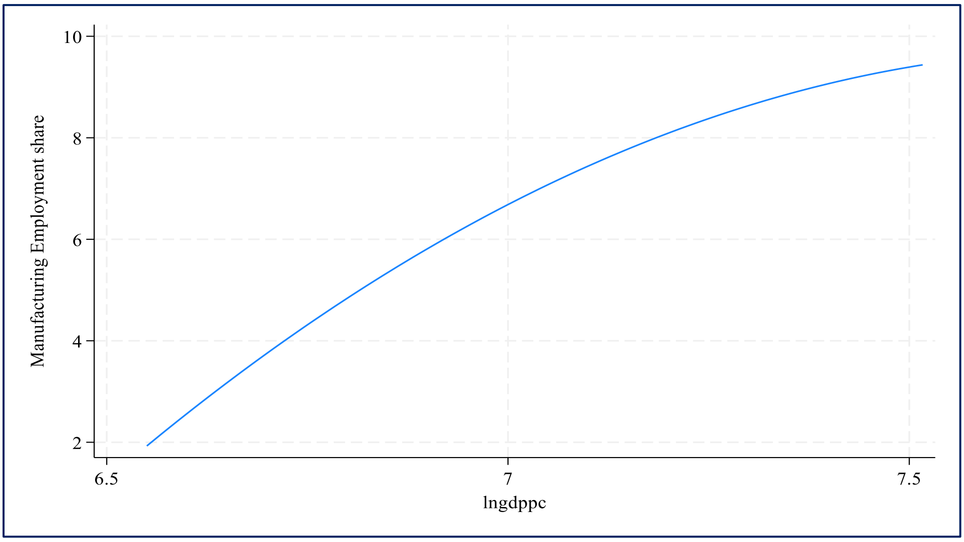


Figure 4: Manufacturing Output share versus GDP per capita

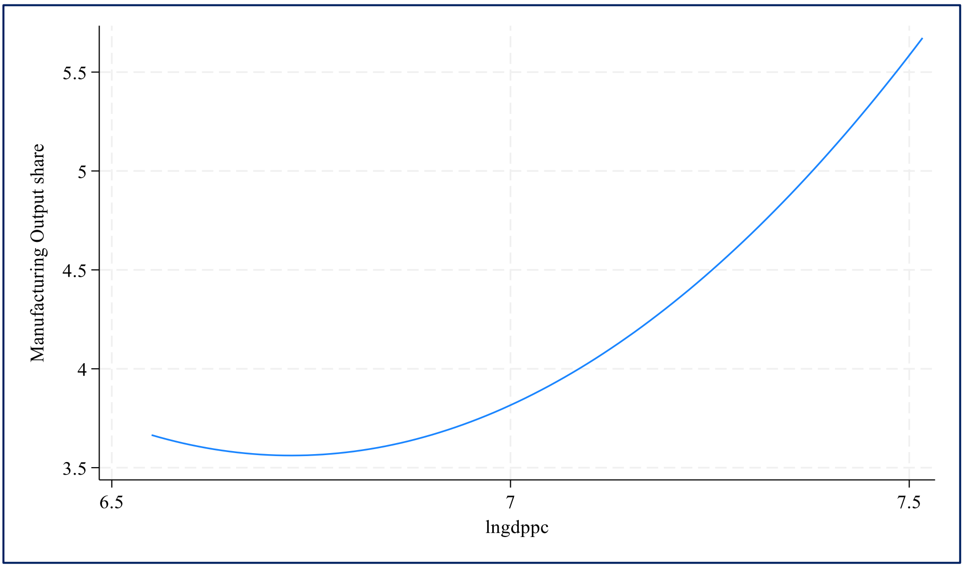


Table 2: Evidence on De (Industrialization): Manufacturing Employment Share 1961-2018

Variables	Fractional Logit Regression		OLS	
	ETD	EASD	ETD	EASD
Ln GDPPC	19.546***	22.620***	0.537***	-0.958***
	(1.908)	(2.799)	(0.071)	(0.114)
Ln GDPPC square	-1.408***	-1.630***	-0.038***	0.073***
	(0.137)	(0.201)	(0.005)	(0.008)
Ln POP	-48.656***	-50.586***	-1.921***	-1.614***
	(10.408)	(10.253)	(0.185)	(0.207)
Ln POP square	1.410***	1.465***	0.055***	0.047***
	(0.294)	(0.290)	(0.005)	(0.006)
1970S	0.079	0.080	0.002	-0.001
	(0.095)	(0.092)	(0.002)	(0.002)
1980S	-0.101	-0.094	0.000	-0.004
	(0.149)	(0.145)	(0.002)	(0.003)
1990S	-0.082	-0.060	0.000	-0.004
	(0.210)	(0.210)	(0.004)	(0.003)
2000S	-0.048	-0.040	-0.001	-0.004
	(0.229)	(0.231)	(0.004)	(0.003)
2010S	-0.033		0.004	
	(0.230)		(0.004)	
Intercept	347.659***	354.054***	14.812***	17.128***
	(90.332)	(89.107)	(1.544)	(1.705)
Lind and Mehlum U Test				
Slope at LB of Ln GDPPC	1.102***	1.268***	0.039***	-0.005
	(0.214)	(0.242)	(0.005)	(0.006)
The slope at UB of Ln GDPPC	-1.620***	-1.333***	-0.035***	0.111***
	(0.246)	(0.240)	(0.007)	(0.009)
U test statistics	5.140	5.23	4.970	0.93
	[0.000]	[0.000]	[0.000]	[0.180]
Extreme Point	6.941	6.940	7.057	6.587
In 2011 USD	$ 1034.177	$ 1031.838	$ 1161.029	$ 725.660
95% CI, Delta Method	[6.805, 7.078]	[6.831, 7.048]	[6.952, 7.162]	[6.516, 6.659]
95% CI, Fieller Method	[6.806, 7.077]	[6.824, 7.053]	[6.813, 7.078]	[6.495, 6.649]
Observation	58	55	58	55

Notes: Robust standard errors are in parentheses. *, ** and *** denotes statistical significance at 10%, 5% and 1% respectively. LB and UP denote the lower boundary and upper boundary respectively. The Fieller method follows an inverse test to construct a confidence interval for the ratio of normally distributed statistics. For U-test this method is preferred.

4.2 Econometric Analysis of De (Industrialization)

The previous section highlighted the historical trends of manufacturing share in national employment and output and their relationship with GDP per capita. This section presents econometric evidence on industrialization or deindustrialization trends in Ethiopia by estimating the empirical model in equation (3) which simultaneously controls for income and demographic effects and includes decade dummies (for the 1970s, 1980s, 1990s, 2000s, and 2010s). Table 2 reported the estimated results obtained using the manufacturing employment share in total employment as the dependent variable.

The second column reported our baseline results estimated using our preferred method (fractional logit regression, which accommodates a dependent variable taking a value between 0 and 1) and our primary data source, the historically linked Economic Transformation Databases (ETD). To ensure the robustness of the result, we supplement this data with the Expanded Africa Sectoral Database (EASD). The third column displays this result obtained using EASD, estimated with the same fractional logit regression model. The fourth and fifth columns present results obtained using the same data sources but estimated with the standard linear model (OLS estimation) for comparison. We also estimated the empirical equation using the beta regression model. However, those results are not reported here because they are almost identical to the result obtained from fractional logit regression, making it redundant to include them.

It is seen from Table 2 that, irrespective of the data source and estimation technique utilized, the estimated coefficient of the natural log of GDP per capita and its squared term are highly statically significant, displaying their expected positive and negative signs, respectively. Furthermore, the Lind-Mehlum exact U-curve test confirms the presence of an inverted U-shaped relationship between the manufacturing employment share and GDP per capita, with a turning point at a GDP per capita of $1,034.17 (2011 USD). An inverted U-shape relationship between manufacturing employment share and GDP per capita underscores employment deindustrialization.

The primary variables of interest are the coefficients of the period dummies, which represent the size of manufacturing share during each decade relative to the excluded 1960s decade. The results indicate that, after controlling for income and demographic trends, the estimated coefficients for the period dummies are statistically insignificant for all decades across all the estimated models, despite being positive for the 1970s and negative for other decades. This implies that there has been no statistically significant change in the manufacturing employment share in relative terms since the 1960s. However, it does not mean that Ethiopia's manufacturing employment share has not declined between 1961 and 2018. Instead, it suggests that the general downward direction or deindustrialization is well explained by income and demographic trends, with no deindustrialization left to be accounted for by time trends. To sum up, the existence of an inverted U-shape relationship between manufacturing employment share and GDP per capita across all estimated models suggests employment deindustrialization. However, the regression analyses using various data sources and estimation techniques consistently show that the coefficients for the period dummies are not statistically significant. This indicates there has been neither much nor less deindustrialization since the 1960s.

Table 3 reported the estimated results obtained using the manufacturing real value-added share in GDP as the dependent variable. Columns 2-3 show the results from the fractional logit regression model, while columns 4-5 display the results obtained using OLS estimation techniques. Our baseline results, which are estimated using our preferred fractional logit regression and primary data source ETD, are reported in the second column of Table 3.

Table 3 shows that irrespective of the data source and estimation method, the estimated coefficients for the period dummies are negative across all decades. However, these coefficients are statistically significant only for the 1990s and 2010s, suggesting a declining trend in manufacturing output share during these decades. Specifically, the result suggests that controlling for income and demographic trends, the manufacturing output share is 1.02% lower in the 1990s and 1.5% lower in the 2010s relative to the excluded 1960s, whereas the manufacturing output shares in the 1970s, 1980s, and 2000s are not significantly different from the 1960s decade.

Table 3: Evidence on De (Industrialization): Manufacturing Output Share 1961-2018

Variables	Fractional Logit Regression		OLS	
	ETD	**EASD**	**ETD**	**EASD**
Ln GDPPC	-15.077***	-8.005**	-0.791***	-0.340*
	(2.760)	(4.156)	(0.156)	(0.188)
Ln GDPPC square	1.113***	0.586**	0.058***	0.025*
	(0.197)	(0.302)	(0.011)	(0.0137)
Ln POP	32.470***	32.785***	0.915**	0.918***
	(8.748)	(8.228)	(0.358)	(0.326)
Ln POP square	-0.894***	-0.904***	-0.025**	-0.025***
	(0.248)	(0.233)	(0.010)	(0.009)
1970S	-0.043	-0.028	-0.002	-0.001
	(0.070)	(0.068)	(0.002)	(0.003)
1980S	-0.078	-0.059	-0.003	-0.002
	(0.100)	(0.098)	(0.003)	(0.004)
1990S	-0.248*	-0.230*	-0.010*	-0.009
	(0.0135)	(0.134)	(0.006)	(0.006)
2000S	-0.219	-0.198	-0.009	-0.008
	(0.154)	(0.152)	(0.007)	(0.006)
2010S	-0.312*		-0.015*	
	(0.168)		(0.008)	
Intercept	-246.390***	-272.682***	-5.637**	-7.165***
	(73.442)	(69.672)	(2.822)	(2.631)
Lind and Mehlum U Test				
Slope at LB of Ln GDPPC	-0.493**	-0.322*	-0.029***	-0.018**
	(0.227)	(0.246)	(0.010)	(0.010)
The slope at UB of Ln GDPPC	1.659***	0.614**	0.083***	0.022*
	(0.261)	(0.312)	(0.101)	(0.015)
U test statistics	2.18	1.31	3.39	1.46
	[0.0168]	[0.098]	[0.001]	[0.0749]
Extreme Point	6.771	6.825	6.802	6.909
In 2011 USD	$ 875.544	$ 920.0576	$ 899.998	$ 1001.245
95% CI, Delta Method	[6.620, 6.922]	[6.583, 7.067]	[6.680, 6.925]	[6.692, 7.128]
95% CI, Fieller Method	[6.574, 6.909]	$[-\infty, 8.157]$	[6.682, 6.902]	$[-\infty, \infty]$
Observation	58	55	58	55

Notes: Robust standard errors are in parentheses. *, ** and *** denotes statistical significance at 10%, 5% and 1% respectively. LB and UP denote the lower boundary and upper boundary respectively. The Fieller method follows an inverse test to construct a confidence interval for the ratio of normally distributed statistics. For U-test this method is preferred.

The estimated coefficients for the natural logarithm of GDP per capita and its quadratic term are highly statistically significant, but arrived with unexpected negative and positive signs, respectively. It is evident from Table 3 that the Lind-Mehlum U-shape test rejects the null hypothesis of an inverse U-shape or monotonic relationship, confirming that the true relationship between GDP per capita and manufacturing output share is U-shaped. This implies that at lower income levels, increases in GDP per capita are associated with a decrease in manufacturing output share until a certain threshold is reached; beyond this threshold, further increases in GDP per capita lead to a rise in manufacturing output share. This finding is inconsistent with Engel's law but aligns with similar studies on African countries. For instance, our results corroborate those of Mijiyawa (2017), who also identified a U-shaped relationship between the manufacturing share of GDP and per capita income in Africa. According to Mijiyawa, this relationship characterizes less competitive countries in a highly competitive and globalized world. In such countries, rising per capita income is likely to increase demand for manufactured goods, which is often met by increased imports, thereby reducing the country's manufacturing share of GDP.

To sum up, when industrialization is measured in terms of manufacturing real value-added share in GDP, deindustrialization is not evident across all the estimated models. Instead, the result merely shows a decline in the manufacturing output share in the 1990s and 2010s decade compared to the 1960s.

4.3 Evidence of De (Industrialization) at Firm Level: Manufacturing in Registered and Unregistered Firms for the Period (1990-2015)

Thus far, we investigated the patterns of industrialization or deindustrialization using sectoral employment or output data. Using aggregate sectoral data, we find employment deindustrialization but we find neither output industrialization nor output deindustrialization. As it is known Ethiopia's manufacturing sector is characterized by the existence of a very large number of small, typically informal enterprises that produce low-value and low-technology products for the local market and a small number of large firms that account for the bulk of manufacturing output. Various scholars suggest that industrialization in Africa relates to the expansion of small-scale manufacturing firms (Diao et al. 2021; Mensah 2020). Given the unique characteristics of Ethiopia's manufacturing, this study questions: whether industrialization or deindustrialization is more related to the expansion or contraction of large (registered) versus small often informal (unregistered) manufacturing firms. To find an explanation for this important question, in this section, we extend our analysis to examine the patterns of industrialization or deindustrialization conditional on the size of manufacturing firms using firm-level data gathered from industrial surveys.

For this analysis, we used the UNIDO INDSTAT2 Database and the Economic Transformation Database (ETD). The ETD manufacturing data is largely based on population census data and so covers manufacturing in both the formal and informal sectors (Timmer, de Vries, and de Vries, 2015). By contrast, INDSTAT2 records data for formal sector firms in the manufacturing sector (UNIDO, 2020). Accordingly, we refer to firms in industrial surveys as registered (large) firms. To separate data for unregistered (small and informal) firms, following Diao et al. (2019), we subtract the total manufacturing employment and value-added of registered firms in INDSTAT2 from the ETD totals for each year. This residual represents the data for unregistered firms. This approach allows us to classify manufacturing firms into registered and unregistered firms.

Thus, we estimate the empirical model stated in equation (3) to examine industrialization or deindustrialization trends based on firm size for both registered (or large) and unregistered (or small often informal) manufacturing firms. Table 4 reported the estimated result which is used for examining industrialization or deindustrialization trends at registered and unregretted firms measured in terms of manufacturing employment share reported in columns 2-3 and manufacturing output share reported in columns 4-5 of Table 4 respectively.

The second column of Table 4 displays the result for the manufacturing employment share of registered (large) firms. As can be seen from the table, conditional on income and demographic trend, the period dummies are negative for both decades, but only significant for the 2000s suggesting a decline in the manufacturing employment share of registered firms during this decade. However, the reduction is only fractional specifically manufacturing employment share of registered (large) firms were shirked by 0.03% in the 2000s decade compared to the 1990s.

The estimated coefficient of the natural log of GDP per capita and its quadratic term are highly statistically significant but arrived with unexpected negative and positive signs, respectively. Furthermore, the Lind Mehlum appropriate U-shape test confirms the true relationship between the manufacturing employment share of registered firms and GDP per capita is U-shaped.

The third column of Table 4 reported the result for the manufacturing employment share of unregistered (small typically informal) manufacturing firms. After controlling for income and demographic trends, the estimated coefficient of the period dummy for the 2010s decade is positive and statistically significant suggesting employment industrialization or employment expansion in unregistered firms during this decade. Specifically, the result shows that manufacturing employment share of unregistered or small and informal firms is 0.6% higher in the 2010s decade relative to the 1990s. The estimated coefficients of the natural log of GDP per capita and its squared term are highly significant and display their expected positive and negative signs respectively. The Lind Mehlum exact U-shape test confirms the presence of an inverted U-shaped relationship between the manufacturing employment share of unregistered firms and GDP per capita with a turning point at GDP per capita of $1,021.99 (in 2011 USD).

The fourth column displays the result for the manufacturing output share of registered firms. After controlling for income and demographic effect, the period dummies are positive for both decades, but statistically significant only for the 2000s suggesting output industrialization (or expansion) in registered firms during this decade. Specifically, the result indicates the manufacturing output share of registered firms is 0.4% higher during the 2000s decade relative to the 1990s. The result suggests that registered (large) firms experienced output industrialization in the 2000s. Moreover, the Lind Mehlum U-curve test suggests that the true relationship between the manufacturing output share of registered firms and GDP per capita is a monotonically increasing curve.

Table 4: Regression on Manufacturing Employment and Output Share in Registered and Unregistered Firms for the Period (1990-2015)

	Manufacturing Employment Share		Manufacturing Output Share	
Variables	**Man Emp. Share of Registered Firms**	**Man-Emp. Share of Unregistered Firms**	**Man-Output Share of Registered Firms**	**Man. Output Share of Unregistered**
ln GDPPC	-0.128***	0.738***	-0.829***	-0.018
	(0.033)	(0.187)	(0.185)	(0.033)
Ln GDPPC square	0.010***	-0.053***	0.066***	0.001
	(0.002)	(0.014)	(0.014)	(0.003)
ln POP	-0.171	-1.961	6.689***	1.280***
	(0.121)	(1.646)	(2.353)	(0.423)
ln POP square	0.005	0.057	-0.187**	-0.036***
	(0.003)	(0.046)	(0.066)	(0.012)
2000s	-0.0003**	-0.002	0.004**	0.001
	(0.000)	(0.002)	(0.003)	(0.000)
2010s	-0.001	0.006*	0.002	0.001
	(0.001)	(0.004)	(0.004)	(0.001)
Intercept	1.964*	14.336	-57.175	-11.371***
	(1.014)	(14.336)	(20.895)	(3.738)
Lind and Mehlum U Test				
Slope at LB of ln GDPpc	-0.003**	0.040**	0.035	0.001
	(0.001)	(6.930)		(0.003)
Slope at UB of ln GDPpc	0.013***	-0.045**	0.141	0.002***
	(0.004)	(0.023)		(0.005)
U test statistics	3.46	1.94		0.15
	[0.001]	[0.033]		[0.442]
Extreme Point	6.695	6.930	6.282	6.706
In 2011 USD	$808.741	$1021.98 8		$817.275
95% CI, Fieller Method	[6.623, 6.809]	[6.707, 7.413]	[5.837, 6.561]	[]
Observation	26	26	26	26
Remark	U-shape	Inverse U-shape	Monotone	Monotone

Notes: Robust standard errors are in parentheses. *, ** and *** denotes significance level at 10%, 5% and 1% level of significance respectively. LB and UP denote the lower boundary and upper boundary respectively. For U-test the Fieller method is preferred.

The final column reports the result for the manufacturing output share of unregistered firms. Conditional on income and demographic effect, the estimated coefficients for period dummies are statistically insignificant for both decades. This implies that there has been neither significant output industrialization nor output deindustrialization trend in unregistered firms since the 1990s. Furthermore, the Lind Mehlum U-curve test reveals the fact that the true relationship between the manufacturing output share of unregistered firms and GDP per capita is monotone.

To summarize, the findings identified a trend of employment deindustrialization and output industrialization in registered or large firms. These contrasting trends suggest a potential productivity effect. Despite being more productive and contributing significantly to manufacturing output in Ethiopia, large firms have a minimal impact on job creation for both unskilled and skilled labor. This limited job creation may be due to large firms' heavy investment in adaptation of labor-saving technologies. According to Oqubay (2018), the poor employment performance in Ethiopia's manufacturing sector is likely caused by the high capital intensity of large firms, the intense pressure to boost productivity, and the decline of public sector enterprises. Our findings align with the reality on the ground and are supported by related empirical studies, such as those by Diao et al. (2021), who also noted productivity growth without a corresponding increase in employment by large firms in Ethiopia and Tanzania. Conversely, we observed significant employment industrialization in unregistered (small and informal) firms, though there was neither output expansion nor output contraction in these firms. This study highlights that while small and informal enterprises dominate in number and significantly contribute to job creation in Ethiopia's manufacturing sector, they do not show substantial output growth. This is mainly due to their limited capital and use of traditional technology, leading to a noticeable productivity gap in unregistered firms. Our results are consistent with other studies in Africa that found employment industrialization linked to the expansion of small typically informal manufacturing firms whereas output industrialization is led by large firms (Diao et al., 2021; Kruse et al., 2022; Mensah and Szirmai, 2018; de Vries et al., 2020).

4.4 Evidence of Risk of Premature Deindustrialization

Our regression analysis so far focuses on examining industrialization or deindustrialization trends specifically the vertical shift of the manufacturing-income curve. And we have documented deindustrialization in terms of manufacturing employment share. However, the result does not show whether the deindustrialization was premature or not. So, our empirical exercise in this section aimed to identify (characterize) whether deindustrialization is premature or not. To do so we utilized two different empirical methods. One approach to identify deindustrialization as premature or not is to examine whether the hump-shaped manufacturing-income curve has shifted closer to its origin in recent periods. Accordingly, our first approach closely follows Rodrik (2016) and examines whether the hump-shaped manufacturing-income curve has recently shifted closer to its origin, which would indicate if the deindustrialization is premature or not by estimating the empirical model stated in equation (4). Table 5 reported these results obtained by running a regression with interaction terms which can be used to explore the occurrence of premature deindustrialization in Ethiopia.

The dependent variable is manufacturing employment share since we have documented a hump-shaped manufacturing-income relationship (deindustrialization) only in terms of manufacturing employment share from our previous empirical results. It can be seen from Table 5, that the estimated coefficients of the natural log of GDP per capita and its squared term for both without and with interaction term are statistically highly significant and display their expected sign across all periods used as a breakpoint (i.e., the 1980s, 1990s, or 2000s). Furthermore, the magnitude of the coefficients with interaction term (for the post-1980s, post-1990s, and post-2000s) is lower than without interaction term suggesting manufacturing employment share peaks at a lower level of GDP per capita in recent period. However, this is only a necessary condition to declare that the hump-shaped curve is moving closer to its origin in recent periods.

Table 5: Evidence of Premature Deindustrialization: First Approach

Variables	Dependent Variable: Manufacturing Employment share		
	1980s	**1990s**	**2000s**
ln GDPPC	17.494***	17.303***	17.287***
	(1.873)	(1.809)	(1.827)
ln GDPPC square	-1.113***	-1.132***	-1.200***
	(0.144)	(0.137)	(0.139)
ln POP	-80.452***	-77.182***	-74.489***
	(6.202)	(5.734)	(11.641)
ln POP square	2.303***	2.214***	2.146***
	(0.174)	(0.163)	(0.333)
ln GDPPC x1980s	2.354***		
	(0.384)		
ln GDPPC square x1980s	-0.342***		
	(0.055)		
ln GDPPC x1990s		1.912***	
		(0.306)	
ln GDPPC square x1990s		-0.280***	
		(0.045)	
ln GDPPC x2000s			1.014**
			(0.461)
ln GDPPC square x2000s			-0.154**
			(0.070)
Intercept	630.915***	603.247***	580.241***
	(55.215)	(51.318)	(101.699)
Observation	58	58	58

Notes: Robust Standard errors are reported in parentheses. *, ** and *** denotes statistical significance at 10%, 5% and 1% respectively.

As a sufficient condition, we calculated the level of GDP per capita at which manufacturing employment share peaks for both pre-and post-1980s, 1990s, and post-2000s periods which is reported in Table 6. As is seen from Table 6, the level of GDP per capita at which manufacturing employment share peaks in the post-1980s, 1990s, or post-2000s is much lower than the corresponding GDP per capita level at which manufacturing employment share peaks before the 1980s, 1990s, and 2000s periods, indicating that manufacturing employment share peaks at a lower level of GDP per capita in recent periods (in the post-1980s, 1990s or post-2000s) periods. Furthermore, we computed the 95% confidence intervals for natural log GDP per capita at which manufacturing employment shares peaks using the delta method for each of the pre-and post-1980s, 1990s, and 2000s periods. It is evident from Table 6, that the bands for the peak do not overlap across all periods used as a breakpoint, suggesting that the post-1980s, 1990s, or post-2000s shift of the hump-shaped manufacturing curve towards the origin is statistically significant, thereby highlighting the existence of premature deindustrialization risk in terms of manufacturing employment structure. However, the limitation of these results which prevents us from concluding is that the calculated GDP per capita level at which manufacturing employment peaks in the post-1980s, the 1990s, and 2000s periods is not with the interval of the data range/ actual data. Therefore, we hardly found robust evidence to conclude that the deindustrialization observed while measured in terms of manufacturing employment share is occurring prematurely.

Table 6: Peak level of Industrialization for Pre- and Post-1980, 1990 and 2000

	Pre-1980s	Post-1980s	Pre-1990s	Post-1990s	Pre-2000s	Post-2000s
ln GDP per capita at the peak	7.85	3.43	7.64	3.41	7.20	3.30
GDP per capita at the peak in 2011$	$2580.55	$31.11	$2081.23	30.55	$1339.43	27.16
95% CI, Delta Method	[7.41, 8.29]	[3.41, 3.45]	[7.31, 7.96]	[3.37, 3.46]	[6.92, 7.47]	[3.25, 3.35]

Source: own computation using STATA Version 18.0

One limitation of the first empirical approach utilized above is that it relies entirely on the assumption of the presence of an inverted U-shape manufacturing-income relationship. However, during the initial stages of industrialization, identifying clear inverted U-shaped relationships may be difficult. For instance, in our cases, we did not observe an inverted U-shaped curve while we measured the degree of industrialization in terms of manufacturing value-added share of GDP. In such cases, the first approach is not applicable.

To address this limitation, our second approach follows Taguchi and Tsukada (2021) and adopts the latecomer index to explore the risk of premature deindustrialization by estimating the empirical model stated in equation (5). The advantage of this approach is that the adaptation of the latecomer index in the empirical model facilitates the identification of downward shifts in the manufacturing-income relationship of latecomer countries (Ethiopia), regardless of the presence of a peak in the manufacturing ratio (manufacturing employment or output share). The latecomer index measures the degree of development lateness of the latecomer's country and is calculated as the ratio of a latecomer country's (Ethiopia) GDP per capita to that of a benchmark country in a specific year (in this study, we chose China as the benchmark for calculating the latecomer index).

The results from estimating the empirical model in equation (5), which integrates the latecomer index into the basic econometric model of equation (1), and used to examine the risk of premature deindustrialization regardless of the presence of a peak in manufacturing share, are shown in Table 7. Table 7 provides these results with three different estimations: (a) estimates the latecomer's index without any interaction terms, estimation (b) includes a specification where the post-1990s dummy interacts with the latecomer's index, and estimation (c) includes both post-1990s and post-2000s dummies interacting with the latecomer's index. The second, third, and fourth columns of Table 7, present the results obtained using manufacturing employment share as the dependent variable.

It is seen from Table 7 that, when manufacturing employment share is used as a dependent variable the estimated coefficient of the natural log of GDP per capita and its quadratic term are highly statically significant, displaying the expected positive and negative signs across all estimations (a-c), respectively. Furthermore, the Lind-Mehlum exact U-curve test confirms the presence of an inverted U-shaped relationship between the manufacturing employment share and GDP per capita, across all three estimations.

Here, the key variable of interest is the coefficient of the latecomer index. Specifically, a significantly positive value of the latecomer's index coefficient (γ), i.e., a linkage of a later development of a country with a lower manufacturing ratio (a downward shift of manufacturing-income relationship) could be proof of the existence of premature deindustrialization risk.

Table 7 clearly shows that the estimated coefficient of the latecomer's index, without any dummy as a cross term, is positive and highly significant across all estimations (a-c). This positive and highly significant coefficient of the latecomer's index suggests a link between a later development phase of a country and a lower manufacturing employment share, indicating a downward shift in the manufacturing-income relationship and highlighting the existence of premature deindustrialization risk in terms of manufacturing employment share. However, the coefficients of the latecomer's index with interaction term are still positive but not significant. In summary, the consistently positive and highly significant coefficient of the latecomer's index without a time dummy across all three specifications (a-c) indicates the presence of premature deindustrialization risk in terms of manufacturing employment structure.

The fifth, sixth, and seventh columns present the estimated results using the manufacturing output share as the dependent variable. Table 7 shows that the coefficients of the latecomer's index are negative and statistically insignificant across all three estimations (a-c), indicating no evidence of premature deindustrialization risk in terms of manufacturing output share.

In summary, the findings from both empirical approaches suggest the presence of premature deindustrialization risk in terms of manufacturing employment share. However, there is no evidence of deindustrialization when industrialization is measured in terms of manufacturing real value-added share in GDP. The deindustrialization observed in terms of manufacturing employment share, without a similar trend in terms of manufacturing real value-added share in GDP is scarcely pronounced as premature deindustrialization. Therefore, taking together these results, we hardly found strong and consistent evidence that Ethiopia is deindustrializing prematurely. Instead, the appropriate interpretation of the result suggests that the stagnation of Ethiopia's manufacturing sector is due to stalled industrialization rather than premature deindustrialization.

Table 7: Evidence of Premature Deindustrialization: Second Approach

Variables	Manufacturing employment share			Manufacturing output share		
	a	b	c	a	b	c
ln GDPPC	18.03***	18.58***	18.54***	-9.07***	-14.71***	-14.71***
	(1.58)	(2.49)	(2.57)	(2.43)	(2.07)	(2.05)
ln GDPPC square	-1.31***	-1.34***	-1.34***	0.68***	1.07***	1.07***
	(0.11)	(0.17)	(0.17)	(0.17)	(0.15)	(0.14)
ln POP	-39.26***	-39.37***	-39.72***	26.88***	28.92***	28.92***
	(5.60)	(5.50)	(5.79)	(4.87)	(4.80)	(4.82)
ln POP square	1.17***	1.17***	1.18***	-0.75***	-0.80***	-0.80***
	(0.15)	(0.15)	(0.16)	(0.13)	(0.13	(0.13)
LAC	1.34***	1.33***	1.37***	-0.31	-0.14	-0.14
	(0.33)	(0.33)	(0.40)	(0.41)	(0.34)	(0.39)
LAC x1990s		0.13	0.08		-1.05***	-1.05**
		(0.58)	(0.69)		(0.32)	(0.39)
LAC x2000s			-0.13			0.00
			(0.44)			(0.42)
Intercept	263.26***	262.39***	265.27***	-215.37***	-215.39***	-215.40***
	(50.77)	(50.39)	(53.73)	(42.78)	(43.91)	(44.27)
Lind and Mehlum U Test						
Slope at LB of	0.93***	0.98***	0.96***	-0.11	-0.66***	-0.66***
ln GDPPC	(0.12)	(0.26)	(0.32)	(0.19)	(0.18)	(0.21)
slope at UB of	-1.73***	-1.75***	-1.77***	1.29	1.53***	1.53***
ln GDPPC	(0.13)	(0.13)	(0.13)	(0.20)	(0.16)	(0.18)
U test	7.53	3.81	2.98	0.56	3.73	3.14
statistics	[0.00]	[0.00]	[0.00]	[0.28]	[0.00]	[0.00]
Extreme Point	6.91	6.92	6.91	6.63	6.86	6.86
In 2011 USD	$998.24	$1008.28	$999.25	$755.21	$945.56	$945.56
95% CI, Fieller Method	[6.85, 6.95]	[6.77, 7.01]	[6.70, 7.04]	[6.17, 6.79]	[6.73, 6.94]	[6.68, 6.98]
Observation	58	58	58	58	58	58

Notes: Robust standard errors are in parentheses. *, ** and *** denotes statistical significance at 10%, 5% and 1% respectively. LB and UP denote the lower boundary and upper boundary respectively. The Fieller method follows an inverse test to construct a confidence interval for the ratio of normally distributed statistics. For U-test this method is preferred.

5. Conclusion and Policy Implication

5.1 Conclusion

This study is motivated by the emerging pattern of structural change observed in developing economies like Ethiopia in recent decades. The historical dominance of agriculture in the national economy has been overtaken by the service sector while the structure and performance of the manufacturing sector remained in its doldrum which is a symptom signaling a risk of premature deindustrialization in Ethiopia. Despite there is concerns and claims among policymakers and researchers about the early deindustrialization of Ethiopia's economy on account of the stagnation of the manufacturing sector, compressive empirical studies on this issue are scarce. In light of this research gap, this paper investigates industrialization and deindustrialization in Ethiopia using the historically linked newly constructed Economic Transformational Database (ETD) for the period spanning from 1961 to 2018, and employing fractional logit regression, OLS estimation, and the Lind and Mehlum exact U-curve test as part of its empirical strategy.

The results from various empirical approaches, data sources, and estimation techniques consistently demonstrate an inverted U-shape relationship between manufacturing employment share and GDP per capita, underscoring employment deindustrialization. Additionally, the findings from the regression analysis investigating the occurrence of premature deindustrialization, suggest a risk of premature deindustrialization in manufacturing employment structure. However, no evidence of deindustrialization is found when industrialization is measured by manufacturing real value-added share in GDP. The observed deindustrialization in terms of manufacturing employment share, without corresponding trends in manufacturing output share, cannot be identified as deindustrialization. Therefore, these results do not provide conclusive and robust evidence that Ethiopia is deindustrializing prematurely. Instead, the appropriate interpretation of the result suggests that the sluggish performance of Ethiopia's manufacturing sector highlights stalled industrialization rather than premature deindustrialization.

In an extended analysis, we examined industrialization or deindustrialization trends by the size of manufacturing firms by distinguishing manufacturing firms into registered (large) and unregistered (small, often informal) firms using firm-level data from 1990-2015. The findings show that employment industrialization is driven by the expansion of small, typically informal firms whereas output industrialization is led by large (registered) firms.

5.2 Policy Implication

Since the 1950s, the Ethiopian government has implemented various industrial policies in pursuit of industrialization and economic structural transformation. This ambition to industrialize is quite understandable from a theoretical and historical perspective. However, unlike the experiences of early industrializers and economies in Eastern Asia, Ethiopia's impressive growth over the past decade and a half is not accompanied by the creation of quality manufacturing jobs or a visible structural transformation of the economy towards the industrial sector. The study's findings indicate that there has been no significant industrial development since the 1960s, as measured by the manufacturing sector's share of employment and output.

Despite the Ethiopian government's commitment to industrial development through putting in place a comprehensive industrial policy, industrialization remains an unfulfilled aspiration. While the country has significant potential, particularly in labor-intensive manufacturing, the challenges today are more formidable than in the past. Even it is disappointing while considering the economic cost of internal war in the north that devastated huge social infrastructures including factories valued at billions of dollars. This has disrupted the investment climate and discouraged new investment, negatively impacting the industrialization process.

The unresolved question in all these is whether Ethiopia should continue pursuing industrialization as a development strategy or consider other sectors for economic transformation and development. The findings of this paper do not conclusively indicate that Ethiopia is deindustrializing prematurely. Instead, the result suggests that the weak performance of Ethiopia's manufacturing sector points to industrial stagnation rather than premature deindustrialization. Therefore, the study's overall result is optimistic and suggests that the country has not yet run out of the opportunities manufacturing presents for development, thereby recommending that manufacturing remains crucial for creating quality jobs for the growing youth population and driving structural transformation. However, propelling manufacturing growth is not an easy task since Ethiopia's manufacturing is suffering from coordination failure.

First and foremost, ensuring peace, security, and political stability is fundamental for achieving any developmental goals of the nation. Without political stability, even the most carefully designed industrial policies are unlikely to succeed. Therefore, the government must prioritize resolving conflicts with different opposition groups through negotiation and dialogue, demonstrating a strong commitment to unity and development. Furthermore, given the current state of Ethiopia's economy, the government should prioritize resource allocation for rebuilding productive social and economic infrastructures, including factories damaged as a consequence of internal war.

Second, to unlock Ethiopia's industrialization potential and stimulate manufacturing growth a "big push" strategy is required. This approach involves substantial investment in key areas to address the binding constraints hindering industrial development. These interventions include investing in human capital development to enhance the skill and productivity of the industrial workforce, leveraging digital technology for modernizing services essential for manufacturing such as trade logistics, customs processes, and public services, and expanding infrastructure, particularly in energy, transportation, and port facilities. Additional efforts should focus on allocating substantial resources to research and development, fostering entrepreneurial innovation through competitive grants and awards, enhancing access to finance via innovative lending solutions, and fostering the development of the financial sector of the economy. Furthermore, targeted policy interventions to develop competitive national industrialists in selected strategic sectors are crucial to accelerating manufacturing growth.

Third, refining the design and implementation of industrial policies by learning from past experiences and shortcomings is essential for manufacturing breakthroughs. Industrial policy instruments should align with firms' needs and address sector-specific constraints. In this regard, the study's finding reveals that employment industrialization is related to the expansion of small, often informal firms whereas output industrialization is explained by large or registered firms. Specifically, manufacturing job growth, which is critically needed, is predominantly driven by small and often informal (unregistered) firms which are characterized by their low productivity and shorter survival rate. Conversely, manufacturing output growth or the bulk of manufacturing output is produced by a few large firms that are more productive but create fewer jobs due to the adaptation of labor-saving technology. In light of this, one important policy implication from the study is that the prospect for manufacturing-led growth hinges on the effectiveness of industrial policy intervention aimed at addressing firms' informality, stimulating the productivity of small and informal firms to survive and grow, along with enhancing labor absorption capacity and jobs creation by large firms. To achieve this the government must exert maximum integrated effort through collaboration with the academic community, development organizations, and the private sector to formalize informal firms and support the growth and transition of small and informal enterprises. This requires designing and implementing a set of complementary policy and reform measures including but not limited to: simplifying regulations for business registration and exit, reducing tax burden, providing affordable and flexible credit and lease finance facilities, offering access to working spaces, market linkage, delivering skill development training programs, extend social protection. These interventions must be informed by comprehensive research to understand the nature, causes, and dynamics of firm informality. A nuanced approach combining policy reforms and institutional adjustments will be essential to drive sustainable manufacturing growth and job creation. In addition, an appropriate institutional/legal framework should be established that imposes the necessary constraint structure to discourage firms from adopting inappropriate labor-saving technologies that hardly fit with the local context.

Lastly, Ethiopia's industrial policy, which heavily emphasizes exports and attracting foreign direct investment (FDI), tends to discourage domestic production and the growth of local firms. However, production for the domestic market is as important as exports, and the roles of foreign and domestic firms should be balanced. Therefore, Ethiopia's export-oriented industrialization strategy should be complemented by import-substitution industrialization, as they are mutually inclusive rather than independent approaches. An adequate incentive structure should be established to develop domestic industrialists, instead of focusing excessively on attracting FDI. Furthermore, expanding and enhancing initiatives like "Ethiopia Tamrit" is essential for driving growth in the manufacturing sector.

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The Effects of Climate Change on Crop Yield in Selected Zones of Oromia Region, Ethiopia

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Abstract

Climate variability and trends affect crop yields, and these are characterized as highly dependent on location, crop type, and irrigation. This paper evaluates climate impacts on barley, sorghum, and wheat yields in selected zones of Oromia region by employing extensive crop yield and climate datasets from 1995–2021. Through analyzing barley, wheat, and sorghum yields, the study aimed to characterize the inter-annual variability and identify the corresponding climate-related trends. The coefficient of variation (CV) was used to measure the dispersion of crop yields, indicating the variability across zones. The results obtained show that CV of barley yield ranged from 28.23% in Guji zone to 45.95% in Wollega, highlighting significant variations in barley yield variability. The trends in crop yield per hectare per year showed differences in the direction and rate of change in yields over 27-year period. An average air temperature and total precipitation during the Meher season were assessed, revealing high geographic variability in temperature and precipitation trends across zones. These climate trends can have vital implications on agricultural crop production by affecting yields, irrigation management, and other crop and soil management practices. Further, the climate explained yield variability (CEYV) ranged from 7% for wheat to 19.2% for sorghum. Again, observed higher temperatures have generally corresponded with reduced yields in barley and sorghum, whereas precipitation effects varied among different crops. These findings indicate the complexity of the interactions between climate and agricultural productivity. While climatic variables like temperature and precipitation play a significant role in dictating yield performance, this study underscores that they offer an incomplete explanation of yield variability—inviting additional research integrating broader data on agronomy, soil science, and socioeconomic factors.

Keywords: Climate variability, Climate impacts, Climate explained yield variability

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1. Introduction

Global agricultural productivity is shaped by the convergence of technological advancements, genetic innovation, climate variability, and adaptive agronomic practices. Over the past decade, research has emphasized the role of precision agriculture—incorporating technologies such as remote sensing, GPS-based machinery, and machine learning—in optimizing resource use and enhancing yield potential across various regions (Chlingaryan et al., 2018; Zhang et al., 2022). These technologies enable site-specific management, improving the efficiency of inputs like water and fertilizers, which is especially valuable in addressing yield gaps in regions with resource limitations.

At the genetic level, recent developments in gene-editing techniques, particularly CRISPR-Cas systems, have accelerated the creation of crop varieties with enhanced resilience to environmental stresses such as drought and heat. Studies show that gene-edited crops not only exhibit better yield stability but also require fewer resources, underscoring the potential of biotechnology to complement traditional breeding for climate resilience (Chen et al., 2019; Gao, 2021).

However, climate change remains a formidable challenge. In recent years, global meta-analyses have demonstrated the substantial impact of warming temperatures and changing precipitation patterns on crop yields, with yield reductions observed in key staples such as wheat, maize, and rice (Zhao et al., 2017; Tigchelaar et al., 2018). For instance, Zhao et al. (2017) quantified that every degree Celsius of warming could reduce global wheat yields by approximately 6%, illustrating the scale of adaptation required. These changes disproportionately affect smallholder farmers in regions like sub-Saharan Africa and South Asia, where adaptive capacity is constrained, thus heightening the risk of food insecurity (Rosenzweig et al., 2020).

Furthermore, localized studies emphasize that climate impacts are region-specific, necessitating tailored agronomic practices. For example, increased rainfall variability in the Sahel has compelled farmers to adopt drought-tolerant crops and alter planting dates (Rippke et al., 2016). Meanwhile, in temperate regions, extended growing seasons have introduced challenges related to pest management and crop maturity (Kistner et al., 2020).

This variability reinforces the importance of localized decision-making in fertilizer application, tillage, and irrigation practices to bolster resilience (Daryanto et al., 2017; Hatfield & Beres, 2023).

The Oromia region is an ideal location for studying the diverse impacts of historical climate on crop yields due to its vast geographical expanse and significant variations in environmental and crop developmental factors (CSA, 2018). This region contributes substantially to national agricultural production and economy, accounting for 43.72% of total pulses, 49.82% of oilseeds, 40.81% of root crops, and 21.79% of total fruit crop production. Additionally, it supplies 36.99% of the country's total vegetable yield and 49.35% of grain products for national consumption (CSA 2018). The Oromia region is also rich in water resources, with 63 rivers and 688 tributary streams, providing approximately 58 billion cubic meters of surface water, which accounts for half of the country's surface water resources. However, despite this abundance, only 5% of the irrigated land, approximately 1.7 million hectares, is utilized for agricultural production (CSA 2018). The estimated total irrigated land in the region is approximately 85,402 hectares, which is predominantly divided into traditional irrigation schemes (48,816 ha), small-scale irrigation (9,160 ha), and large-scale irrigation (27,426 ha) (CSA 2018). This unique landscape provides an excellent opportunity to investigate the relationship between climate impacts and crop yields, particularly regarding irrigation practices, which has not been extensively explored in the existing literature. Given the region's significant contribution to national food production and its exposure to climate variability, it is imperative to address various complex scientific questions (Foley et al., 2011). By doing so, we can provide valuable insights, scientific information, and data to inform policy and decision-making processes, as well as aid resource planners and managers at the national, regional, and local levels (Godfray et al., 2010). This research will enhance our understanding of the dynamics between climate and agricultural production, enabling the development of effective agricultural practices in response to changing climatic conditions. The study addresses the following questions:

1. What is the extent of variability in crop yields within the region, and what are the spatial patterns associated with climate variations?

2. How much of the overall variability in crop yields can be attributed to climate factors, specifically air temperature and precipitation, and what are the geographical patterns of this climate-related yield variability?
3. Which climate factor, either air temperature, precipitation, or both, has the greatest influence on spatial crop yield variability, and what proportion of regional food production is affected by it?
4. How do crop yields respond to fixed changes in air temperature and precipitation, and how does this sensitivity vary across different areas within the region?
5. What are the actual yield gains or losses experienced by each crop in response to climate variations across the region?
6. To what extent do climate-induced yield trends contribute to the overall yield trends observed in the region?

This manuscript analyses extensive datasets to answer the above questions for barley, sorghum, and wheat crops in the Oromia region during the period 1995–2021. In answering the above scientific questions, this manuscript serves to potentially enhance our knowledge on climate-crop performance interactions substantially in the light of recent work in the literature. First, this manuscript focuses on three important crops for the Oromia region, namely barley, sorghum, and wheat. While the past studies explore maize yield variability followed by teff, barley, sorghum, and wheat have not received enough attention in this direction. Secondly, our study addresses determination of actual historical climate impacts in terms of crop yield/production (scientific question 5) by quantifying sensitivity magnitudes of crop yields to unit changes in temperature and precipitation (scientific question 4). In addition, role of climate-induced yield trends relative to the overall yield trends observed was also evaluated by quantifying time equivalent of temperature and precipitation impacts on crop yields (scientific question 6). Addressing these questions is critical as there is limited scientific knowledge on these aspects. A greater emphasis has been placed in the literature to determining the changes in crop yield variability and the climate contribution to influence this variability (scientific questions 1, 2 and 3). Finally, our study assesses climate impacts during 1995–2021 (27 years). Overall, our study encompasses fundamental questions such as characterizing yield variability and climate trends to more complex ones as the climate-influenced crop yield gain/loss within a single comprehensive framework, which in itself is the novelty of the work.

2. Material and Methods

2.1 Crop Yield and Climate Datasets

Region-level crop yield datasets were obtained for barley, sorghum, and wheat for the period of 1995–2021 from the Federal Democratic Republic of Ethiopia Central Statistical Agency (CSA). The beginning date of the study period (1995) was based on the start of the state level crop yield records. The analysis on crop yield variability was limited to zones with data available for least 60% of the study period. Monthly weather dataset consisting of maximum air temperature, minimum air temperature, and precipitation were obtained from the FAO Climate Information Tool. The FAO datasets are subjected to rigorous quality assurance reviews. Historical monthly weather datasets for the period 1995–2021 were obtained for 8 zones of Oromia region.

2.2 Development of Region-Based Climate Data

For the purpose of exploration and investigation of impacts of climate on the agricultural crop yields, it is crucial that both datasets (climate and crop yields) are at the same spatial and temporal scales, hence rendering them suitable for inter-comparison. These scales have to be appropriate in terms of space and time so that the resulting climatic impacts are represented in a detailed, consistent, and relatable manner. In this study, a region has been chosen as an appropriate scale to investigate and report the findings. This is because several other sets of information such as commodity prices, crop yields, fertilizer inputs and management practices are reported on region-level basis. Thus, quantifying climate impacts on agricultural production on a region basis results in increased potential for the application of these findings by the state and federal agencies working in the disciplines of agriculture and natural resource conservation.

2.3 Trends in Climate and Crop Yields

We focused on the trends that occurred in crop yields and growing season climatic variables (average air temperature, T_{avg}, and precipitation, P) during the period of 1995–2021. Trends were calculated for region level barley, sorghum, and wheat yields *(kg ha^{-1} yr^{-1})* and region averaged T_{avg} ° *(°C yr^{-1})* and *P (mm yr^{-1})* during the crop growing season (Meher season) using linear regression analysis. Qualitatively, these trends in yield and climate can be realized as the direction of change in these values over the 27-year period, whereas in quantitative terms, the trends are slope of the linear regression analysis performed with yield or climate on the ordinate and the time (year) on the abscissa. This process resulted in to 24 regressions for yield (8 zones × 3 crops) and 16 regressions for climate (8 zones × 2 variables). The outcomes of these regression analyses, including both directions and magnitudes of the trends were represented using tables and plots, to better observe the trends in a spatial context, and acknowledge the extent of variability that occurs in both yield and climate change on spatial scales.

2.4 Estimation of Climate Contribution towards Crop Yields

A series of steps and computations were involved in quantifying the contribution of climate towards trends in crop yields (climate-driven yield trends). Since the climate dataset was complete in all regards (all 8 zones and all 27 years), the analyses were restricted by the availability of crop yield records. It was decided that the analyses be performed for only those zones which had continuous crop yield data for all years during the study period (1995–2021). Since the analysis was primarily statistical, missing data were interpolated in the analyses keeping in mind the potential errors it can introduce into the analyses. The following procedure outlines the constituent steps involved:

The region-level crop yields were detrended using linear regression, with crop yield as the dependent variable and time (year) as the independent variable. This was done to remove the effects of non-climatic variables from the raw time series of yield records. Primarily, the non-climatic variables include technological improvements, genetic advancements, and crop and soil management improvements. This step considers inter-annual sensitivity to climate/weather factors as a proxy for sensitivity to long-term changes in climate, which is widely accepted practice for scientific studies that have similar natures to ours. Detrending results in crop yield residuals (kg ha^{-1} yr^{-1}), which would be used in the further calculations.

Similarly, the region level climate variables (growing season Tavg (averaged for Meher season) and growing season total P (summed for Meher season) were detrended using each of the climate variables as the dependent variables and time as the independent variable. Consequently, this resulted in Tavg and P residuals *(°C yr^{-1} and mm yr^{-1}*).

Using multiple linear regression, the yield residuals were regressed against climate residuals. The purpose of this step was the evaluation of sensitivity of yields to individual climate variables. The resulting slope coefficients from these analyses represent yield increments per unit change (or sensitivity) in the *Tavg (kg ha^{-1} °C^{-1})* and *P (kg ha^{-1} mm^{-1})*. Also, the coefficient of determination (R2) for the regression provides information about what magnitudes of variability in yields can be explained by variability in climate (i.e., temperature and precipitation) for different zones (or climate explained yield variability, CEYV). Moreover, statistical significance of the impacts of individual climate variables on yields was also tested at 90% confidence interval.

The multiple regression coefficients derived from afore-explained steps were multiplied with the climate trends *(°C yr^{-1} or mm yr^{-1})* obtained during the 27-year period to derive the impacts of temperature and precipitation to yield trends (*kg ha^{-1} yr^{-1}*). Further, total change in yield during the study period that was attributed to climate was calculated by multiplying the obtained values by the number of study years (27).

Mean region-level yields during the study period were calculated to represent average levels of yields obtained in a particular region. The contribution of individual climate variables towards yield trends were represented (in percent) as the ratio of absolute change in climate-attributed yield to the region-average yield as well as region-average yield. This was done to represent the proportion of changes in yields due to climate trends relative to average yield of a region and whether the climate impact on yield was positive or negative.

Finally, the climate-induced yield trend was divided by overall yield trend for the period 1995–2021 for each relevant region to quantify the relative importance of climate in the overall yield trends.

3. Result

3.1 Variability and Trends in Crop Yield

In this section, we attempt to answer our first scientific question, that is where and by what magnitude have the crop yields varied inter-annually across zones during 1995–2021. To represent these changes, we used the coefficient of variation (CV), which is yield variability normalized by mean yields as a measure.

The result presented in Table 1 highlights the variability and trends in barley, wheat, and sorghum yield across different zones. The coefficient of variation (CV) is used to measure the dispersion of the yield data.

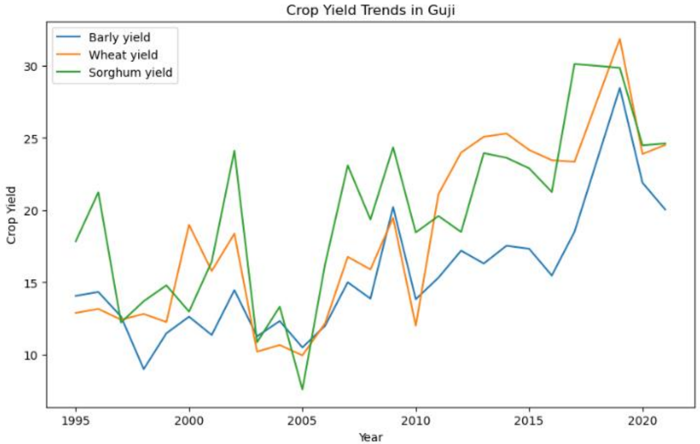
In terms of barley yield CV, Wollega, Borena and Jimma have the highest values at 45.95%, 44.59% and 41.53%, indicating a relatively high variability in barley yield. Guji and Bale have the lowest barley yield CV at 28.23% and 29.65%, suggesting a more consistent yield in comparison. The difference between the highest (Wollega) and lowest (Guji) barley yield CV values is approximately 17.72%, reflecting a notable variation in barley yield variability across zones. Similarly, for wheat yield CV, Jimma, Wollega and Borena have the highest values at 39.93%, 39.89% and 36.03%, implying a greater variability in wheat yield within those zones. Hararghe has the lowest wheat yield CV at 31.17%, indicating a more consistent yield. The difference between the highest (Jimma) and lowest (Hararghe) wheat yield CV values is around 8.76%, showing a moderate difference in wheat yield variability across zones. Regarding sorghum yield CV, Bale and Borena has the highest values at 38.90% and 34.81%, suggesting a significant variability in sorghum yield within those zones. Hararghe has the lowest sorghum yield CV at 27.30%, indicating a more consistent yield. The difference between the highest (Borena) and lowest (Hararghe) sorghum yield CV values is approximately 11.60%, highlighting variations in sorghum yield variability across zones.

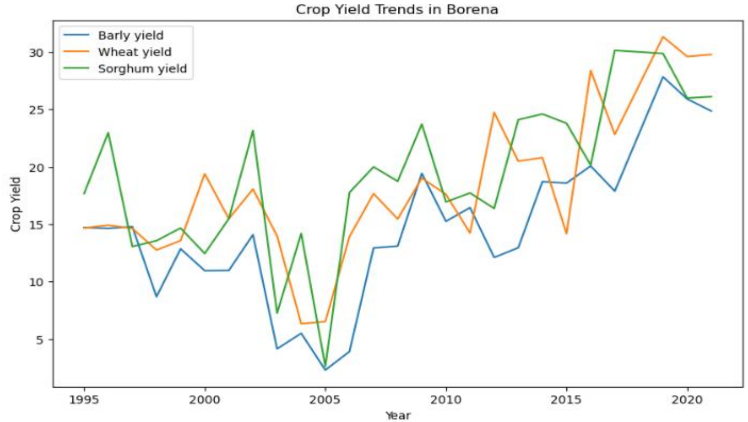
Additionally, the trends in yield are also mentioned in the table and Figure 1. These trends provide insight into the direction and rate of change in crop yield over time. The yield trend represents the change in yield per hectare per year over the 27 years. The yield trend is measured in quintal per hectare per year. For barley, the highest yield trend is observed in Arsi at 0.077 qt/ha/year, while the lowest yield trend is in Borena at 0.041 qt/ha/year. Similarly, for wheat, the highest yield trend is in Bale at 0.086 qt/ha/year, and the lowest yield trend is in Borena at 0.052 qt/ha/year. For sorghum, the highest yield trend is in Wollega at 0.091 qt/ha/year, and the lowest yield trend is in Borena at 0.057 qt/ha/year.

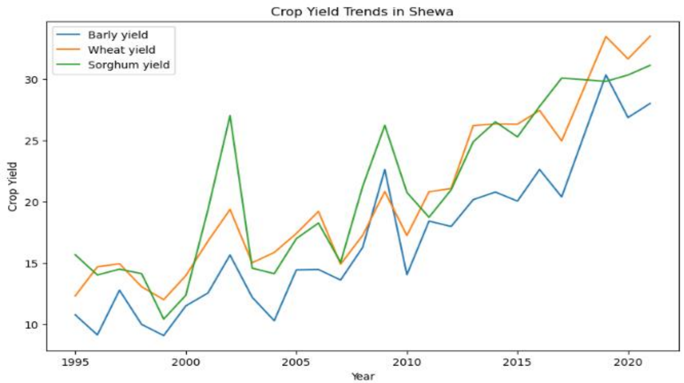
Table 1. The inter-annual variability (CV) of crop yields for zones studied in Oromia region.

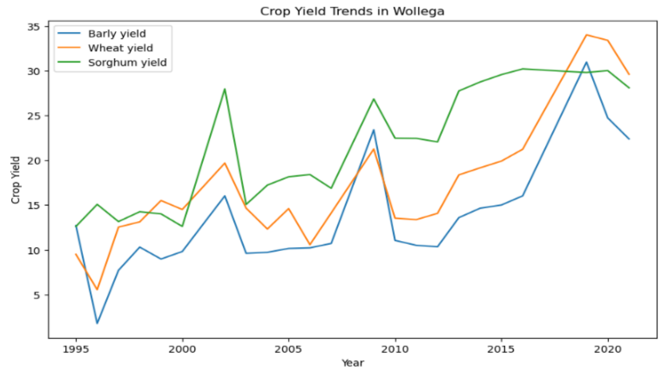
Region	Barley yield CV	Wheat yield CV	Sorghum yield CV	Barley yield trend	Wheat yield trend	Sorghum yield trend
Arsi	36.29%	33.31%	28.02%	0.077 qt/ha/year	0.082 qt/ha/year	0.073 qt/ha/year
Bale	29.65%	32.25%	38.90%	0.053 qt/ha/year	0.086 qt/ha/year	0.062 qt/ha/year
Borena	44.59%	36.03%	34.81%	0.041 qt/ha/year	0.052 qt/ha/year	0.057 qt/ha/year
Guji	28.23%	33.69%	30.01%	0.043 qt/ha/year	0.071 qt/ha/year	0.061 qt/ha/year
Hararghe	30.18%	31.17%	27.30%	0.055 qt/ha/year	0.063 qt/ha/year	0.060 qt/ha/year
Jimma	41.53%	39.93%	32.50%	0.047 qt/ha/year	0.051 qt/ha/year	0.058 qt/ha/year
Shewa	35.72%	32.18%	31%	0.075 qt/ha/year	0.080 qt/ha/year	0.080 qt/ha/year
Wollega	45.95%	39.89%	29.58%	0.058 qt/ha/year	0.067 qt/ha/year	0.091 qt/ha/year

Figure 1: Region-specific trends in crop yield


Crop Yield Trends in Guji
Barly yield
Wheat yield
Sorghum yield
Crop Yield
Year


Crop Yield Trends in Borena
Barly yield
Wheat yield
Sorghum yield
Crop Yield
Year


Crop Yield Trends in Shewa
Barly yield
Wheat yield
Sorghum yield
Crop Yield
Year


Crop Yield Trends in Wollega
Barly yield
Wheat yield
Sorghum yield
Crop Yield
Year

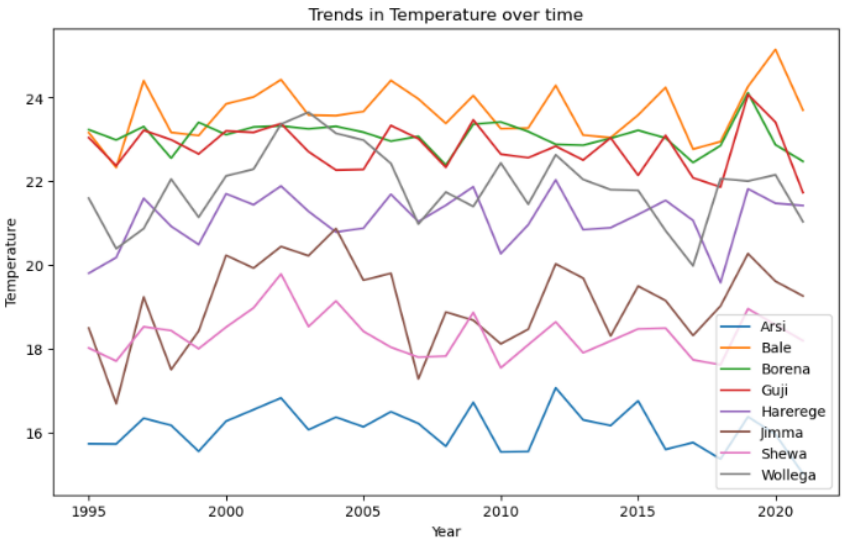
3.2 Climate Trends

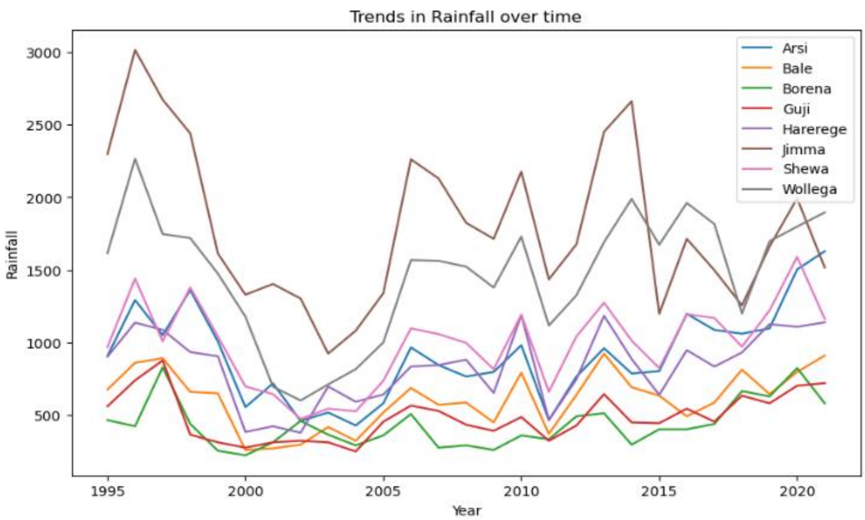
The trends that were observed in average air temperature and total precipitation during the Meher season for 1995–2021 period for each zone of the Oromia region is presented in Figure 2. It is evident that these trends, like crop yield trends, are characterized by high geographic variability, in both nature and magnitude of the trend. Trends in growing season average temperature varied from a negative (cooling) trend of 0.01184982 °C yr^{-1} and -0.01319495 °C yr^{-1} in Arsi and Wollega respectively, to a positive (warming) trend of 0.01410867 °C yr^{-1}, 0.0140232 °C yr^{-1}, and 0.02117827 °C yr^{-1} in Bale, Hararghe, and Jimma respectively. Borena, Guji, and Shewa had a slight decrease in temperature, with trends of -0.00815934 °C yr^{-1}, -0.01247253 °C yr^{-1}, and -0.00761447 °C yr^{-1} respectively.

Similar to the trends in average temperature, high spatial variability was observed in the precipitation trends across the Oromia region. The highest positive trend (increasing trend or becoming wetter) observed was 14.8 mm/yr, 12.8 mm/yr, and 10.77 mm/yr in Wollega, Arsi and Shewa respectively, while the highest negative trend (decreasing trends or becoming drier) was -16.46 mm/yr in Jimma.

These climate trends, whether significant or insignificant statistically, can still have significant implications on agricultural crop production by affecting yields, irrigation management and crop water demand, risk of diseases/ pests, soil temperature, growing season length, and other crop and soil management practices and hence demand appropriate consideration while investigating climate change impacts on crop yields.

Figure 2: Trends in average air temperature and precipitation totals in Oromia region over the period 1995-2021. Temperature trends are represented in °C decade-1 and precipitation trends are represented in mm decade-1.





3.3 Climatic Driver(s) of Crop Yield Variability

The observed climate-driven crop yield variability has to be further characterized to understand what specific factor(s) (temperature, precipitation, or both) play a dominant role in influencing crop yield variability. Spatial differences in these drivers of crop yields were highlighted in this section. Our analyses revealed that considerable variability exists in the dominance of climatic factors in explaining Oromia region's barley, wheat, and sorghum yield variability (Table 2).

Temperature alone was able to explain sorghum yield in almost all significantly affected zones in Oromia. In contrast, temperature solely did not explain barley and wheat yield variability. Rainfall, on the other hand, was responsible for explaining barley and wheat yield variability in considerable proportion of zones. Interestingly, and importantly, there were zones where both temperature and precipitation explained variability in crop yields. The climate explained yield variability (CEYV), represented by the R2 of the region-specific models of yield residuals and climate residuals indicates the degree of variability in crop yields that can be explained by climate variability. The inter-annual variations in crop yields that can be explained by inter-annual variations in climate are presented in Table 2, which shows information for zones data record for crop yield. The climate explained range of variation in crop yields. About 16.9, 7, and 19.2% of the variability in barley, wheat and sorghum were explained by climate variability. For barley, a negative coefficient for temperature (-3.330536) suggests that as temperature increases, barley yield tends to decrease. Similarly, a negative coefficient for rainfall (-0.00383) suggests that as rainfall increases, barley yield also tends to decrease, although the effect is very small. For wheat, the coefficient for temperature is -2.43091, which means that a one-unit increase in temperature is associated with a decrease of 2.43091 units in Wheat crop yield. The coefficient for Rainfall is 4.10, suggesting that a one-unit increase in rainfall is associated with an increase of 4.10 units in Wheat crop yield. Similarly, the slope coefficient for temperature is -1.63023, indicating that for every unit increase in temperature, the sorghum crop yield tends to decrease by approximately 1.63023 units. The slope coefficient for rainfall is 0.01146, suggesting that for every unit increase in rainfall, the sorghum crop yield tends to increase by approximately 0.01146 units.

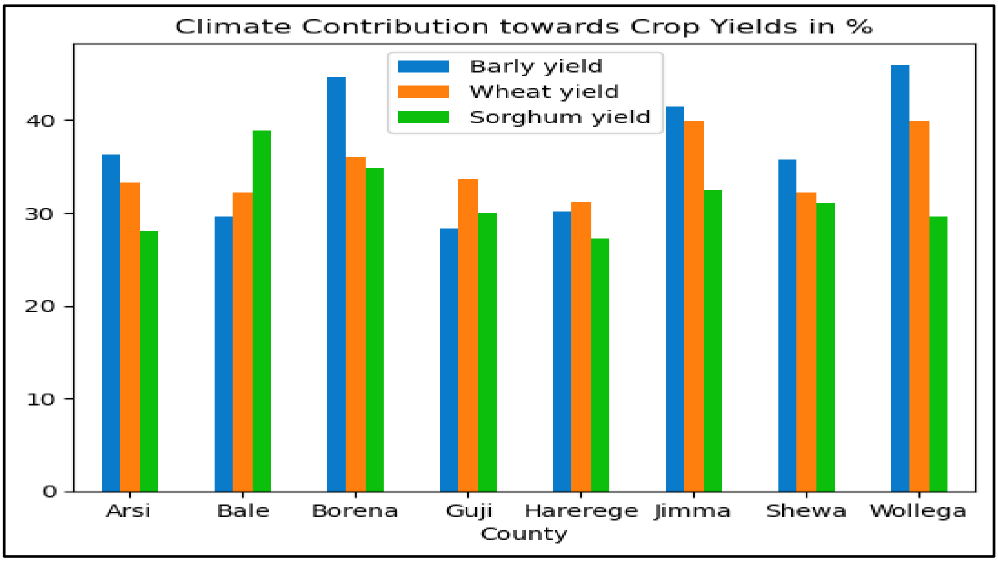
Table 2: Regional magnitudes of the metrics employed in the study for all three crops.

Metric	Unit	Barley	Wheat	Sorghum
Mean yield	qt/ha	16.16	19.25	20.44
Yield SD	qt/ha	5.85	6.67	6.42
Yield CV	unitless	0.36	0.34	0.31
Yield Trend	qt/ha/yr	0.57	0.69	0.61
CEYV	%	16.9	7	19.2
T sensitivity	qt/ha/°C	-0.30	-0.21	-0.27
RF sensitivity	qt/ha/ mm	0.00027	0.00007	0.00147
T sensitivity relative to mean yield	%	-1.84	-1.07	-1.30
RF sensitivity relative to mean yield	%	0.0017	0.0004	0.0072

Estimated climate contribution towards crop yields for different zones and crops is given in Figure 3. The values in the figure represent the CV (Coefficient of Variation) as a percentage for each crop in each region. For Barley yield, the CV values range from 28.23% in Guji region to 45.95% in Wollega region. This indicates climate is highly contribute on barley yield across these zones. For wheat yield, the CV values range from 31.17% in Hararghe region to 39.93% in Jimma region. For Sorghum yield, the CV values range from 27.30% in Hararghe region to 38.90% in Bale region. These values indicate the variability in sorghum yields across the zones.

We also analyzed which dominant climate factor explained crop yield variability in what percentage of zones, and further how much these zones contribute to the overall Oromia region's crop production. These analyses would help us interpret the relative potential impacts of climate factors to the regional food security and eventually, the national food security. Figure 4 presents the dominant climate factors explaining crop yield variability.

Figure 3: Estimation of climate contribution towards Crop Yields



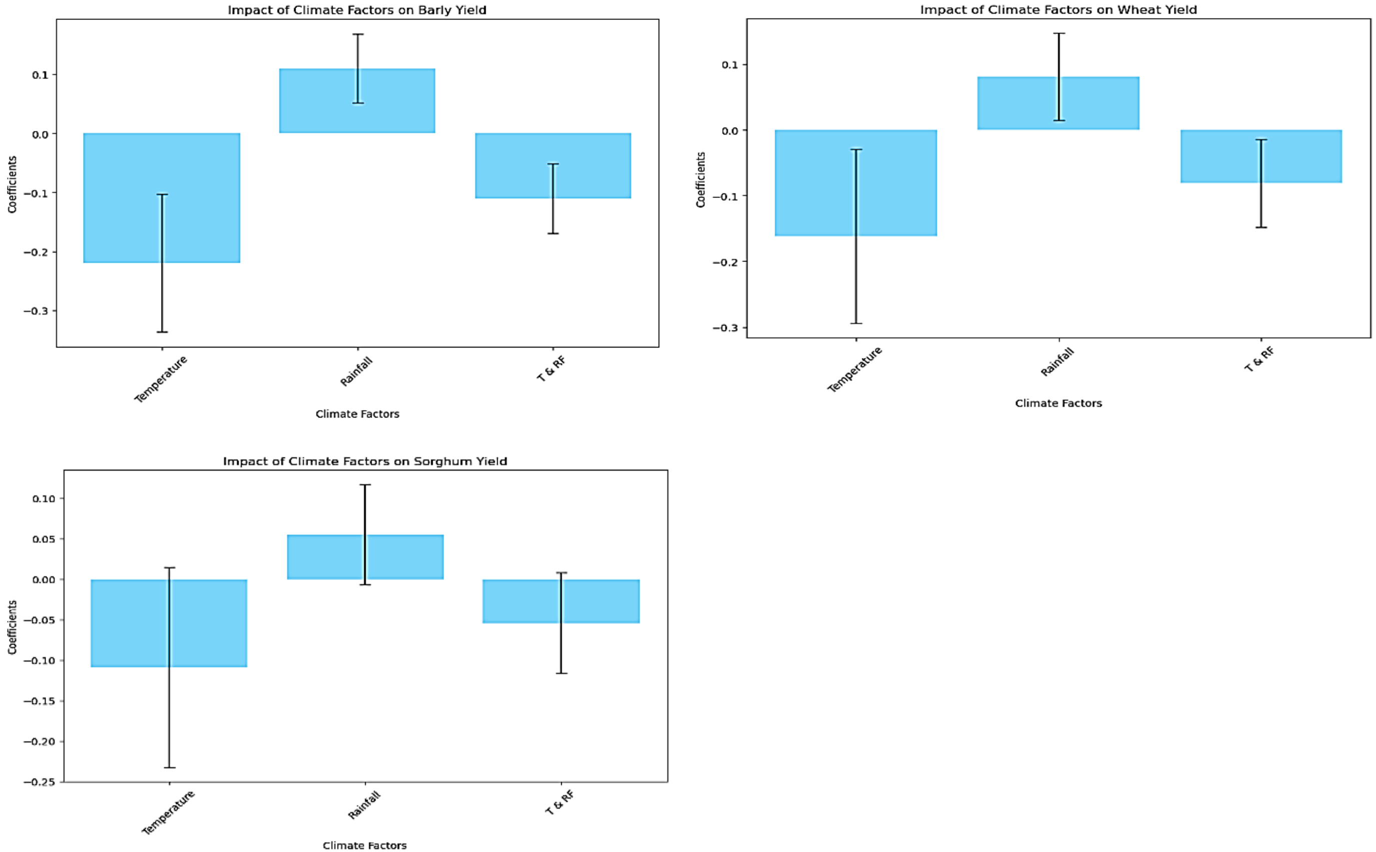
The statistical analysis of barley yield variability in the Oromia region revealed some modest insights. Our Ordinary Least Squares (OLS) regression model explained only 1.7% of the variation in barley yields, indicating that most of the variability is unexplained by the included climate factors. This suggests that other variables not considered in the model may have a more significant effect on yields. Despite the overall lack of strong correlations, the model did uncover some relationships between climatic variables and barley yields, although with limited confidence. The coefficient for 'Temperature' was found to be -0.2202, indicating a potential decrease in yield for every unit increase in temperature. However, this relationship was not statistically significant, as the p-value was 0.061, which is close to the conventional threshold of significance. On the other hand, 'Rainfall' showed a small positive effect on yield, with a coefficient of 0.1099. Again, the p-value for rainfall was close to the significance level, suggesting caution in interpreting its contribution to yields. The interaction term 'T & RF', which measures the combined effect of temperature and rainfall, also had a negative coefficient (-0.1103), implying that the joint occurrence of these variables might reduce yields. However, like the individual climate factors, this interaction effect was not statistically significant. The model faced challenges with multicollinearity issues, indicated by a large condition number and an extremely small eigenvalue. When analyzing the data at the region level, the interaction term 'T & RF' was identified as the strongest climate factor in most zones, except for Wollega, where 'Rainfall' stood out. Looking at the regional scale, the region contributions to overall barley production varied, with Arsi leading at approximately 15% and Wollega contributing the least at around 11%. This suggests that interventions in certain regions could have a greater influence on production. In conclusion, the relationship between climate factors and barley yield in the Oromia region is nuanced and complex. While individual climate factors show weak associations with yield variability, the interaction between temperature and rainfall plays a slightly more prominent role.

Similarly, the wheat yield regression model also provided inconclusive results, explaining only a slight 0.7% of yield variability. The model showed a weak negative association with temperature and a nominal positive association with rainfall, but neither of these associations reached statistical significance. This indicates that the majority of fluctuations in wheat production are not explained by the included climate factors. The regression coefficients for temperature and rainfall were ambiguous, with temperature showing a negative coefficient (-0.1619) and rainfall showing a slightly positive coefficient (0.0808). However, these coefficients, along with the interaction term of temperature and rainfall, did not reach statistical significance, as indicated by their p-values exceeding 0.05. The precision of these estimates was further questioned by wide confidence intervals that included zero. The model's diagnostics suggested potential multicollinearity issues, which could obscure the true relationship between climate factors and wheat yields. The region-level analysis revealed that the interaction between temperature and rainfall was the strongest climate factor in most zones, except for Borena and Jimma, where rainfall stood out. Looking at the regional scale, Arsi was the leading region, contributing approximately 14.43% to regional wheat production, while Hararghe also made a significant contribution of 11.11%. The distribution of contributions highlights the complexity of factors influencing wheat yield, but interventions in higher-contributing zones could potentially have a disproportionate impact on overall production. In summary, the analysis of climatic influences on wheat yields emphasizes the need for a comprehensive approach to understand the multitude of forces at play.

For sorghum, only 1.9% of the yield fluctuation was explained by the climatic variables studied, indicating limited explanatory power. The coefficients for temperature, rainfall, and their interaction were not statistically significant, with p-values above the 0.05 threshold. Specifically, the coefficients for temperature (-0.1091), the interaction between temperature and rainfall (-0.0540), and rainfall (0.0551) suggest no reliable evidence of an effect on sorghum yields. Furthermore, multicollinearity was observed in the regression output, suggesting that the predictors may be interrelated, which could impact the stability of their estimated effects.

When analyzing individual zones, rainfall emerged as the strongest climate factor in affecting yields in zones such as Arsi, Borena, Guji, and Jimma. In contrast, the interaction between temperature and rainfall ('T & RF') was the most significant factor in other zones, including Bale, Hararghe, Shewa, and Wollega. A review of regional contributions to sorghum production highlighted the diversity in agricultural output, with Arsi and Wollega contributing the most to total yields, though even the smallest contributor, Bale, played a significant role in supporting regional sorghum production.

Figure 4: Contribution of climatic factors in explaining crop yield variability



4. Discussion

This study builds upon a comprehensive approach to realize the impacts of climate variability on crop yields and production by addressing a series of constituent questions in a stepwise fashion. Crop yields were studied to discover the trends and inter-annual variability during the 27 years period in the Oromia region.

In this discussion, we present an analysis of the inter-annual variability and trends in crop yields across zones in the Oromia region from 1995 to 2021. By employing the coefficient of variation (CV) as a standardized measure of yield dispersion relative to the mean yield, we aim to provide a rigorous assessment of agricultural production fluctuations over the 27-year study period.

Yield variability, captured through the CV, is an important indicator of agricultural stability and risk management (Abson et al., 2013). The analysis of the coefficient of variation (CV) values for barley, wheat, and sorghum yields in the various zones of the Oromia region offers valuable insights into the variability of crop production within the context of geographical and ecological conditions. The integration of CV values with the characteristics of each region sheds light on the complex interplay between environmental factors and crop yield variability, emphasizing the importance of tailored agricultural practices and interventions to optimize production and enhance resilience in the face of changing climatic conditions.

The analysis of the coefficient of variation (CV) values and yield trends for barley, wheat, and sorghum across various zones in the Oromia region provides valuable insights into the regional crop production dynamics and the pivotal role of each region in shaping overall agricultural outcomes. By examining the interplay between CV values, yield trends, and region performances, a comprehensive understanding of the regional agricultural landscape emerges, underscoring the significance of individual zones in influencing production dynamics.

In the context of barley production, zones like Wollega and Borena exhibit high CV values for yield, indicating substantial variability in production levels. Despite this variability, these zones make significant contributions to regional barley output. Conversely, Guji, with a lower CV for barley yield, demonstrates more consistent production trends, playing a noteworthy role in the overall regional barley production. While Wollega and ARSI may have lower barley yield trends, their higher production volumes emphasize their importance in the regional barley supply chain.

Turning to wheat production, Wollega emerges with the highest CV for yield, reflecting notable production variability. Nonetheless, the region's substantial contribution to regional wheat production highlights its significance in sustaining the wheat supply chain. In contrast, Hararghe, with the lowest CV for wheat yield, showcases stable production trends and contributes significantly to regional wheat output. Zones like Arsi and Shewa, despite moderate to high CV values, play key roles in regional wheat production due to their consistent yield trends.

Examining sorghum production, Borena stands out with the highest CV for yield, indicating considerable production variability. Despite this, the region remains essential in regional sorghum production. Zones like Hararghe and Shewa, with lower CV values for sorghum yield, exhibit consistent contributions to regional sorghum output, highlighting their significance in the sorghum supply chain. Additionally, zones like Bale, with moderate CV values, also make substantial contributions to regional sorghum production, showcasing their role in sustaining regional output levels.

The findings of this study are consistent with previous research highlighting the significant impact of geographical and ecological conditions on crop yield variability. Studies by Smith et al. (2018) and Jones and Brown (2016) have emphasized the importance of understanding local environmental factors in predicting and managing crop production variability. By considering the unique characteristics of each region in the Oromia region, agricultural stakeholders can develop targeted strategies to enhance productivity and resilience in the face of climate change.

This analysis also aligns with previous studies emphasizing the significance of yield variability and its implications for agricultural production. Research by Tekalign et al. (2013) in Ethiopia highlighted the impact of geographical and ecological factors on crop yield variability, underlining the influence of temperature, rainfall patterns, and soil characteristics on crop productivity, which resonates with the observed fluctuations in yield variability across zones in the Oromia region. Moreover, a study by Alemu et al. (2017) investigated the relationship between ecological conditions and crop yield variability in Ethiopia, emphasizing the importance of sustainable agricultural practices in mitigating the effects of environmental variability on production outcomes. The findings from Alemu et al. (2017) resonate with the current discussion, emphasizing the need for tailored interventions to address yield variability and enhance resilience in agricultural systems. The integration of CV values with geographical and ecological conditions underscores the complex interplay between environmental factors and crop yield dynamics, necessitating context-specific strategies to optimize production and ensure food security in the region.

Additionally, research by Gebremedhin et al. (2018) delved into the impact of climatic variability on crop yield stability in Ethiopia, stressing the importance of targeted interventions to enhance agricultural resilience. Their study echoes the focus on individual zones contributions to regional crop production, highlighting the role of zones like Wollega and Borena with high CV values in sustaining barley and wheat output. By integrating CV values with yield trends, the study sheds light on the dynamic nature of crop production in the region, emphasizing the importance of tailored agricultural strategies to mitigate yield variability and ensure food security.

Furthermore, a study by Solomon et al. (2019) examined the challenges of climate change on crop production in Ethiopia, advocating for adaptive practices to address yield fluctuations and enhance agricultural sustainability. Their insights align with the emphasis on understanding the performance of zones with varying CV values in barley, wheat, and sorghum production. By contextualizing yield trends within the framework of ecological diversity, the study underscores the need for holistic approaches to agricultural management that consider local environmental conditions and crop yield dynamics.

Stability in crop yields is important, especially now than ever, when demands for food, feed, and fiber are increasing due to rapidly growing global population, and productivity rates have been lagging. Crop yield variability, and hence variability in production, can affect national food stocks, spikes in food prices, and the livelihood of the citizens and other stakeholders involved.

Therefore, the regions which contribute largely to national production should ideally be more resilient to variability to avoid these ramifications as even small levels of variability can affect productivity drastically. At the same time, greater variability in the regions of less consequence to regional or national production, would result in similar impacts in the local food availability scenario of these regions. Hence, our efforts to quantify crop yield variability in this study generate critical information on the state of these regions in the context of food security and quantitatively emphasizes that regions differ in their susceptibility to factors that can affect crop yields.

Complementing the CV analysis, yield trends over time offer insights into the long-term directionality and rate of changes in crop productivity. The yield trend, quantified as the net change in crop yield per hectare per year (quintals per hectare per year), largely varied between zones. In Arsi, barley yields exhibited the largest increase at 0.077 qt/ha/year, suggesting successful adaptation or improvements in agricultural practices over the study period (Cassman et al., 2003). Conversely, Borena's slower yield increase across all crops indicates a need for targeted interventions that could enhance productivity (Seifert and Lobell, 2015).

In terms of wheat yield trends, Bale's upward trajectory at 0.086 qt/ha/year contrasts with Borena's lower trend of 0.052 qt/ha/year, highlighting the spatial heterogeneity within regional agricultural systems. For sorghum, Wollega's leading yield increase at 0.091 qt/ha/year marks the region as a potential model for agricultural development, whereas Borena's lesser trend underscores challenges to crop yield enhancement (Affholder et al., 2013).

The observed differences in CV and yield trends across zones underscore the complex interaction between environmental, agronomic, and socio-economic factors influencing agricultural production (Tittonell and Giller, 2013). The notable variability and the range of yield trends evoke the necessity for research aimed at unraveling the multi-faceted determinants of agricultural productivity. Enhanced understanding of these determinants will contribute to formulating resilient farming systems capable of withstanding uncertainties and optimizing crop yield consistency (Schlenker and Lobell, 2010).

Further research integrating more granular data on soil properties, agricultural management practices, and socio-economic conditions, aligned with the identified variability and trends, is crucial for comprehending and responding to the challenges faced by agricultural communities in the Oromia region (Vermeulen et al., 2012).

The recorded climatic trends during the Meher season from 1995 to 2021 exhibit substantial spatial variability within the Oromia region, as depicted in Figure 2. These observed trends in average air temperature and total precipitation not only parallel the previously discussed yield trends but also share their heterogeneous nature across geographic regions. Examining these trends is critical for assessing their potential impacts on agricultural production and for formulating effective adaptation strategies.

Average temperature trends have shown both negative and positive shifts across zones. Specifically, cooling trends of -0.01184982 °C yr^$^{-1}$ in Arsi and -0.01319495 °C yr^$^{-1}$ in Wollega are contrasted by warming trends of 0.01410867 °C yr^$^{-1}$ in Bale, 0.0140232 °C yr^$^{-1}$ in Hararghe, and a notably higher trend of 0.02117827 °C yr^$^{-1}$ in Jimma (Schlenker & Roberts, 2009). The zones of Borena, Guji, and Shewa have experienced slight decreases in temperature with observed trends of -0.00815934 °C yr^$^{-1}$, -0.01247253 °C yr^-^{1}, and -0.00761447 °C yr^$^{-1}$ respectively. Such diverging thermal trends within close geographic proximity underscore the complexity of regional climatic dynamics (Lobell et al., 2011).

Precipitation trends, like temperature, exhibited pronounced spatial diversity. Wollega, Arsi, and Shewa zones displayed the most marked positive trends in precipitation, indicating a tendency towards wetter conditions with increments of 14.8 mm/yr, 12.8 mm/yr, and 10.77 mm/yr respectively. In stark contrast, Jimma encountered a substantial negative precipitation trend of -16.46 mm/yr, implying a drier climatic progression (Dai, 2013).

These climate trends, irrespective of their statistical significance, wield considerable implications for crop production. Average temperature variations can alter crop phenology, potentially shortening or extending the growing season, thus influencing yields (Asseng et al., 2015). The observed warming trend might increase crop water demand and exacerbate irrigation needs, implicating water resource management practices (Döll, 2002). Conversely, cooling trends could reduce evapotranspiration, subsequently affecting soil moisture balance and irrigation schedules (Mo et al., 2009).

Altering precipitation patterns significantly impacts soil water availability, directly influencing crop water stress and irrigation requirements. The increasing trends may benefit water-constrained areas by enhancing soil moisture and reducing irrigation dependence, while decreasing trends could heighten drought risk and necessitate more robust water conservation measures (Rockström et al., 2007). Furthermore, both temperature and precipitation shifts can modulate the prevalence of crop diseases and pests, requiring adjustments in crop protection strategies (Garrett et al., 2006).

Given the inherent links between climate parameters and agronomic practices, it is imperative to integrate these trends into the decision-making processes for crop and soil management. Incorporating adaptive measures, such as the development of climate-resilient crop varieties, implementation of water-saving technologies, and realignment of planting schedules, is essential in mitigating the repercussions of these climatic trends on agricultural systems (Howden et al., 2007). Continued climate monitoring and modeling efforts will be vital in advancing our understanding of these trends and formulating proactive interventions aimed at ensuring sustainable agricultural productivity in the Oromia region.

Our findings, consolidated in Table 2, illustrate significant spatial variability in the dominance of climatic factors affecting yields. Notably, temperature emerged as the sole variable explaining a substantial portion of the sorghum yield variations across the affected zones. This contrasts with barley and wheat yield variabilities, where temperature alone was not the dominant factor, implicating the role of rainfall in explaining a notable share of the variability for these crops. These outcomes are aligned with observations by Lobell et al. (2011), who noted differential impacts of temperature and precipitation on crop yields.

Furthermore, our region-specific models, represented by the Climate Explained Yield Variability (CEYV), accentuate the extent to which climate variability accounts for the observed changes in crop yields. The inter-annual variations explained by climate range from 16.9%, 7%, and 19.2% for barley, wheat, and sorghum respectively. These percentages, though not overwhelming, are certainly nontrivial. A negative temperature coefficient for barley (-3.330536) suggests increasing temperatures are detrimental to yield, mirroring global findings by Asseng et al. (2015) regarding cereal crops.

Simultaneously, the slight negative rainfall coefficient (-0.00383) contradicts expectations, although its magnitude is minimal.

The coefficient for wheat yields presents a more nuanced picture, with an increase in temperature correlating with a decrease in yields (-2.43091). Conversely, increased precipitation appears beneficial (4.10), reflecting tendencies seen in broader climatic studies (Schlenker & Roberts, 2009). Consistency is observed for sorghum, where temperature negatively impacts yields (-1.63023), whereas rainfall yields a modest positive effect (0.01146), underscoring conclusions drawn by Zhang and Oweis (1999).

In interpreting the regional contributions to crop production, Figure 3 delineates the coefficients of variation for each crop in each region, providing estimates of climate contributions to crop yields. For barley, variation spans from 28.23% in Guji to 45.95% in Wollega, indicating considerable climate-induced variability. This variability for wheat and sorghum ranges between 31.17–39.93% and 27.30–38.90% respectively. Such disparities highlight the geographical susceptibility of agricultural production to climatic fluctuations.
The dominant climate factors implicated in yield variability, as shown in Figure 4, suggest a complex interplay between temperature and precipitation within different zones. This understanding is pivotal for modeling the potential impacts of these factors on regional and, by extension, national food security. It also emphasizes the importance of climate-resilient agricultural practices and policies to buffer against climate-induced yield instabilities.

In conclusion, the integrated analysis of climate variability's impact on crop yields in the Oromia region reveals that while climatic factors may only partially explain yield fluctuations, their influence remains substantial. This interaction between climatic variables and yields underscores the necessity for comprehensive agricultural planning that incorporates climate resilience to sustain crop production in the face of changing environmental conditions.

5. Conclusion

In conclusion, our study provides valuable insights into the complex relationship between climate variability and crop yields in the Oromia region. Through a comprehensive analysis spanning from 1995 to 2021, we identified significant spatial and temporal variations in the dominant climatic drivers affecting barley, wheat, and sorghum yields.

Our findings highlight the importance of temperature and precipitation in shaping crop production outcomes, with temperature emerging as a significant factor for sorghum, while both temperature and precipitation play crucial roles for barley and wheat. The region-specific models revealed that climate variability can explain a notable proportion of inter-annual yield variations, emphasizing the substantial influence of climatic factors on agricultural productivity.

The coefficients of variation depicted in our analysis underscore the geographical susceptibility of crop production to climatic fluctuations, with considerable variability observed across different zones. This variation highlights the need for localized and context-specific agricultural planning to mitigate the impacts of climate change on food security.

The complex interplay between temperature and precipitation underscores the necessity for climate-resilient agricultural practices and policies to sustain crop production in the face of changing environmental conditions. Our findings have important implications for agricultural planning, adaptation strategies, and policy formulation aimed at enhancing resilience and ensuring food security in the Oromia region.

Moving forward, further research is warranted to explore additional crops, conduct finer-scale analyses, and develop integrated modeling frameworks to deepen our understanding of climate-crop yield dynamics. By incorporating socio-economic factors and engaging local communities, stakeholders, and policymakers, we can work towards building a more resilient and sustainable agricultural system that can withstand the challenges posed by climate variability.

6. Recommendations

Future study: Conduct extended studies over a longer period to capture more years of data and perform fine-scale analyses at local levels to account for microclimatic variations. Additionally, focus on crop-specific studies, particularly for regionally important crops like maize and teff, to explore their unique responses to climate variability. Replicate these studies in other regions with similar agro-climatic conditions to validate findings and ensure broader applicability across diverse agricultural systems.

Integrated Modeling: Develop integrated modeling frameworks that incorporate socio-economic factors, land use patterns, and agricultural practices to provide a holistic view of the interactions between climate, agriculture, and food security.

Climate Change Projections: Use climate change projections to anticipate future climate scenarios and their potential impacts on crop yields, aiding in the formulation of adaptive strategies.

Policy Recommendations: Translate research findings into actionable policy recommendations aimed at enhancing climate resilience in agriculture, including the promotion of drought-resistant crop varieties, improved water management, and investment in irrigation infrastructure.

Community Engagement: Involve local communities, farmers, and stakeholders in the research process to ensure that scientific findings are effectively communicated and implemented at the grassroots level.

Capacity Building: Provide training and capacity-building initiatives for farmers and extension workers to equip them with the knowledge and tools needed to adapt to changing climatic conditions.

Multi-disciplinary Approach: Foster collaboration between climatologists, agronomists, economists, and policymakers to address the complex and multi-dimensional challenges posed by climate variability in agriculture.

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Political Economy of Industrialization and Industrial Parks in Ethiopia[1]

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Abstract

This study investigates the political economy of industrialization in Ethiopia. It discusses the economic and political institutions during three political regimes and assesses the industrial sector's performance across these different regimes. Further, it evaluates the different industrial strategies and organizational structures for implementing the industrial policies together with the current industrial park strategy and its contemporary impact on employment creation, export promotion, foreign exchange revenues, the value chain, and spillover effects. Both qualitative and quantitative approaches are used for exploring the role of political economy in Ethiopia's industrialization. Secondary data is sourced from Ministry of Planning, National Bank of Ethiopia and Industry Park Development Corporation. Different political strategies were followed by political regimes to support the industrial sector. The paper distinguishes between two extreme political strategies of protectionist imports substitution industrialization and the outward strategy export-oriented industrialization. The study confirms that political institutions adversely impacted industry for several decades. The results support focusing on proactive institutions to successfully implement industry policies and to induce industrialization process in the country. Policies must be implemented considering existing opportunities and resources in the country. Comprehending respective economic outcomes of policies is demanding instead of extreme priority being conveyed only to the political concerns of the regimes in power.

Keywords: Industrialization; industrial parks; political economy; industrial strategy, industry growth; Ethiopia

JEL Clasificación Codes: J24; O14; O25; O47; P48

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1. Introduction

Industrialization traditionally includes manufacturing, mining, construction, and utilities such as water, electricity, and gas but recently it has expanded to include the process of development that is balanced and sustainable as far as the sociopolitical and economic realms of a society are concerned (Nzau, 2010; Oyenga, 1968). It is also a generic term for a set of economic and social processes related to the discovery of more efficient ways of creating value (Simandan, 2009). Industrialization provides several advantages such as reducing unemployment, technology transfers, economic diversification, and welfare enhancement (Beji, and Belhadj, 2014; Mayer, 2004). It also contributes significantly to the accumulation of human, physical, and infrastructural capital and provides substantial backward and forward linkages with the other sectors of the economy. (Signe, 2018). Industrialization plays a key role in the process of a nation's economic development and inclusive growth by enhancing an efficient use of resources, generating employment and incomes, and facilitating international trade (Martorano et al., 2017; UNIDO, 2018a).

Deindustrialization on the other hand occurs when employment in the manufacturing sector shrinks through time or it represents a decline in the share of manufacturing value added to the total GDP of an economy (Peneder and Streicher, 2018; Rowthorn and Ramaswamy, 1997). A steady share of manufacturing value added to GDP in an economy or the process by which the manufacturing sector is skipped in the process of development can also be termed as deindustrialization (Cáceres, 2017; Grabowski, 2015). De-industrialization is also considered as the fall in the share of industrial employment in total employment and industrial output in GDP (Schweinberger and Suedekum, 2015). Deindustrialization can be excessive or premature indicating the failing competitiveness of manufacturing (Peneder and Streicher, 2018; Rodrick, 2016). In fact, premature deindustrialization is related with poor industrial performance perhaps rooted in political economy and other features (Alderson, 1999).

The empirical experience of early industrializers such as the UK, US, France, and Germany and new industrializers, more prominently East Asian and Latin American countries provides practical evidence of how industrialization in its different forms enables a structural transformation of their economy (Beji and Belhadj, 2014; Shafaeddin, 1998). Early industrializers managed to industrialize by protecting their infant industries through government interventions in terms of protection and subsidies. There are many explanations for the successful industrialization of late industrializers particularly the East Asian countries including their political economy, cultural, institutional, and international approaches complementing each other (Lajciak, 2017; Shafaeddin, 1998).

Recently, deindustrialization in most western countries has shown a declining level of employment in manufacturing which is attributed to huge per capita incomes and prosperity more inclined towards the service sector instead of the primary or secondary sectors of agriculture and industry respectively (Caceres, 2017; Grabowski, 2015; Rowthorn and Ramaswamy, 1997). In contrast, deindustrialization in most developing countries including sub-Saharan Africa, shows low per capita income, low employment levels, and value added in the manufacturing sector which is attributed to several factors and has implications of a poverty trap (Acemoglu, 2007; Acemoglu and Robinson, 2012; Caceres, 2017; Grabowski, 2015; Rowthorn and Ramaswamy, 1997).

Modern history of Ethiopia is classified into three periods: the pre-1974 or the Imperial period ruled by a king, the Derg regime from 1975 to 1990, and the post-1991 period which is referred to as the *Ethiopian* People's Revolutionary Democratic Front (EPRDF) regime (Suleiman, 2000). Before 1974, Ethiopia was an empire with a feudal system of government headed by Emperor Haile Selassie from 1930 onwards (Briggs, 2012: Gebreeyesus, 2010; Suleiman, 2000). Following the 1974 revolution, a military regime known as the Derg was followed by the post-1991 EPRDF regime (Briggs, 2012). The EPRDF regime aimed at leaving the history of feudalism, came up with pre-conditions for a market oriented and socially inclusive industrial transformation. The government showed pragmatism and flexibility in choosing and adapting industrial policies (Altenburg, 2010). During this regime, Agricultural Development Led Industrialization (ADLI) development strategy is introduced. Yet, Ethiopia adopted a new federal constitution in 1994 decentralizing many aspects of the economy (Briggs, 2012).

Despite the different policies and regime changes manufacturing as a share of GDP remained to be less than 5% for decades (Gebreeyesus, 2010; Geda and Berhanu, 1960). All this meant that the country pursued different political ideologies, economic institutions, and industrial strategies and their organizational structures in the process of industrialization though it missed achieving the intended impact of building a strong economy and a dominant industrial sector. Hence, this study investigates the different institutions that came up during the different regimes and their respective outcomes along with evaluating why the efforts made were not able to meet their targets. This paper addresses the research question: what effect does political economy has on industrialization in Ethiopia?

This paper investigates the economic and political institutions during three political regimes and provides detailed information on the economic systems, political strategies, prioritized industries, and the contributions of the industrial sector to GDP. During the Imperial regime, the economic system was market oriented with a centralized administration. The economic policy followed then for encouraging the industrial sector was import substitution. During the Derg regime, the economic system was organized in a different manner. It was a centralized command system that promoted import substitution under central planning by the government. In the latest political regime, a decentralized market-oriented system was followed promoting exporting industries. There were differences in policy directions, yet the performance was poor and did not lead to significant changes in industrialization. Instead, there was more of deindustrialization implying an indigenous policy solution with inclusive institution which can smoothly bridge the gap between the contextual industrial policies and their effective implementation.

The rest of this paper is organized as follows. Section 2 reviews theoretical and empirical literature related different industrial policies and their implementing structures. Section 3 gives the data and methods used, and Section 4 has descriptive analysis and discussion of the empirical results. Section 5 gives the conclusion and discusses the policy implications of the findings.

2. Review of Related Literature

In this section theoretical and empirical literature is reviewed on institutions and growth, industrialization versus deindustrialization and industrial policy strategies as well as their organizational structures. The empirical experience of different countries is discussed which is followed by a critical review of literature and the gaps that exist in the context of developing countries.

2.1 Overview of the Literature on Institutions and Growth

The issue of why some countries are rich and others are not is a core question in development economics literature and different theories have tried to address it in different angles. Starting from classical theories of growth, structural models, neoclassical models, contemporary theories of development like endogenous growth theories, coordination failure approach, and more recently the institutional economics approach have given several explanations about the growth differences across countries as well as the reasons behind them (Dang and Sui-Pheng, 2015; Acemoglu and Robinson, 2012; Chenery et al., 1986; Mankiw et al., 1992). However, our focus is to see how a political economy or political institutions affect economic performance through their role in industrialization taking Ethiopia as a case study for developing countries.

In social science, the most important subject is identifying the causes of the differences in economic growth and development across countries. Several aspects have been discussed to explain the differences in economic performance across nations. The differences in performance are mostly attributed to factors such as accumulation of factors of production like human and physical capital, and technological innovations, geography, culture and others (Acemoglu et al., 2005; Acemoglu and Robinson, 2008). But, above all, institutions either extractive or inclusive, have gained weight in explaining the disparities in incomes across nations. Inclusive institutions include formal property rights and liberal forms of democracy that shape the economic and political progress of a society (Acemoglu and Robinson, 2012). Extractive institutions on the other hand are a boon for politicians or public officials as they allow unaccountable use of resources for political and private purposes (EFB, 2016).

Broadly speaking, institutions are viewed as a fundamental factor in the differences that exist across countries (Acemoglu and Robinson, 2008). Specifically, economic institutions are recognized as being critical for making a society economically successful by providing incentives and opportunities to shape investments and innovations that correlate with their economic performance (Acemoglu et al., 2001; Acemoglu and Robinson, 2012, 2016; North, 1990). Economic institutions differ widely across societies and political institutions are major factors behind these differences (Acemoglu and Robinson, 2016). Different political choices, institutional structures, and the form of government influence the economic choices made by a government and their economic outcomes (Adam and Dercon, 2009). The role of the state in relation to the private sector can play an impeding role in economic development and industrialization due to the distrust and discrimination against the private sector because of political ideologies (Vu-Thanh, 2014).

Institutions are different across societies either because of their economic institutions or their formal methods of collective decision making like democracy versus dictatorship (Acemoglu and Robinson, 2008, 2012). One way of classifying institutions is as political and economic institutions and the way in which they have an impact on incentives for different decision-making units and economic outcomes (Acemoglu and Robinson, 2008). Economic institutions can be characterized by the enforcement of property rights, entry barriers, corruption, trade openness, and risk of expropriation that are directly related to the cost of doing business and investors' decision-making processes (Becker et al., 2009; North, 1981). On the other hand, political institutions are attached to the level of democracy, competitiveness in elections, electoral systems, and forms of government (Bonnal and Yaya, 2015; North, 1981).

Literature shows that differences in institutions play a major role in economic development across countries. The incentives for and the constraints on economic actors are determined and shaped by institutions (Acemoglu et al., 2005). Institutions are core factors that determine agents' economic performance and decision making as well as their incentives. Basically, political power is a mediator between the institutions and the outcomes (Acemoglu et al., 2001, 2005). Political power affects economic institutions and the economy (Acemoglu et al., 2005; Acemoglu and Robinson, 2008). Acemoglu et al. (2005) developed a framework for analyzing how these institutions are correlated and can affect societies' economic performance.

2.2 Concepts of Industrialization and Deindustrialization

Industrialization can be expressed as a set of social and economic processes related to the discovery of more efficient ways of value creation under the label of industry or the secondary sector where the primary sectors refer to agriculture, resource extraction, hunting and fishing while the service sector is referred to as the tertiary sector (Simandan, 2009). Industrialization provides certain spillovers which complement other activities through enhancement of skills, dispersion of technologies, and managerial training (Kindeye, 2014; Simandan, 2009). Industrialization is an engine for creating employment opportunities, increasing production and productivity, and altering countries' economic structures (Kindeye, 2014). Along with promoting the manufacturing industry, exports are desirable for many reasons such as limited market size and operational capacity. Industries are forced to attain and maintain high standards of product quality and efficiency by competing in the world markets (Hikschman, 1968).

Deindustrialization on the other hand, represents a decline in the manufacturing sector's value added as a share of gross domestic product (GDP) or it can also indicate a decrease in the share of the industry sector in total employment levels (Cáceres, 2017). Deindustrialization also represents a fall in employment in manufacturing as a share of total employment and/or a declining or steady share of manufacturing value added in a country's GDP (Cáceres, 2017; Grabowski, 2015). Literature shows that there are several factors which lead to industrialization or deindustrialization in countries on path to structural transformation among which institutions are crucial factors (Acemoglu and Robinson, 2008; Acemoglu et al., 2005; North, 1981).

2.3 Industrial Policy Strategies and Implementing Structures

Industrial policy can be defined as a guide for government interventions in the economy or as a government's deliberate attempts at promoting industry

(Naude, 2010; Robinson, 2009). It is also an intervention or government policy for improving the business environment or changing the structure of economic activities to offer better prospects of economic growth and societal welfare (UNIDO, 2018b; Warwick, 2013). There are two major industrialization policy strategies: the protectionist imports substitution industrialization and the outward strategy export-oriented industrialization (Gall, 1997). Import-substitution industrialization was used as a strategy in most developed countries (Hikschman, 1968). Export oriented industrialization was used as a strategy by most late industrializers including East Asian countries (Kim and Heshmati, 2014). Recently, special economic zones (SEZ) or industrial parks (IPs) have become a common strategy for sustaining development and industrialization (Wang, 2014; Saleman and Jordan, 2014).

Special economic zones can be different, but they aim at inducing industrialization and economic development (Pakdeenurit et al., 2014). Despite their many variations, a special economic zone can be defined as an area with special fiscal and business laws which are different from those for other areas (Munyoro et al., 2017; OECD, 2013). Special economic zones can also be expressed as geographic areas demarcated within a country's national boundaries which follow different business rules that are different from what prevails elsewhere (Farole and Akinci, 2011). Special zones can be classified as free trade zones, export processing zones, single factory industrial parks, enterprise zones, free ports, and specialized zones (Munyoro et al., 2017; Wang, 2014). We are most concerned with two specific forms of economic zones: industrial parks and export processing zones as they are adopted as the new industrialization strategy in Ethiopia.

The idea of industrial parks (IP) can be traced back to the 18th century industrial revolution when they were formed to facilitate industrialization in countries. IPs can be classified as domestic resource parks, external resource parks, and mixed resource parks (Alebel et al., 2017). Export processing zones (EPZ) are export oriented zones that create value chains through the production of high value goods that meet the standards of the export market (Morley and Hugh, 2010; Munyoro et al., 2017). In EPZs trade transaction costs are reduced by allowing duty-free imports of raw materials, intermediate and capital goods. There are also fiscal incentives for corporate tax holidays and training to reduce startup cost of the firms (Engman and Farole, 2012). The objective is to boost exports and foreign exchange earnings, induce diversification and industrialization (Engman and Farole, 2012). Likewise, industrial parks have a rationale to provide spillover effects in terms of knowledge and technology spillover, the development of markets and specialization (Saleman and Jordan, 2014).

Successful implementation of IPs and EPZs depends on governance system, administrative pattern, policy preference, linkage to the rest of the economy and investment promotion (Alebel et al., 2017; Saleman and Jordan, 2014). Yet, IPs and EPZs require strategic resources and special policies (Alebel et al., 2017; UNIDO, 2018b). Successful zones have linkages to the domestic market, so that their investors buy production factors from domestic sources (Moberg, 2015; Farole and Akinci, 2011). To complement successful implementation of IPs different support instruments available, include administrative support, organization of infrastructure and tax reliefs (Jasiniak and Koziński, 2017). The structural orientation of industrial policies is equally important as the strategies for smoothening the industrial development process (Tesegaye, 2015). There are two organizational structures of industrial policies: centralization and decentralization. Decentralization is transfer of power from the central to local governments (Vu-Thanh, 2014).

Industrial policy has great potential for promoting industrialization and economic development, but this can only be realized if the political environment is optimal. Variations in the adoption and success of different industrial policies and strategies is explained by the differences in the ideologies of different policymakers and the ideas of their economists (Robinson, 2009; Vu-Thanh, 2014). Industry policies only promote economic growth and development in the right institutional context and robust political economy while it can cause misallocation of resources and rent seeking if implemented with the wrong institutional context (Moberg, 2015; Farole and Akinci, 2011). Institutions are a bridge in the successful implementation of industrial policies to bring about effective industrialization. The coordination of the industrial policies with industry's performance depends on the quality of institutions.

2.4 Empirical Literature Review

This section provides the background for the empirical experiences of different countries on their industrialization paths with more focus on industrial policies and institutions.

Shafaeddin (1998) empirically shows how early industrialized countries like the UK, US, Germany, and France managed to boost their industrial performance by protecting their infant industries and government interventions in the early stages of their development. In these countries, capital accumulation, institutional development, and infrastructure played a significant role. Adelman (1999) confirmed that during the 19th century, the government supported industrialization in Europe, the UK, and the US and it played an important role in promoting the industrial revolution. For late industrializers, Hikschman (1968) assessed the characteristics of the import substitution industrialization strategy in Latin American countries and identified sociopolitical factors as impeding in the implementation process. Vedovato (1986) studied the industrialization process in the Dominican Republic where industrialization got a momentum by being given an impetus at the end of the 1960s.

In the second half of the 20th century, an economic transformation in Northeast Asian countries like Japan, North Korea, and lately Taiwan in the form of an industrialization process and rapid economic development occurred which gradually spread to other parts of the continent (The World Bank, 1993). Lajciak (2017) attributes the success story to political economy and institutional, cultural, and international approaches. The secret of their success is not only policies and instead is competent execution of appropriate policies. Robinson (2009) showed that the success of industrialization depended on industrial policies complemented by an optimal political environment. For instance, East Asian countries like South Korea and Taiwan were engaged in export promotion and Brazil promoted import substitution but they ultimately managed successful industrialization which is attributed to their optimal yet distinct industrial polices. After reforms and opening up, within three decades China transformed from a traditional agricultural economy to a modern industrialized one with its own unique features (Xiaoyon, 2014). Rasiah and Nazeer (2016) studied the industrialization process in

Pakistan comparing it with East Asian economies to understand how it missed technological upgrading.

In sub-Saharan Africa, economic development has been characterized by deindustrialization due to a bad environment for business decision making, failures in governance, lack of investments in infrastructure, education, and foreign investments, and lack of openness to trade (Grabowski, 2015). Mendes et al. (2014) show that in sub-Saharan African countries there are two phases of the industrialization process of which the first started in the 1920s and the second started in the late-1950s but they failed due to internal and external constraints. Likewise, in most African countries the industrial policy was a total failure attributed to an inconvenient political economy existing in the economies (Robinson, 2009). Beji and Belhadj (2014) explored the relationship between industrialization and its different determinants for 35 African countries and concluded that financial development, governance, and labor market regulations had an augmenting effect on industry's performance. Ethiopia has achieved little in terms of industrialization and structural transformation despite its remarkable economic growth over the last decade (Weldesilassie et al., 2017; Alebel et al., 2017).

Empirical evidence on the role of institutions and their effect on economic performance argues that institutional failure is a core factor that impedes economic performance and industrial development (Acemoglu and Robinson, 2000). Europeans adopted two extremely different strategies of colonization in which countries such as the United States, New Zealand, and Australia set up institutions that encouraged investments and enforced the rule of law whereas on the other extreme countries like Congo set up extractive institutions which enabled them to transform resources even if the institutions were detrimental to the economic performance of the colonies (Acemoglu et al., 2001). Acemoglu and Robinson, (2008) shows that the economies of South and North Korea diverged because of the differences in their economic institutions and policies. It should be noted that the gap between the two economies can to a large extent be attributed to decades of US sanctions against the North. Lee and Lim (2010) did a case study in Korea and empirically showed that the good governance and transparent policymaking generated successful policy outcomes in an era of democratization.

Yildirim and Gokalp (2016) explored the association between institutional structure and macroeconomic performance empirically where institutions were proxied by indicators such as integrity of the legal system, regulations on trade barriers, restrictions in foreign investments, judiciary's independence, and political stability for 38 developing countries. Their results confirmed that regulations on trade barriers and restrictions on foreign investments had a positive effect while judiciary's independence and political stability had a negative impact on the macroeconomic performance of the countries. Bates and Block (2018) empirically examined the change in political regime from authoritarian to a democratic system in many African countries. Their results showed that democratic reforms led to economic growth.

Chole and Manyazewal (1992) examined the macroeconomic performance of the Ethiopian economy during the Derg regime when there was a very low contribution of industry as a share of GDP. They attributed this to different factors including war and the policy environment. Geda and Berhanu (1960) investigated the political economy of growth in Ethiopia and found that the absence of structural transformation for four decades is attributed to initial conditions and structural problems. Their study also confirmed that productivity growth had a negative role which they attributed to an economy operating in a hostile policy environment and external shocks. Berhanu and Poulton (2014) examined the political economy of the agricultural extension policy in Ethiopia. They find that there was conflicting interest between the objective of stimulating agricultural growth and winning elections which reduced returns to investments for the agricultural extension strategy.

To conclude, review of the literature revealed that industrialization was a major pillar for structural transformation in many countries and institutions were major determining factors in the success of industrialization. Several studies confirm that industry policies can change the structure of the economy. However, this largely depends on the type of institutional environment which can be a tool that facilitates optimal industrialization or leads to deindustrialization. If inclusive, it could lead to industrialization but could also be an impeding factor for industrialization if it is extractive. The role of political economy in industrialization of sub-Saharan countries had contrasting effects where for some it brought a momentum to their industrialization processes whereas for most countries it had a negative impact. Hence, this study investigates the role of political institution on industry performance over time along with the assessment of different industrial policy strategies and their organizational structures relating it with the performance of the Ethiopian industry and the economic structure.

3. Data and Methodology

3.1 The Empirical Model

There has been a growing interest in exploring the role of institutions in promoting growth in developing and emerging economies to determine the extent to which institutions affect growth (Aron, 2000; Stiglitz, 1998; WB, 1993, 1997). The empirical model for specification of institution and growth relationship is formulated (Barro, 1991,1996; Mankiw et al., 1992; Zakaria and Fida, 2009). In our study, an extension is made to sectoral growth taking Ethiopia as a case study.

$$Y = Af(L,K) \qquad \textbf{(1)}$$

In equation (1), Y represents production and the right-hand side variables represent inputs that explain the variations in production; A represents technological progress, L stands for labor while K is capital. To include institutional differences in the model, the literature maintains that institutional quality affects technological progress implying that technological progress is not constant across countries and instead it depends on the differences in their respective institutions (Aron, 2000). Equation (2) gives the functional relationship of production growth with institutional variables and other covariates as control variables:

$$LogY_t = \alpha + \sum_{i=1}^{K} \beta_i I_{it} + \sum_{j=1}^{n} \gamma_j X_{jt} \beta + \varepsilon_t \qquad \textbf{(2)}$$

where Y is representing manufacturing industrial production, α is a constant parameter to be estimated and I represent institutional variables. The polity2 index represents political institutions while the percentage of exports and imports to GDP is used as a proxy for openness. X represents a vector of the inputs or control variables, labor and capital, with α, β, and γ parameters to be estimated, ε represents the random error term and t is a subscript for time.

The role of political institution in the manufacturing industry's growth is empirically modeled in a time series autoregressive distributed lag model (ARDL) framework. Apart from investigating the existence of an empirical relationship between institutions and growth, this study explicitly estimates the long-run and short-run effects. OLS with robust standard errors is estimated for a comparison while the ARDL is used as the main estimation approach because of mixed order of integration which can only be estimated by ARDL. Before the estimation, the bound test for the existence of a long-run relationship between the variables is checked. Then equation (3) is estimated to get the long-run parameter estimates as:

$$LogMVA_t = \alpha_0 + \sum_{i=0}^{p} \alpha_1\, logMVA_{t-1-i} + \sum_{i=0}^{q} \alpha_2 logI_{t-i} + \sum_{i=0}^{q} \alpha_3 logL_{t-i} + \sum_{i=0}^{q} \alpha_4 logK_{t-i} + \varepsilon_t \quad \textbf{(3)}$$

$$LogMVA_t = \beta_0 + \sum_{i=0}^{p} \beta_1\, logMVA_{t-1-i} + \sum_{i=0}^{q} \beta_2 logPolity2_{t-i} + \sum_{i=0}^{q} \beta_3\, logOpnness_{t-i} + \sum_{i=0}^{q} \beta_4 logL_{t-i} + \sum_{i=0}^{q} \beta_5 logK_{t-i} + \varepsilon_t \quad \textbf{(3a)}$$

Equation (4 and 4a) presents the short-run specification of the ARDL model where d indicates change. The dependent variable is logarithm of manufacturing value added (MVA) while institutions are proxied with the polity 2 index which is a proxy for regime change (political institutions) and trade openness as economic institutions. Error correction term (ECM) is included to show to what extent the model adjusts to the long-run equilibrium annually:

$$dlogMVA_t = \alpha_0 + \sum_{i=0}^{p} \alpha_1\, dlogMVA_{t-1-i} + \sum_{i=0}^{q} \alpha_2 dlogI_{t-i} + \sum_{i=0}^{q} \alpha_3 dlogL_{t-i} + \sum_{i=0}^{q} \alpha_4 dlogK_{t-i} + \lambda_1 logMVA_{t-1} + \lambda_2 logI_{t-1} + \lambda_3 logL_{t-1} + \lambda_4 logK_{t-1} + \gamma ECM_{t-1} + \varepsilon_t \quad \textbf{(4)}$$

$$dlogMVA_t = \beta_0 + \sum_{i=0}^{p} \beta_1\, dlogMVA_{t-1-i} + \sum_{i=0}^{q} \beta_2 dlogPolity2_{t-i} + \sum_{i=0}^{q} \beta_3 dlogOpnnes_{t-i} + \sum_{i=0}^{q} \beta_4 dlogL_{t-i} + \sum_{i=0}^{q} \beta_5 dlogK_{t-i} + \lambda_1 logMVA_{t-1} + \lambda_2 logPolity2_{t-1} + \lambda_3 logOpnness_{t-1} + \lambda_4 logL_{t-1} + \lambda_5 logK_{t-1} + \gamma ECM_{t-1} + \varepsilon_t \quad \textbf{(4a)}$$

3.2 The Data

This study uses primary and secondary data taken from the Ministry of Finance and Development Corporation (MoFEC), the National Bank of Ethiopia (NBE, 2016, 2019), Ethiopian Economic Association (EEA), the Ethiopian Central Statistical Authority (CSA, 1995/96, 2011. 2016), the Industry Park Development Corporation (IPDC, 2019) in Ethiopia.[4], and United Nations Conference on Trade and development (UNCTAD). For the primary data, on industrial policy strategies informal interviews, focus group discussions, and personal observations were used along with an extensive document review of different policies, plans, and reports on the industry and the economy for the study period. Secondary data on polity2 was taken from the Polity IV project dataset. Polity2 score is an index ranging from -10 to +10 representing full autocracy and complete democracy respectively while the range between -5 to 5 represents anocracy (Zakaria and Fida, 2009; Marshall et al., 2002). It is used to represent the level of democracy or to represent a political regime change. The data for openness and capital are accessed from UNCTAD while data for labor and manufacturing value added data was taken from MoFEC.

A multivariate regression analysis is done to empirically complement the qualitative analysis of the political economy of industrialization in Ethiopia taking the manufacturing value added as the dependent variable and polity2 as the proxy for political institutions which is a major variable of interest. The expected sign for polity2 is negative indicating that a political regime change has a negative impact on manufacturing growth. The expected sign for openness is positive with the implications of a positive trade impact on manufacturing growth. In the estimation, labor and capital are considered as control variables with expected positive signs.

A time series ARDL framework is used for estimating the parameters of the model. The ARDL approach is robust and efficient for estimating a small sample sizes. Unlike many other models it allows to include variables with a mixed order of integration less than I(2) and it enables an estimation of long-run and short-run coefficients for a specified model (Pesaran et al., 2001). The

[4] The primary data is collected to supplement the analysis of industry parks based on secondary data. the data is collected from Bole Lemi I during the study period, Hawassa and Bole Lemi I were the only operational parks.

ARDL approach also provides unbiased coefficient estimates even when the explanatory variables are endogenous (Harris and Sollis, 2003; Pesaran et al., 2001; Pesaran and Shin,1999). The first estimation procedure is testing for the existence of a long-run relationship among the variables using the bound test. The null hypothesis for the bound test is no cointegration. If the F-statistic's value is higher than the upper critical value, we reject the null and confirm the existence of a long-run relationship. The opposite holds true that if the F-statistic at a given significance level is less than the upper critical value (Pesaran et al., 2001) we fail to reject the null and long-run cointegration is denied. The next procedure is estimating the long-run and short-run coefficients of the specified model.

4. Discussion of the Results

4.1 Descriptive Analysis

This section discusses the performance of the manufacturing and industry sectors across the regimes. Economic and political institutions, industrial policies, and organizational structures are also discussed followed by the different development and industrial strategic plans. Ultimately, the industrial parks in Ethiopia is evaluated to find out their contribution to employment generation, export promotion, foreign exchange generation, and value chain along with indications of their limitations for future policy use.

4.2 Industry and Economic Performance in Ethiopia Across Regimes

Table 1 gives the contribution of different sectors to the overall economy across the three regimes. During the Imperial regime, agriculture dominated the economy with a 66% share of GDP followed by service and industry sectors with 25% and 8% share respectively. During the Derg regime, the contribution of agriculture declined by 8% though it was still the leading sector in the economy whereas the contribution of the service sector increased to 31% and the industry sector also had a 2% increase. In the current regime, on average, agriculture is contributing 50% to GDP, the service sector 39%, and the industry sector 10%. The low manufacturing sector share imply that for more than eight decades its contribution to the economy did not exceed 5% due to many factors some of which are explained later.

Table 1: Sectoral share of GDP and their respective growth across regimes in %.

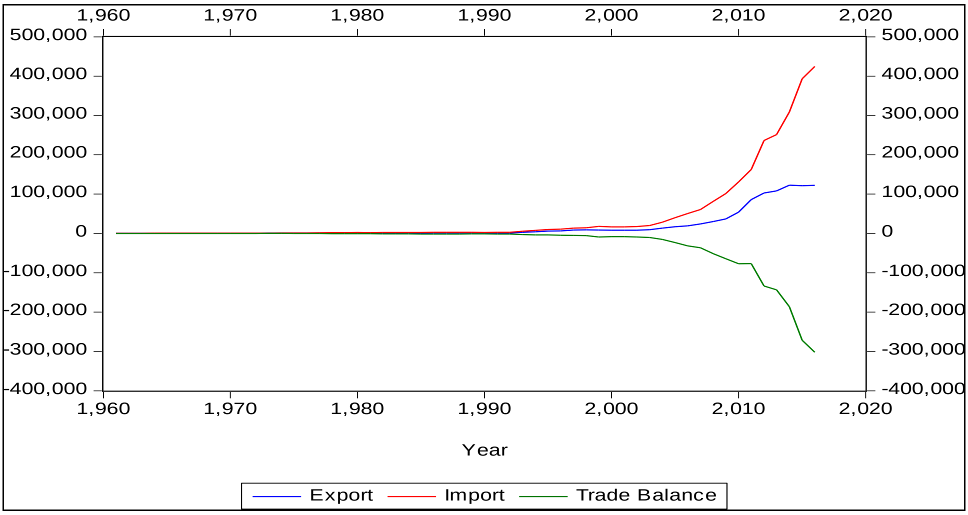
Regimes	Imperial (1930-1974)		Derg (1974-1991)		EPRDF (1991 onwards)	
	Share	Growth	Share	Growth	Share	Growth
Agriculture	66	2	53	2.0	50	6
Industry	8	7	10	1.8	10	10
Manufacturing	3	8	5	1.6	4	9
Service	25	7	31	1.6	39	12

Source: Authors' compilation based on EEA and MoFEC data.

A comparison of the share of exports and imports determine the trade balance. During the Imperial regime, the proportion of exports and imports seemed to be balanced with imports having a slight dominance. In the Derg regime, imports dominated and even in the recent regime the dominance of imports is indicating a negative trade balance or trade deficit which requires foreign exchange from other sectors to balance import expenditure. In sum, the data shows that Ethiopia has been experiencing trade deficit for decades which can be attributed to the low performance of the manufacturing and industry sectors. Manufacturing contributed less than 5% to the GDP for several decades which impeded the export sector and made the export to rely on primary commodities trade in the international market.

In Figure 1, the trade balance or the difference between exports and imports for the three regimes is given. Relatively, the dominance of imports is significantly large in the current regime indicating a high trade deficit which weakens the sector and will be transmitted to the overall economy. The challenges of a large deficit will have an impact on the structural transformation that should take place in the country. Large trade deficit implies an accumulated government debt and the limited foreign exchange reserve is spent to pay for the imports.

Figure 1: Trade performance across the regimes



Source: Authors' computation.

Table 2 provides the major export and import items during the three regimes. The table also classifies the current regime into the first decade where agricultural development led industrialization (ADLI)[5] was implemented and the later one which is after the introduction of the industrial development strategy (IDS)[6]. Coffee had the lion's share as a major export item across the three regimes. In the Imperial regime, apart from coffee, skin and hide, primary commodities were dominant export items. In the same regime, cotton was a major import item with a 41% share of the total import value followed by petroleum, metal products, and salt having another 20% share in total imports. During the Derg regime, leather products were the second major exported item followed by oilseeds, pulses and chat. Machinery and aircraft were the major imported items along with petroleum, road motor vehicles, food, and live animals.

[5] Ethiopia adopted the agricultural Development Led Industrialization (ADLI) strategy in 1993 aiming at enhancing industrial development, reducing poverty and ensuring a dynamic and sustainable growth in the Economy (Dube et al., 2019).

[6] The overall aim of industrial development strategy (IDS) in Ethiopia adopted in 2003 is to bring about sustainable structural change through industrial development (FDRE Ministry of Industry, 2013).

Figure 2 shows that Asia is a major source of Ethiopia's imports and destination for exports (36% and 62% out of the total respectively). The second destination for exports and source of imports is Europe (32% and 18%) Africa is the third destination of exports at 21% but only 6% of the imports. 10% of the exports go to the US and 13% of the total imports come from the US. This shows that the main source of imports and destination of exports is dominated by Asian countries mostly China. Technology and knowledge spillover effects of trade are limited and more inclined in Asia's favor. Asian companies are penetrating the country in the construction industry as well as the industrial park project because of the advantage of cheap labor and tax holiday. The managing positions of the projects are run by the Asian partners leaving no room for local experts. This should ring alarm bells for Ethiopia to work on its international relations to get real transfer of knowledge, technology, and value chains for the local industries.

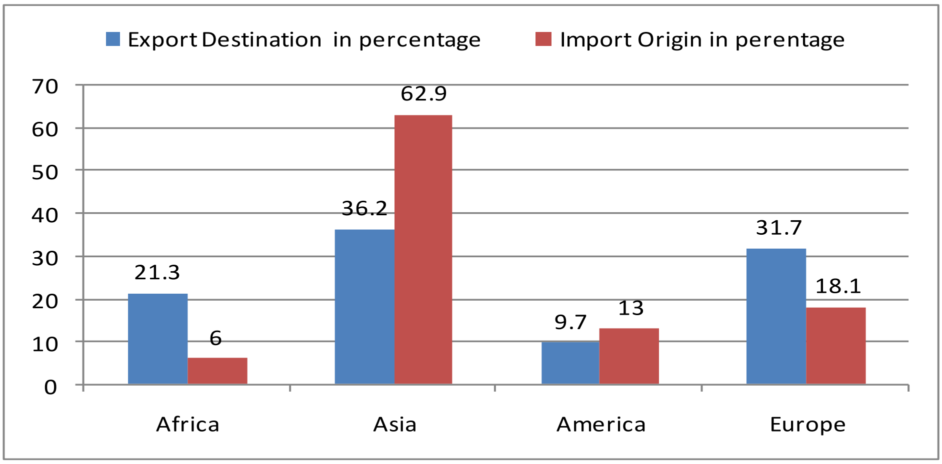
Table 2: Major export and import items across regimes

Regimes	Major Export Items	Share, %	Major Import Items	Share, %
Imperial	Coffee	46	Cotton products	41
	Skin and Hide	18	Petroleum products	7
	Flour and Vegetable oils	17	Metal and metal products	5
	Cereals and Pulses	15	Salt and/or sugar	4
Derg	Coffee	64	Machinery and aircraft	16
	Leather and Leather products	16	Petroleum crude	13
	Oilseeds and Pulses	4	Road motor vehicles	12
	Chat	3	Food and live animals	11
EPRDF (ADLI)	Coffee	60	Petroleum production	14
	Leather and Leather products	13	Road motor vehicles	13
	Chat	9	Machinery and aircraft	12
	Oilseeds and Pulses	6	Others	17
EPDRF (IDS)	Coffee	31	Petroleum production	14
	Oilseeds and Pulses	22	Machinery and aircraft	14
	Chat	10	Metal & metal manufacturing	11
	Leather and Leather products	6	Others	22

Source: Authors' calculations using MCI (1955).

Notes: ADLI = agricultural development led industrialization, IDS = industrial development strategy.

Figure 2: Ethiopia's current export destinations and import origins in %.



Source: Authors' computation.

In the early period of the contemporary regime, coffee was an exported item followed by leather products, chat, oilseeds, and pulses. Later, oilseeds became a dominant exported item with a declining share of leather products. Regarding import items, petroleum, road motor vehicles, and metal products became dominant. However, the import of food, live animals, and consumer goods is still significantly huge implying the weak engagement of the domestic industries in working on their comparative advantages like cereal production, textiles, food, live animals, and leather products. In general, the trade sector shows that for decades the country was engaged in exporting a limited number of primary commodities and importing capital goods which shows an unexploited export sector that negatively impeded the trade balance due to a failure in diversifying the sector and neglecting to empower the domestic infant industry.

Table 3 gives the industry and manufacturing value added as a share of GDP and industry exports as a share of total merchandise exports and GDP respectively during the Imperial, Derg and EPRDF periods. As the table shows, industry did not exceed 10% and manufacturing value added as a share of GDP was 4% for the two periods. Industrial exports as a share of total exported merchandise was 16% and not more than 1% of the total GDP during the same period. This shows that for almost five decades under these two political regimes the contribution of manufacturing industry and its exports share to GDP was close to zero.

Table 3 shows the manufacturing and industry's value-added share of GDP during the first ADLI implementation period and after the implementation of IDS complemented by consecutive development plans such as SDPRP, PASDEP, GTP I, and GTP II. Besides, it also shows the contribution of industry to the export sector and industry exports as a share of GDP. During the first decade, industry value added was 8% and manufacturing value added was 3% while industry exports as a share of GDP was only 1%. These figures showed a slight improvement indicating the potential of the sectors to change from their steady stance for more than eight decades if supported by relevant industrial policies that go along with the competitive advantage of the country and its overall economic environment.

Table 3: Industry and manufacturing's performance indicators during the Imperial, Derg and EPRDF Regimes

Regimes	Industry Value added (%GDP)	Manufacturing Value added (%GDP)	Industry Export/Total Merchandize Export (% GDP)	Industry Export (% GDP)
Imperial	8	4	1.8	-
Derg	9	4	15.6	0.5
EPRDF	11	4	8	4
ADLI	8	3	12	1
SDPRP	9	3	11	2
PASDEP	9	4	6	4
GTP I	12	4	4	9
GTP II	24	6	4	4

Source: Authors' compilation.

Table 4 gives the current percentage distribution of manufacturing industries across different regions in Ethiopia. When Ethiopia adopted a new federal constitution in 1994, with the borders defined along ethno-linguistic lines, the country was divided into a set of eight regions and three city states (Briggs, 2012). Currently, we have two city states Addis Ababa and Dire Dawa while the regions include Amhara, Tigray, Afar, Oromiya, Somaliya, Benishangul, Southern Nations, Nationalities and Peoples' State (SNNP), Harari and Gambella (CSA, 2016). As the table confirms, on average during 2012-2016, of the existing different industries in the country 34.8% are located in Addis Ababa. Oromiya, Amhara, and Tigray regions have 28%, 11.2%, and 9% share of the industries respectively.

Table 4: Current percentage distribution of industries by regional states

Regions/Years	2012	2013	2014	2015	2016
Amhara	13	12	12	11	8
Afar	0.53	0.68	0.36	0.25	0.22
Tigray	8	8	8	7	14
Oromiya	26	27	30	32	28
Somalia	0.94	1.10	1.10	0.95	0.64
Benishangul Gumuz	0.20	0.34	0.36	0.19	0.17
Gambella	0.08	0.04	-	-	-
Harari	0.94	1.10	1.20	1.20	0.56
SNNP	12	11	12	10	9
Addis Ababa (City State)	37	33	33	35	36
Dire Dawa (City State)	2.50	2.90	3.30	2.90	2.90

Source: Central Statistical Agency of the FDRE (CSA, 2016).

4.3 Economic and Political Institutions across Different Regimes

Table 5 shows the political institutions in terms of forms of governance and government ideology and economic institutions across the three regimes. During the Imperial regime, there was a monarchical form of government in which political power was centralized in the hands of the King with an ideology of feudalism along with a parallel market-oriented economy. Whereas, during the Derg period there was dictatorship with a central planning ideology and a command economic system which gave a platform only to the public sector ignoring the private sector which is the seed for efficient production in any economy. The current regime has an anocracy[7] form of governance with a developmental government ideology giving space to the government and the public sector for organizing production and administrating institutions along with private sector participation. The economic system promotes public-private sector partnerships as the main actors in the economy. Hence, in the three regimes the political economy, government ideology, and economic institutions were different. Table 5 shows that for the three political periods the value added contribution of manufacturing to GDP never exceeded 5% implying

[7] Anocracy is a form of governance which is neither pure democratic nor does a pure autocratic. It combines both features (Deacon, 2009).

that even though the political institutions were different they were weak and impeding the economic outcomes giving priority to political rent seeking behavior rather than nation development.

Table 5: Political and economic institutions across regimes in Ethiopia

Regimes	Forms of Government (Political Institution)	Government Ideology	Economic Institutions	Value Added/ GDP in %
Imperial (1930-74)	Monarchy	Feudalism	Market Economy	3
Derg (1974-91)	Dictatorship	Socialism	Command Economy	4
EPRDF (1991-to date)	Anocracy	Developmentalism	Mixed Economy	4

Source: Compiled by the authors using different data sources.

4.4 Industrial Strategies and Organizational Structures in Ethiopia

During the Imperial period economic development in the country was mainly relied on subsistence farming and with an almost non-existent industrial sector (David and Thomas, 2013). However, national development policies were implemented for promoting industrial activities under a series of three five-year plans. The plans focused on industry and provided development incentives such as tax exemptions and low interest rate loans (Suleiman, 2000; TGE, 1993).

During the Derg regime the industrialization policies could not be separated from the country's agricultural policies. The war time economic policy focused on mobilization of resources to serve the war economy leading to serious damage to the economy (Deguefee, 2006; Oqubay, 2018; Tiruneh, 1990). The overall objective of the government for development was building a socialist society where the major route to economic transformation was central planning (Suleiman, 2000). In this regime, a significant number of manufacturing enterprises owned by foreigners were nationalized (David and Thomas, 2013). The socialist policy also promoted public ownership of natural resources (Suleiman, 2000). Among the key strategies in the Derg's industrial policy were import substitution, central planning, social ownership, and self-reliance (Oqubay, 2018).

During the EPRDF regime, several reforms were introduced on the basis of which the long-term economic development strategy, the Agricultural Development Led to Industrialization (ADLI) strategy was formulated. This new policy aimed at raising agriculture's productivity and promoting an export oriented agro-based industry sector. The target was achieving sustainable economic growth and development (Suleiman, 2000; TGE, 1993). The new policy had been employed in some form by many African countries. The policy lacks disaggregation of the existing situation in the country in terms of resources, institutions, infrastructure, and other related relevant issues (Briggs, 2012; Suleiman, 2000; TGE, 1993).

Table 6 gives the development plans and strategies that have been pursued by the country across different regime periods. During the Imperial regime, there were three consecutive five-year national plans: the first five-year plan (FFYP), the second five-year plan (SFYP), and the third five-year plan (TFYP) which all aimed to enhance the economic performance. During the first decade of the Derg regime there was no plan at the national level but for its second decade the government came up with a 10-year prospective plan. During the current regime, different development plans have been introduced at the national level such as the sustainable development and poverty reduction program (SDPRP), a plan for accelerated and sustained development for ending poverty (PASDEP), growth and transformation plan I (GTP I) and the recent growth and transformation plan II (GTP II).

In Table 6 different development ideologies are pursued giving the role of a follower and a leader to the industry for achieving structural transformation and poverty reduction goals. The first development plan was the ADLI which gave priority to the agriculture sector whereas the second was the IDS which prioritized development of the industry as a means of achieving structural transformation targets. The ADLI mainly focuses on agriculture sector by improving the productivity of peasant farmers to enable the sector to contribute to economic growth (MPED, 1993) The IDS mainly focus on labor intensive industries, export promotion industrial strategy, strong government leadership role, and private public partnership (PPP) (FDRE Ministry of Industry, 2013). This shows that the country has been through different types of development plans across the regimes and pursued distinct development strategies and yet all been ineffective in transforming the structure of the economy. The failed industrialization can be attributed to weak institutions and unfavorable political environment.

Table 6: Development plans and strategies across regimes

Regime	Development Plans	Development Strategy
Imperial	✓ First Five-Years Plan (FFYP) ✓ Second Five-years Plan (SFYP) ✓ Third Five-Years Plan (TFYP)	✓ Unstructured
Derg	✓ Ten-Year Prospective Plan (1984-1994)	✓ Unstructured
EPRDF	✓ Sustainable Development and Poverty Reduction Program (SDPRP) (2002/03) ✓ A Plan for Accelerated and Sustained Development to end Poverty (PASDEP) (2005/06) ✓ Growth and Transformation Plan I (GTP I) (2010/11) ✓ Growth and Transformation Plan II (GTP II) (2015/16)	✓ Agricultural Development led Industrialization (ADLI) (1994) ✓ Industrial Development Strategy (IDS) (2002)

Source: Authors' compilation.

Table 7 gives different industrial strategies and organizational structures and prioritized industries during the three governance periods. In the Imperial regime, import substitution industrialization was a major industrialization strategy with a centralized industrial policy. In the central planning period, the industrial policy was the same as the former regime, but the major actor was the inefficient public sector. In the EPRDF period, the industrialization strategy was export oriented targeting labor-intensive manufacturing industries. This shows that two extreme industrial strategies with different organizational structures were implemented in Ethiopia across these periods focusing on labor intensive industries. All in all, the manufacturing industry has for several decades failed to respond to the different policies implemented. This can be attributed to the large gap between the policies and the way they were implemented which did not consider the initial conditions in the country. Instead of focusing on the real situation, the focus was on producing political reports. It seems policies were implemented with a priority focus of the political goals than the economic outcomes.

Table 7: Industrial and organizational strategies across regimes

Regimes	Strategies	Organizational Structures	Dominant Ownership	Prioritized Industries
Imperial (1930-74)	Import Substitution	Centralized	Foreign company	Labor intensive
Derg (1974-91)	Import Substitution	Centralized	Public sector	Labor intensive
EPRDF **(**1991-todate**)**	Export Promotion	Partially Centralized	Private sector	Labor intensive

Source: Authors' compilation.

4.5 Contribution of Industrial Parks and their Limitations in Ethiopia

Table 8 gives the number, type, location, and operational status of industrial parks in Ethiopia along with the type of employment in the production processes. As of date there are 11 industrials parks in the country located in different areas. Most of the parks are focusing on textiles, apparel, and garments except Killinto and Adama which are pharmaceutical hub and machinery equipment hubs. This shows that the parks are not considering the country's competitive advantage which is agroindustry and leather production along with textiles. Among these parks, only Bole Lemi I and Hawasa industrial parks have been operational and are engaged in employment creation, production, and exports. Most of the employees are unskilled who are given short term training on how to run machines which limits the technology and knowledge transfer goals of the industrial park industrialization strategy.

The industry parks are dispersed across the country. As can be seen the parks are distributed all over Ethiopia without taking the logistical and infrastructural conditions into consideration. They are located on the grounds of political motivation of allocating parks to all areas in order to avoid sociopolitical unrest. Instead, the implementation should have been strategic and targeted based on static and dynamic outcomes of the industrial policy's strategy by considering excessive investment cost saving. The optimal strategy should aim to augment the strategic policy in a way that exploits the competitive advantages of the parks and strengthens the infant domestic private industries that can sustain industrialization in the country.

Table 8: Characteristics of industrial parks in Ethiopia

Establishment/ Name of the IP	Types	Locations	Operational status	Employment
Bole Lemi I	Apparel & Textile	Addis Ababa	Operational	Unskilled labor
Bole Lemi II	Apparel & Textile	Addis Ababa	Not Operational	-
Kilinto	Pharmaceutical Hub	Addis Ababa	Not Operational	-
Hawassa phase _I	Textile and Garment	Hawassa	Operational	Unskilled labor
Hawassa phase _II	Textile and Garment	Hawassa	Operational	Unskilled labor
Adama	Machinery, Equipment, Apparel & Garment	Adama	Not operational	-
Dire Dawa	Garment, Apparel & Textile	Dire Dawa	Not operational	-
Mekele	Apparel & Textile	Mekele	Operational	Unskilled labor
Kombolcha	Apparel & Textile	Kombolcha	Operational	Unskilled labor
Jimma	Apparel & Textile	Jimma	Inaugurated	Unskilled labor
Bahir Dar	Apparel & Garment	Bahir Dar	Not operational	-
Debre Birhan	Apparel & Garment	Debre Birhan	Inaugurated	Unskilled labor

Table 9 presents the investment costs of the industrial parks in Ethiopia. The Hawasa industrial park was the first large project set up at a cost of 6.8 billion Ethiopian birr followed by Dire Dawa and Adama industrial parks with 3.0 billion and 2.9 billon birr as investment costs respectively. Mekele, Kombolcha, Jimma, and Bahir Dar industrial parks, on average, cost 1 billion birr each. This implies that launching an industrial park involves high fixed costs and if they are not implemented properly the opportunity costs are significant which contribute to the accumulated debt. Instead of launching industrial parks with high initial investment cost in every part of the country, choosing strategic locations would have saved capital that could be used to support local industries to become productive and improve the quality of their products.

Table 9: Project investment costs of industrial parks in Ethiopia

No.	Project name	Project investment cost in birr[8]
1	Bole Lemi I industrial park	525,620,301
2	Hawasa industrial park	6,830,726,519
3	Mekelle industrial park	1,837,235,013
4	Kombolcha industrial park	1,775,354,563
5	Adama industrial park	2,901,638,220
6	Dire Dawa industrial park	3,016,582,161
7	Debre Birhan industrial park	952,798,094
8	Jimma industrial park	1,490,737,363
9	Bahir Dar industrial park	1,125,626,510
10	Kilinto industrial park	8,590,523

4.6 Operational Industrial Parks and their Contributions

Table 10 presents the major investors in the two operational industrial parks: Hawassa and Bole Lemi I along with their major sources of inputs for production in the parks. About 75% of the investor companies are from Asia whereas another 5% are from the US, 5% from Africa, 10% from Europe, and only 5% are domestic investors. This shows that most investors in the operational parks are from the rest of the world implying the limited

[8] The exchange rate for the local currency varies over time. The average exchange rate in 2016 was 1USD=27 Ethiopian Birr (NBE, 2016)

participation of local infant industries which are supposed to sustain the industrialization and structural transformation of the country. All the industries located in the parks use imported inputs leaving little space for the industrial parks to contribute to the value chain.

Table 10: Hawassa and Bole Lemi-I industry parks' investors by origin in %

Investors Country by Origin in Hawassa	Ownership in %	Sources of inputs	Investors by Country in Bole Lemi-I	Owners hip in %	Sources of inputs
USA	5	Imported	India	45	Imported
Europe	10	Imported	China	27	Imported
Asia	75	Imported	South Korea	27	Imported
Africa	5	Imported	Africa	-	-
Ethiopia	5	Imported	Ethiopia	-	-

Source: Authors' compilation.

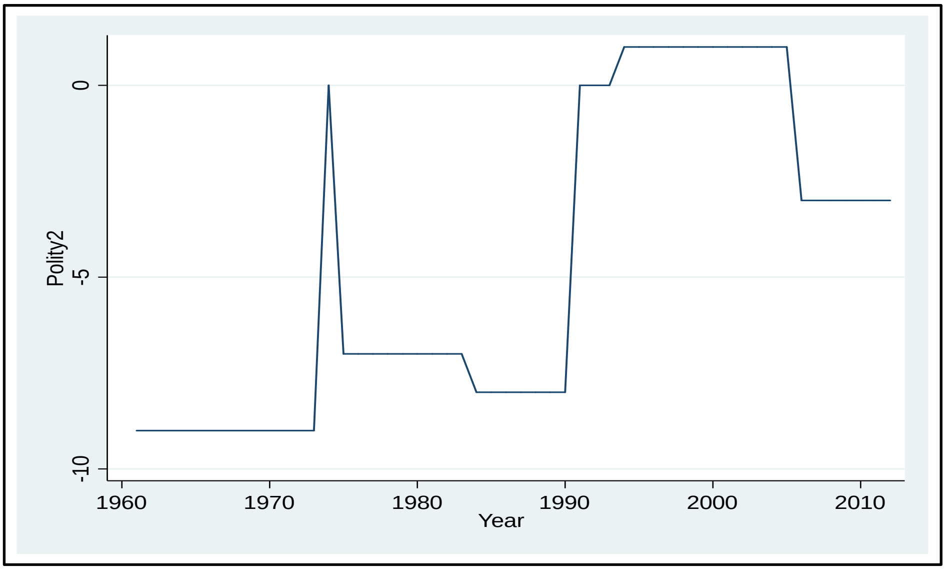
Concerning employment, in Hawassa industry park of the 60,000 full capacity employment, 44% or 26,599 persons were employed by the companies located in the park. In Bole Lemi, 67% of full capacity of 25,000 or 16,763 persons were employed in the park as of to date. Regarding to exports, Hawassa exported approximately 63 million USD and 40 million USD was generated from the Bole Lemi industrial park. The parks create temporary employment opportunities for thousands of people but as it is indicated in Table 8 the employees are unskilled without the potential of taking advantage of technology and knowledge spillover effects. They are also unable to take over and sustain production in the absence of the foreign employees. Around 95% of employees in the parks are imported labor.

5. Regression Analysis of Polity and Manufacturing Industry's Growth

This section empirically discusses the role of polity2 in the manufacturing industry's growth in Ethiopia. Polity2 measures the level of democracy across different regimes with a value ranging from -10 to 10 indicating autocracy (-10) in an extreme case and the democracy (10) level of a country. The values ranging from -5 to 5 represent a case called anocracy with the features of a mixed democracy and autocracy (Deacon, 2009). This section provides the overall trend in polity2 in Ethiopia across regimes followed by the regression results of the impact of the political institution proxied by polity2 index on industry's growth controlling for openness, labor and capital in the model.

Figure 3 gives the overall trend of the polity2 index for the three political periods in Ethiopia. During the Imperial period, the polity2 was close to -9 indicating a level very close to autocracy with centralized powers with the government. During the Derg regime, except for a few periods in which the index indicated anocracy the entire regime was autocratic with an economy that had centralized planning and an ideology of socialism. During the EPRDF period, the index indicates that the anocracy level of democracy or governance altered at different levels. This shows that the level of democracy measured by the index over time was more autocratic in the two regimes and currently more of anocracy with some level of democracy.

Figure 3: Development of Ethiopian polity2 index trend over time



The descriptive statistics for the variables in the regression model are presented in Table 11. The dependent variable is manufacturing industry's value added (MVA). There are four explanatory variables in total and a major explanatory variable of interest is polity2 index measuring the form of governance in the country. The index indicates political institution while labor, capital and openness are considered as control variables in the model. In the sample, there are 44 time-series observations from 1970 to 2013. The study period is limited by data availability on the polity2 index. Table 11 gives the summary statistics of the data prior to log transformation.

The first step in any time-series regression analysis is testing for the stationarity of the series using different unit root tests. Table 12 provides the Augmented Dickey Fuller unit root test's results for the variables in the model. Manufacturing value added, capital, and the polity index are non-stationary at level but stationary at first difference indicating that these variables are integrated of order one while labor is trend stationary and is integrated of order zero. Hence, this calls for a method of estimation such as ARDL that accommodates the mixed order of integration.

Table 12: Augmented Dickey Fuller unit root test's results

Variables	At level		At First Difference		Order of Integration
	Intercept	Trend with intercept	Intercept	Trend with intercept	
MVA	0.9631	0.8331	0.0055	0.0164	I (1)
Labor	0.9999	0.0022	0.6591	0.9642	I (0)
Capital	0.8512	0.2075	0.0000	0.0000	I (1)
Polity2	0.2266	0.3676	0.0000	0.0000	I (1)
Openness	0.6815	0.7409	0.0000	0.0004	I (1)

Before the estimation, the optimal lag length is selected based on different selection criteria with two being opted for as an optimal lag length for the model. Based on a number of tests (LR, FPE, AIC, SC and HQ) [9] shows all the variables in the model have two as the optimal lag length.

[9] To conserve spaces, all results are not presented here. They are available from the authors upon request.

The bound test for the existence of a long-run relationship confirms the existence of a long-run relationship between the form of government or political institutions and the manufacturing industry's growth in Ethiopia. The value for the F-statistic with 4 restrictions (7.29) is greater than the upper and lower bound at the 1% level of significance. This result confirms the existence of long-run relationship but does not provide the direction of the relationship and the magnitude of the relationship between the variables of interest. Hence, we proceed to the long-run and short-run estimation of the coefficients.

Table 13 gives the estimation results from ARDL. In both the cases polity2 is found to be statistically significant and negatively impacting manufacturing growth in Ethiopia. Trade openness in both the models is statistically significant and positive. However, the OLS coefficients are not taken because some variables in the model are not stationary at level resulting in spurious results but corrected by the ARDL approach. Based on the ARDL estimation results, polity2 is significant with a negative effect. A one-unit change in polity2 or regime change from democracy to autocracy will reduce manufacturing growth in the long-run. This means when power is centralized it negatively impacts the performance of industry. Similarly, the form of government is statistically significant and negatively affects manufacturing growth in the short-run. Openness in the ARDL model's estimation is statistically significant and positive both in the long-run and short-run. The adjustment coefficient is statistically significant with a negative coefficient value indicating 26% adjustment to the long-run equilibrium annually.

Table 13: Determinants of manufacturing industry value-added in Ethiopia

Variables	**ARDL Long-run**			**ARDL Short-run**	
	Coef.	**p-value**	**Variables**	**Coef.**	**p-value**
Labor	1.3707	0.0005	D(Polity)	-0.0089	0.0000
Capital	0.1970	0.4114	D (openness)	0.2949	0.0000
Polity2	-0.0492	0.0003	D(openness (-1)	0.2928	0.0001
Openness	0.5366	0.0482	CointEq(-1)	-0.2575	0.0000
Constant	-4.8426	0.0831			

Adj R^2 = 0.8805, F-test probability = 0.0000, Number of Observations = 44

To consider the implications of the estimated results one must check the model through diagnostic tests. In this study a post estimation test for normality, autocorrelation, heteroscedasticity, and model specification tests was done with the probability value of the tests statistics enabling us to reject the null hypothesis of the existence of the statistical problems. The diagnostic test results are in favor of the estimated model. The normality test of the residuals in the model and the Jarque-Bera probability is 0.88. Based on that, we fail to reject our null hypothesis that the residuals in our model are normally distributed. In testing the post-estimation coefficient stability of the model, the results showed that at the 5% significance level the estimated coefficients in the model are stable.

6. Conclusion and Policy Implications

This study investigated the political economy of industrialization in Ethiopia. The Ethiopian modern history covers three political regimes that pursued different industrial policies organized in the framework of different economic systems. The Imperial period was characterized by a centralized market economy with an import substitution industrial policy for labor intensive industries. The Derg regime, which had a centralized command system, pursued an import substitution policy. The current regime which is organized as a non-centralized market-oriented system promotes exports for labor-intensive industries.

In the three regimes, despite the different economic systems and policy strategies the contribution of the industry sector to GDP and employment was not significant. The share of manufacturing industry did not exceed 5% for more than eight decades and the share of manufacturing exports in total exported merchandise and GDP was very minimal. The trade sector across different regimes was also in deficit. The study showed that coffee was a major export item during this period. In general, exports were dominated by primary commodities and capital goods were the major imports with an insignificant share of industrial products in the export sector. Currently, Asia is the dominant continent for Ethiopia’s international trade and Addis Ababa is a major city for industries (35% share) followed by Oromiya, Amhara, and Tigray with 28%, 11%, and 9% share respectively.

The political and economic institutions in the country too were different during the different regimes. For instance, the form of government during the Imperial regime was monarchical giving powers to the King with a feudal ideology. The economic system was centralized and market-oriented. In the Derg regime, the form of government was dictatorship with a socialist ideology and command economic institutions. In the recent regime, the form of government is anocratic with a developmental ideology and a mixed economic system. In all the three regimes, political institutions influenced economic institutions adversely and the manufacturing industry failed to contribute more than 5% to GDP.

The study also showed that different development plans and industrial strategies were implemented in the country during the three political regimes. Specifically, there were an industrial strategy of import substitution industrialization and an export-oriented strategy, but analysis of the industry's performance shows that the policies failed to have an impact in both the cases. This result shows that something is missing between the policies and their optimal implementation which can be attributed to the government's focus on centralized political issues rather than on decentralized economic priorities.

Very recently, industrial parks (IPs) have become a strategy for industrialization and 11 industrial parks have been established across the country with a major focus on apparel and textiles. The good thing about the parks is that they are creating employment opportunities for the unemployed people but with short term effects. The industries are dominated by foreign companies attracted by cheap unskilled labor, tax incentives and infrastructure to access the national and African markets. From Ethiopia's perspective, the employment potential in the parks does not absorb the technology and knowledge spillovers to take over production in the long-run because of the dominance of an unskilled labor force. The parks focus more on apparel and textiles ignoring other agriculture-based industries with Ethiopian competitive advantage.

Again, the locations of the industries show that this selection is ad-hoc which violates the industrial parks' establishment objectives and capacity utilization. The requirements clearly show that the parks must be strategically located taking the required infrastructure and logistics into consideration that can make the zones to be more competitive in the international market.

However, for political reasons the industrial parks are located as painkillers for social unrest. The companies in the parks import their raw materials from the rest of the world without using inputs produced domestically. Excessive imports of raw materials put the sustainability of industrialization at a risk with nil linkages or value chain effects required to sustain the sector.

The bound test for cointegration confirmed the existence of long-run relationship between political institution and manufacturing growth in Ethiopia. Besides, the estimation results indicated that political institution is a statistically significant factor that negatively affected industrial growth both in the long-run and short-run. Trade openness is statistically significant and a positive factor explaining the growth of manufacturing both in the long-run and short-run. This shows that political institutions have a significant role in explaining the manufacturing industry's slow growth in Ethiopia.

Based on these findings, we conclude that the different policy strategies used by different regimes in the past alternated between import substitution, export promotion and recently industry park establishment. The policies did not bring about the expected outcomes in the form of industrialization and economic growth. Hence, relevant province specific research on indigenous opportunities and challenges faced by the industry and the economy should be conducted. The focus should be shifted from giving priority to political issues to focusing on the fundamental and competitive advantages of the country. In addition, the country needs a development strategy that gives weight to the sectors based on their competitive advantage. The agricultural development led industrialization policy does not focus much on industry and other sectors are ignored in the industrial development strategy.

For several decades, the political institutions have been a major factor impacting economic institutions in the wrong direction and making the policies to have a retarding impact on different sectors including the industry sector. Policy strategy and instruments should be managed in a way that they can bring real structural change by managing the political interests of a regime and its organization in favor of the national economic outcome. This ultimately call is for a benevolent governance system that gives priority to the welfare of the people and the economy rather than focusing on how to sustain political power for unlimited time periods.

An optimal and efficient strategy to induce industrialization could be a development strategy that gives priority to the development of the mining industry for supplying raw materials to the industry sector along with a focus in the competitively advantageous sectors in the economy. This will reduce Ethiopia's dependency on imported raw materials by enhancing its self-sufficiency. Investments in human capital combined with a regulation of foreign investments, especially mixed allocation of domestic and foreign low skill and high skill labor in production and management, will enhance local management and the technological capacity of the country. Ultimately, the progress gained in the development of mining and industry sectors and technological capabilities will spill over to agriculture, manufacturing, and ultimately to the service sectors as well as to governance and institutions. This ultimately will lead to economic development both in the sectors and regionally and efficient productivity based resource allocations and inclusive and sustainable development with reduced ethnic unrest.

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Farmers' Willingness to Accept a Compensation for Evicted Land in Peri-urban Areas of Amhara Regional State, Ethiopia

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Abstract

Urban expansion has led to the displacement of indigenous communities residing on the outskirts of cities and urban areas. These communities are being compelled to leave their lands through compensation mechanisms, which do not fully compensate the displaced people. However, the current cash compensation provided is insufficient and fails to consider what is lost by evicted farmers. Thus, the main objective of this study is to investigate willingness of evicted peri-urban farmers to accept compensation. The study considered peri-urban respondents from three towns (Injibara, Burie and Gish-Abay) of Amhara regional state from 393. The Contingent Valuation Method (CVM) was applied to assess respondents' willingness to accept compensations for the land and property they lost. Various factors including initial bid vector, age, education and total annual income significantly influence the Willingness-to-Accept (WTA) compensations in the single-bounded dichotomous choice model. In the double-bounded dichotomous choice model, age and total income are the key variables that significantly affect the WTA compensation. Currently, the compensation amount paid to evicted farmers is determined by multiplying the monetary value of the total annual output of their land including animal and crop products and biproducts at the current price by 10, which is the production year. However, the evicted households are not satisfied with this existing compensation offer. The results from both the single-bounded dichotomous and double-bounded dichotomous choice CVM models indicate that the respondents' willingness

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to accept compensation were29.24 and 29.27, respectively. The latter estimate (29.27) could be preferred by the evicted farmers due to its wider confidence interval. It is worth noting that the estimated compensation amount (29.27) that households are willing to accept is significantly higher than the current offer that 10. This highlight inadequacy of the existing compensation in supporting sustainable livelihood of the affected farmers. In light of these finding, the study recommends that both the federal and the local governments should provide adequate compensation offers that prioritize well-being of the peri-urban community when implementing urban expansion programs as long as the evicted farmers lost their most valuable asset-land. Therefore, ensuring sustainable living conditions and reducing vulnerability among those who have been evicted necessitates appropriate compensation measures.

Key words: Contingent valuation, Compensation, Willingness to accept

1. Introduction

Although the rhythm of urbanization in Africa is the highest in the world, the continent is still the least urbanized region in the world. By 2021, the whole of Africa had only 44.3% of its population living in urban areas (ECA/AfDB, 2022). This proportion lags far behind that of the OECD, Latin America and the Caribbean, and the Arab States, which are, respectively, 57%, 77%, and 75%. Moreover, Africa has the fastest-growing urban population in the world, with annual growth rates approaching 4.4%. It is predicted that half of Africa's population will live in urban areas by 2030. Moreover, UN-HABITAT, (2017) projected that by 2040, there will be one billion people living in cities across Africa, up from 395 million in 2010 (Anderson et al., 2019). This indicates that urbanization in Africa will increase alarmingly and demanding more agricultural land to the urbanities affecting the peri-urban evictees.

Table 1: Urban Population Projection (2017-2037) based on 2007

Region	Percentage of urban population			Rate of urbanization in %	
	Census	Projection			
	2007	2017	2037	From 1994 - 2007	Projected 2007 - 2037
Amhara	12.3	17.0	37.1	3.94	6.02
Afar	13.4	19.2	50.5	6.62	7.53
Tigray	19.5	26.1	50.5	4.52	5.17
Oromia	12.4	15.0	31.8	4.13	5.12
SNNP	10.3	14.0	24.6	6.04	4.77
Benishangul	14.6	21.2	43.4	7.69	5.94
Gambela	25.4	32.1	60.4	8.03	4.75
Somali	14.0	14.4	18.6	2.71	2.65
Harari	54.2	55.7	62.4	2.02	2.30
Dire Dawa	67.9	69.3	74.8	2.28	2.20
Addis Ababa	100	100	100	2.10	2.10
National average	16.1	20.4	31.1	3.77	3.86

Sources: CSA, 2007.Poplation projection of Ethiopia, 2007–2037; and Summary and Statistical Report of the 2007.

Population and housing census results, 2007. There are towns in the region that have drastically increased their urbanisation, especially when compared to other towns nationwide. Projections from Ethiopia's national censuses in 1994 and 2007 show that many of the towns in the regional state are growing at a pace of more than 6% per year, which is much higher than the national average (Alamneh et al., 2023a). Although Injibara, Burie and Gish Abay towns are categorized under small and medium sized cities, the rate of urbanization is among the fastest (7.41%, 9.01% and 8.45%, respectively) from 2007 to 2016 compared to the towns and cities in the regional state (Alamneh et al., 2023a).

Ethiopia is significantly under-urbanized, even by African standards. But the slow speed of urbanization of the country continued until the middle of 1930s, while after this period, it happened more rapidly (Abate and Vision, 2019). Urbanization has been most visible in Ethiopia's northern half, where the majority of large cities are located. As part of northern Ethiopia, the situation of

Amhara regional state urbanization is growing faster (6%) compared to other regions and the national growth rate (4%)(CSA, 2020).

Table 2: Population trend in large and medium towns of the regional state

Towns in Amhara region	Censuses				Growth rate	
	1984	1994	2007	2017	1994 to 2007	Projection 2007 to 2016
Gondar	80,886	112,249	207,044	341,991	6.50	6.518
Bahir Dar	54,800	96,140	155,428	297,794	4.74	9.160
Dessie	68,848	97,314	120,095	198,428	1.80	6.523
Debre Birhan	25,753	38,717	65,231	107,827	5.27	6.530
Debre Mark'os	39,808	49,297	62,497	103,263	2.06	6.523
Kombolcha	15,782	39,466	58,667	96,968	3.74	6.529
Debre Tabor	NA	NA	55,596	91,968	NA	6.542
Woldiya	15,690	24,533	46,139	76,331	6.77	6.544
Mota	NA	NA	26,177	43,322	NA	6.550
Finote Selam	NA	NA	25,913	42,882	NA	6.548
Dangila	NA	NA	24,827	41,067	NA	6.541
Injibara	NA	NA	22,466	45,874	NA	7.41
Burie	NA	NA	25,971	62,049	NA	9.01
Gish Abay	NA	NA	6,772	15,240	NA	8.45

NA- no available data.

Source: CSA, 2007, Population projection of Ethiopia, 2007 – 2037.

The rapid process of urbanization has significant consequences especially on the peri-urban farmers of the regional state. One of the primary impacts is the conversion of peri-urban productive agricultural land into urban residential areas. As a result, farmers in the peri-urban areas have been frequently displaced from their livelihoods, accompanied by the loss of valuable agricultural land (Kabir et al., 2023). This conversion is driven by the rapid expansion of cities into the periphery, motivated by the need for urban residential settlements and the development of public infrastructure (Gebeyehu et al., 2022b), (Tassie, 2018). As urban areas continue to grow extensively, the number of displaced farmers increases, leading to a multitude of challenges. The foremost challenge is the limited availability of agricultural opportunities for these farmers after they have been evicted. The loss of agricultural land and the lower opportunities for farming not only disrupt their way of life but also threaten their economic stability. Without viable alternatives or support systems in place, these farmers may find themselves pushed towards destitution, facing severe economic hardships and uncertainties about their future (Gebeyehu et al., 2022b) .

To ensure the well-being of affected individuals, compensation for forced acquisition of buildings and land often relies on the agreement between buyers and sellers. In some cases, such as when land is acquired for religious or spiritual purposes, a replacement cost model may be utilized when market value is unclear (Romano et al., 2016). Compensation estimates worldwide are influenced by various factors, including the cost of substitute land, necessary capital, location, utility, type of land, and level of development in the area. However, in Ethiopia, consideration of these factors in compensation estimation is minimal. As a result, farmers frequently reject compensation payments for their land, as they perceive the monetary value, they intended to receive is lower. Moreover, the compensation provided to evicted farmers is often insufficient or undervalued due to inaccurate property valuations. This issue has been emphasized in studies conducted by Shen, (2015) and Tagliarino, (2017). In addition to the attributes that should be taken into account when estimating Willingness to Accept (WTA) compensation, the methodological approach employed also holds significant importance.

The widely applied methods used to estimate willingness to accept compensation are open-ended questionnaires, bidding games, and payment card systems, having their own advantages such as easiness to answer by the respondents, and time saving methods, however, they have significant weaknesses. For example, the payment card format and bidding games tend to result in lower willingness to accept estimates compared to CVM formats that affects welfare ness. Hence, both methods of estimation techniques have negative welfare effect on evicted farmers (Hatton et al., 2010). On the other hand, open-ended questionnaires may suffer from unanswered or inconsistent responses. To overcome aforementioned problems, ensure consistency and minimize random answers, the Contingent Valuation Method (CVM) has been developed, which includes the Single-Bounded Dichotomous Choice (SBCV) and Double-Bounded Dichotomous Choice (DBCV) approaches. The SBCV method involves respondents choosing a price from a set of bids and responding with a "Yes" or "No" to a bid. However, the SBCV method requires a large number of observations to estimate the distribution of willingness to accept accurately. The DBCV method, introduced by Hanemann (1991) and Carson, (2017) presents a second bid to the interviewee, either lower or higher than the initial bid. Therefore, estimating the willingness to accept compensation using appropriate methodological approaches, CVM, can contribute valuable insights to the academic knowledge on this subject. Hence, the objective of this study is to estimate the willingness to accept compensation of peri-urban farmers using CVM approach in selected towns of Amhara region, Ethiopia.

2. Literature Review

2.1. Compensation Strategies and WTA Compensation

There are different compensation practices in different countries. In some countries compensation price is set by the government either in consultation with/ without consultation the evicted farmers. In other countries, the compensation shall be provided if the amount which the land if sold in the open market by a willing seller might be expected to realize.

According to a report (USAID, 2013), compensation practices in Zambia for development-induced projects involving private land use restrictions are governed by the law. The law states that adequate compensation should be provided to individuals who suffer from eviction as a result of the exercise of powers conferred by the law, using funds appropriated by Parliament. The provisions of the Land Acquisition Act outline the compensation process, including the consideration of market value and the application of various principles. One such principle is that the value of the property should reflect its potential sale price in the open market if sold by a willing seller at the time of land acquisition or commencement of public utilization. Moreover, in Uganda, the compensation process involves negotiations between private landowners and the government/ project owners. During these negotiations, affected parties have the right to hire their own valuers to assess the impact on the land and other properties. The valuations provided by the landowners are then considered by utility company valuers and property managers. Although there is no specified mechanism for determining the compensation amount, the law allows landowners to engage in negotiations with public agencies. These negotiations often involve referencing market values and the expertise of qualified valuers. Furthermore, in Kenya, compensation assessments are based on market value, which refers to the price that a willing seller could reasonably expect to obtain from a willing purchaser, including speculative buyers.

In China, the total compensation fees for cultivated land acquisitioned include land compensation fee, resettlement fee, compensation for the aboveground buildings and other attached objects, and compensation for green crops on the land. Land compensation fee is 30 times of the average annual output value three years preceding the expropriation (the multiplying bid vector is 30)(Zhang and Lu, 2011). The standards for land compensation and resettlement fee for other purposes of land requisitioned shall be determined by various provinces, autonomous regions and municipalities in reference to the land compensation fee and resettlement fee for cultivated land requisitioned. But the combined total of land compensation fee and resettlement fee shall not exceed 30 times the average output value for the three years prior to land requisition”. However, the local government shall subsidize expropriated farmers using the land grant fee if 30 times the average annual output value can still not restore their original living standard. In China’s practice, compensation standards are usually made according to the original purpose (for agriculture, forest, but no compensation for barren/hill land) of land expropriated (Luand Song, 2016). However, compensation in Ethiopia is 10 times of the average annual output value three years preceding the expropriation (multiplying with 10 bid vector) (FDRE, 1995).

3. Materials and Methodology

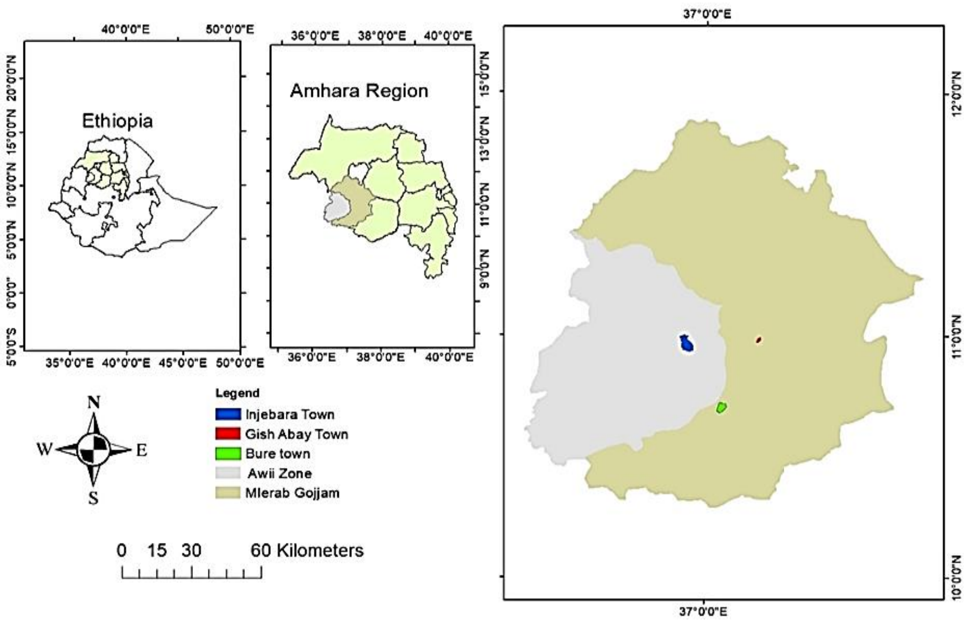
3.1 Description of the Study Area

The research was conducted in Injibara, Burie, and Gish Abay towns of the Amhara National Regional State. Injibara is the administrative centre of Awi Zone, located 135 kilometres southwest of Bahir Dar and 420 kilometres northwest of Addis Abeba. According to the 2007 census report, the entire population was anticipated to be 21,065; by 2023, it was expected to increase to 56,723 people. It was established in 1991 at a location called Kosober and connects the route from Addis Abeba to Bahir Dar with the road heading west towards the Grand Ethiopian Renaissance Dam.

Established in 1608, the town of Bure is located in western Ethiopia and acts as the administrative center of the district. Situated in the Amhara Region's west Gojjam Zone, it serves as an important trading center and a link between Shewa, Gondar, and Wolega. The coordinates of Bure are 10°42'0" N 37°4'0" E, and its elevation is 2091 meters above sea level. It is also one of the largest hubs for agricultural and industrial parks in the country.

In west-central Ethiopia, in the Amhara Region's West Gojjam Zone, is located the town of Gish Abay. It is the administrative centre of Sekela woreda and is named after Mount Gish and the Abay River (Blue Nile), which has its source on the mountain's slopes. A 39-kilometre gravel road connects the town to Tilili, which is located on the main Addis Ababa-Debre Markos-Bahir Dar Road. At 2,744 metre above sea level, Gish Abay is located with coordinates of 10°59'N and 37°13'E (Central Statistical Agency, 2013).

Figure 1: Map of the study areas



3.2 Data type, Source and Data Collection Tools

In order to make a closer investigation on the willingness to accept compensation qualitative and quantitative data were collected from respondents. Qualitative data is descriptive and non-numerical, focusing on capturing subjective experiences, opinions, and behaviors of peri-urban farmers. However, quantitative data is applied to measured and analyzed using statistical techniques. The research employed different data sources, which includes primary and secondary data sources. The primary data was collected from household surveys through face-to-face interview, and focus group discussions. The study had three focus group discussions each containing ten members of representative household heads totaling twenty-four male-headed households and six female-headed households. Moreover, key informants' interviews were made with three municipality mayors, eleven peri-urban *Kebele* administrators, and six municipality experts. Guidelines / check lists both open- and closed-ended questionnaires were used. Secondary data was collected and used from the relevant literature and institutions such as ....

The data analysis approach employed in this research was mixed-methods where it combined both quantitative and qualitative methods to gain a comprehensive understanding of a research problem. The analysis made by one of the methods was triangulated by using the data analysis approaches (Kothari, 2004).

3.2.1. Sampling procedures and sample size

The selection of respondents from the population was made randomly, using simple random sampling taking random number tables. In the first stage, Amhara region was selected purposively due to its fast urbanization rate compared to the other regional states in the country. In the second stage, to be representative and free of bias in selection, two zonal administrations (Awi and West Gojjam zones) were randomly selected from the eleven zones of the region based on their swiftness of urban expansion. In the third stage, three municipalities from the two zonal administrative (Awi and west Gojjam zones) (Injibara, Burie and Gish Abay) were purposely selected. The municipalities represent the major urban expansion features (medium to small-sized towns, fastest urban growing, establishment of industrial parks and residential places, convenient geographical location for multiple regional states (junction for Amhara, Oromiya and Benishangul regions) and high trade and business connections, so that it became the destiny of mass exodus of people) and are fast growing of urbanization where large number of investors are attracted, public sector projects are expanding drastically and land demand for residential is accelerating compared to others. In the third stage, the respective peri-urban Kebeles were selected purposively for easy access of the targeted population. There are 5, 4 and 2 peri-urban *Kebeles* in Injibara, Burie and Gish Abay cities, respectively. In the fourth stage, households' lists in the selected *Kebeles* were obtained from each Kebele administration. The final sampling procedure was to select peri-urban farm household heads. From 11 peri-urban *Kebeles in 3 towns*, a total of 393 households were selected randomly based on the proportion to size in the population. To reduce the possible sampling error, random sampling method was employed. To be specific, a systematic random sampling technique was employed to assure the representativeness of on-target group-households that are subject to land expropriation and thus get displaced. Based on their proportions in the population, 393 farm households were randomly chosen from 11 peri-urban *Kebeles*. The total number of samples needed was calculated using the (Kothari, 2004) formula:

$$n = \frac{z^2 \times p \times q \times N}{e^2(N-1)+z^2 \times p \times q} \tag{1}$$

where n = the number of sample sizes, z = the value of the standard variate (z =1.96), P = sample proportion, q = 1-p, and e = acceptable error. *N* is the total number of populations.

Thus, the sample size of households is:

$$n = \frac{(1.96)^2 \times 0.5 \times 0.5 \times 8060}{(0.07)^2(8060-1)+(1.96)^2 \times 0.5 \times 0.5} \approx 393$$

As a result, 393 respondents were randomly chosen from the roasters at each kebele administrative office using the stratified sampling frame that was produced using the systematic random sampling technique. The data was collected from September, 2022 to January, 2023 from respondent with face-to-face (in person) interview.

Table 3: Distribution of sample households by municipalities

Municipality	Peri-Urban *Kebele*	Target Population	Sample Size
Burie	Wan Gedam	846	39
	Fereswega	777	36
	Wundigi	543	25
	Derequa Mewucha	761	35
Injibara	Besena-Basa -01	971	45
	Bahunk Michael- 02	1134	53
	Charate Gebriel-03	806	37
	Akaita-04	748	35
	Abo Gumbi-05	672	31
Gish Abay	Abay	466	31
	Sangib	340	25
Total		**8060**	**393**

Source: Each Municipality's Documentation, 2022

3.2.2. Design of the questionnaire and value elicitation format

a. Design of the questionnaire

The data sources for contingent valuation method were the direct responses given by individuals and questionaries were the main tools for data collection (Venkatachalam, 2004). The National Oceanic and Atmospheric Administration (NOAA) panel recommended that, besides the willingness to accept questionaries, the survey would contain a range of other questions (Arrow et al., 1993) like income, age, prior information about the community, prior curiosity in the community, attitude towards compensation, belief in the scenarios, etc.

b. Value elicitation formats

In the CV literature, many response modalities have been employed to determine respondents' WTA (Welsh and Poe, 1998). One of the original approaches involved asking respondents open-ended questions about the lowest amount they would agree to receive for a certain program. An alternate way is to use payment cards, where respondents select the least amount of compensation they will accept from a variety of options. A third common tactic is to present DC questions as a referendum vote, with the sample divided into smaller samples, each with a different cost or bid. The percentage of supporters is calculated for each sub-sample, and the mean willingness to accept is calculated using this data (Morrison, 2011).

Theoretically, the referendum format (dichotomous choice (DC)) is the most effective and is recommended by the NOAA panel (Arrow et al., 1993). For CV practitioners, this strategy has evolved into their go-to elicitation technique. The other approaches have been shown to have issues with incentive compatibility, where survey participants can influence results by providing information about their genuine WTA (Mcconnell, 2018).

c. Preliminary survey and selection of bid vector

The bid vector is a factor used for multiplying the output of land that is taken from the evictees to provide them cash compensation for evicted farmers. Effectiveness of the dichotomous choice parameter and welfare estimations can be increased by selecting a proposed bid price. A pre-test survey of 50 to 100 observations or a focus group discussion can provide information on the distribution of bids prior to the foremost survey, which is essential to select the suitable bids (Morrison, 2011). As a result, a pre-test pilot survey was conducted among 60 randomly chosen households in this study to identify the starting bid vectors that provide efficiency to estimate and to verify the validity and consistency of the questionnaire. The data gathered from the pre-test survey revealed that the responses ranged from 10 to 40. The pilot result showed that the starting bid vectors for WTA were 10, 20, 30, and 40. By using these initial bid vectors, set-off follow-up bid prices were determined by doubling and halving the initial bid amount.

3.2.3. Method of data analysis

3.2.3.1. Theoretical framework of contingent valuation approach

CVM is defined as a technique used for the valuation of non-market resources and in fact the commonly used technique for valuing both the use value and non-use value. CVM is a survey-based method where people are asked directly how much money they would be willing to pay or willing to accept to be compensated for or to maintain the existence of some features. The technique is called CVM because people are asked to state their willingness to accept, contingent on specific hypothetical scenario and description of the situation. This method uses a survey to determine the Willingness To Accept (WTA) for compensation for a loss or Willingness To Pay (WTP) of a particular resource. It provides a direct method of measuring the value of natural resources without resorting to market valuation method (Okorji, 2000).

Contingent valuation does have its peculiar advantages as compared to the other valuation techniques. First, it is analytically much simpler. Second, if the goal of the study is to produce a single valuation estimate for a program, then it is more appropriate than choice modeling. Thirdly, it is generally easier to use for valuing particularly complicated goods (choice modeling requires that goods be separated in to attributes and that levels be assigned to each of these attributes; this is often quite difficult). Fourth, there is empirical evidence that suggests contingent valuation produces valuation estimates that are either equal to or more conservative than those from choice modeling (Morrison, 2011).

A. Modelling Framework

The core model for examining dichotomous CV responses is the random utility model. It is assumed that each person's observed discrete choice response in the random utility model represents a utility maximisation process. The status quo, or q^0, and a particular level of progress, or q^1, are the two possible degrees of livelihood status involved. Assume for the moment that the household representative receives money in return for the expropriated land. Hence, each household’s utility function at status quo (no compensation) is:

$$U_{0i} = U(y_i, z_i, q^0, \varepsilon_{0i}) \quad \textbf{(2)}$$

Individually, household's utility function with compensation is:

$$U_{1i} = U(y_i, z_i, q^1, \varepsilon_{1i}) \quad \textbf{(3)}$$

By combining equation (1) and (2), we can find:

$$U_{ji} = U_j(y_i, z_i, q^i, \varepsilon_{ji}) \quad \textbf{(4)}$$

Where i = 1, 2,..., n indicates individual households; j = 0; 1 symbolizes the two distinct livelihood status; U_{0i} and U_{1i} reflect indirect utilities at the status quo and hypothetical better scenario, respectively; Y_i is the highest individual household's discretionary income; z_i is independent and design variables (first bid levels, etc.); q_i is the quality of the land being estimated; and ε_{ji} is a vector of additional variables that the utility maximizer is aware of, but which are not observed by the researcher and are presumed to have a zero mean.

Note that the household's utility changes from U_{0i} = U (yi, zi, q0, 0i) to U1i = U (yi, zi, q1, 1i) when the status of the land changes from q^0 to q^1 (due to a policy change). Here, $q^1 > q^0$ demonstrates that the suggested scenario or cash compensation has a greater benefit than the current situation. According to economic theories, a rational consumer should try to maximise utility within their means. Income, the presence of remuneration, and other socioeconomic and demographic characteristics are thought to be sources of utility. The given bid is accepted by the household because if it increases their income (Carson et al., 2018). Individual i therefore responds "yes" to the bid amount ti is assumed by:

$$(y_i + t_i, zi, q^1, \varepsilon_{1i}) > U(y_i, z_i, q^0, \varepsilon_{0i}) \quad \textbf{(5)}$$

We can only infer probabilities from "yes" or "no" responses due to uncertainty to know the random choice. The likelihood that someone will answer "yes" is the likelihood that they believe the proposed scenario is better for them, even with the offered pay, resulting in $U_1 > U_0$. The likelihood that an individual will select utility maximizer i and respond "yes" is provided by:

$$Pr(yes)= pr(U(y_i + t_i,\ z_i, q^1,\ \varepsilon_{1i}) > U(y_i,\ z_i, q^0,\ \varepsilon_{0i})) \quad \textbf{(6)}$$

Two modelling decisions are required, per (Winters et al., 2010), for the parametric estimate of the aforementioned model. The study must first decide on a functional form for the expression U ($y_i + t_i$, z_i, q^1, ε_{1i}). The error term's distribution must also be stated. Whether they employ a utility differential model or a random WTA model, most applied empirical studies begin by assuming a utility function that is additively separable into systematic and stochastic components of preferences:

$$U_j(y_i,\ z_i,\ \varepsilon_{ji}) = V_j(y_i, z_i) + \varepsilon_{ji} \quad \textbf{(7)}$$

The likelihood that utility maximizer will provide a favorable answer to the valuation question is as follows, given the specification in equation (7):

$$Pr\ (yes) = pr\ (v_1\ (y_i{+}t_i, z_i, q^1) + \varepsilon_{1i} > v_0\ (y_i, z_i, q^0) + \varepsilon_{0i}$$
$$= pr\ (v_1\ (y_i{+}t_i, z_i, q^1) - v_0\ (y_i, z_i, q^0) + > \varepsilon 0i - \varepsilon 1i \quad \textbf{(8)}$$

Note that the following is the likelihood that the utility maximizer will respond negatively, rejecting the compensation is:

$$Pr\ (no) = 1 - pr\ (yes) \quad \textbf{(9)}$$

Although this equation is still too general for parametric estimate, it is possible to assume that the systematic component of the preference function is linear in income and other factors. This means that the equation does not indicate likelihood to prefer the compensation bid vector to decide whether they accept or reject it. Therefore, it has to converted to the reduced form of the equation. Hence, the model can then be reduced to the following:

$$Pr\ (yes) = pr\ (\alpha z_i + \beta t_i + \varepsilon_{ji} > 0) \quad \textbf{(10)}$$

Suppose that the error term has nii (0, 1) (Mcconnell, 2018).

Assume that $\mu = \varepsilon_{0i} - \varepsilon_{1i}$ and F_μ () is the cdf of μ, then the probability that the household is willing to accept compensation is given by:

$$Pr(yes) = F\mu(\Delta V) \quad \textbf{(11)}$$
$$Pr(no) = 1 - F\mu(\Delta V)$$

Where, $\Delta V = (v_1(y_i + \beta t_i, z_i, q^1) - v_0(y_i, z_i, q^0)$

Keep in mind that the analysis' primary goal is to determine WTA and generate a WTA function from the presumptive utility function. If Wi represents the household's actual but unobservable WTA for compensation, then:

$$W_i = \alpha z_i + \beta(y_i)$$
$$\alpha_0 z_i + \beta(y_i + \varepsilon_{0i}) = \alpha_1 z_i + \beta(y_i + ti + \varepsilon_{1i}) = \alpha_i z_i + \beta(WTA_i) + \mu_i \quad \textbf{(12)}$$

Therefore, the household's WTA can be expressed as:

$$WTAi = \frac{\alpha zi + \mu i}{\beta} \quad \textbf{(13)}$$

The actual WTA for an individual can be expressed as follows: Wi, the unobservable individual's actual WTA for the improved compensation, has a linear relationship to the original bid ti and the variables.:

$$WTA_i = 1 \text{ if } WTA_i > W_i \text{ and } WTA_i = 0 \text{ if } WTA_i < W_i \quad \textbf{(14)}$$

When using DC-CVM, the i^{th} family is asked whether it would be willing to accept the first offer (ti) in exchange for a specific compensation improvement. The following can be used to show the likelihood of a "yes" or "no" response:

$$pr(yes) \text{ to } t_i = pr(w_i) \geq t_i \text{ and } pr(no) \text{ to } t_i = pr(W_i < t_i). \quad \textbf{(15)}$$

With the model's theoretical foundation in place, we can describe the empirical models for DBDC and SBDC in the section that follows.

4. Results

4.1 Descriptive Result

Based on the survey data,63.36% of households are male-headed, while the remaining 36.64% are female-headed households with a minimum and maximum age value of 21and 80 years, respectively, and the sampled respondents' average age was 44.9 years. The selected respondents have 3.2 family members on average, with the minimum and maximum values being 1 and 8, respectively. The respondents' average dependency ratio is 1.14, with minimum and maximum values of 0.3 and 4.3, respectively (see Table 4).

The average land size of the respondents is 0.79 hectares. The minimum and maximum land size of the respondents is 0 and 2 hectares, respectively. Moreover, the average tropical livestock unit of the respondents is 2.11 with the minimum and maximum value of 0 and 8.1, respectively. The maximum and minimum distance of the respondents is 9 kilometers and 3 kilometers from market places, respectively, with an average distance of 5.8 kilometers. However, the mean annual income of the respondents is 31,228.61 birr with the minimum and maximum annual earnings of 19,625 birr and 96,640 birr, respectively.

Table 4: Descriptive result of explanatory variables

Variable	Observation	Mean	Standard Deviation	Minimum	Maximum
Age	393	38.87	10.9	21	80
Education	393	3.56	3.63	0	12
Family Size (Number)	393	3.75	1.6	1	8
Dependency Ratio	393	0.93	0.88	0.3	4.3
Land Size	393	0.79	0.42	0	2
TLU	393	2.11	1.6	3	9
Distance to Market	393	2.8	1.66	0.5	6
Total Income	393	31228.61	7539.12	19625	96640

Source: Author's computation, 2022.

4.2 Compensation Practices

Table 5 presents trends of the compensation rate in Birr. Sample data was taken from displaced households in the towns of Injibara, Burie, and Gish Abay regarding the amount of compensation and land holdings taking expropriations were triangulated with the municipalities of the Land Development and Management department in 2022. According to the information that was made available, 3.349 million birr[3] in financial compensation was given for 197 expropriated residents' land holdings totaling 61.9 hectares in the aforementioned municipalities.

As a result, the amount of compensation given was 10 times of the average annual output value three years preceding the expropriation. The average nominal land price given as compensation to the evictees was 1.74 birr/m^2. However, the price varies across municipalities, where Injibara paid 2.1 birr/m^2, Burie paid 1.902 birr/m^2, and Gish Abay paid 1.21 birr/m^2. The compensation also varies across time, where it was given over the periods of 2007 to 2018. For example, between 2007 and 2018, evictees received an average compensation of 1.74 birr/m^2. However, when municipalities leased land to investors, the prices ranged from 300 birr/m^2 to 11,200 birr/m^2. Additionally, municipalities sold designated land plots for cooperative housing at a price between 30 and 210 birr per square metre. This depicted a significant disparity between the compensation received by evictees and the amount collected by municipalities as compensation from third parties for the same plot of land acquired from the farmers.

[3] Birr is the currency of Ethiopia where the average Exchange Rate of One Birr = 0.0193 Us Dollar In 2022.

Table 5: The trends of compensation rates in Birr/m^2/year

Year	Injibara			Burie			Gish Abay			
	Compensation	Lease Price	Allocation Price	Compensation	Lease Price	Allocation Price	Compensation	Lease Price	Allocation Price	Average Compensation
2007	1.52	300	40	1.40	375	30	1.31	-	30	1.457
2008	1.635	950	40	1.601	1950	30	1.30	-	30	1.5454
2009	3.11	1850	40	2.90	2200	40	2.22	-	30	2.833
2010	1.85	3200	50	1.60	3600	50	0.89	-	50	1.255
2011	2.54	4000	50	2.01	4100	50	1.98	-	50	2.1096
2012	1.80	6000	50	1.61	4450	50	1.38	-	50	1.60
2013	2.10	7200	50	1.80	4700	50	1.61	-	50	1.889
2014	2.92	8100	80	2.71	5000	70	2.68	300	70	2.72
2015	2.90	9200	100	2.72	5500	100	2.70	600	90	2.72
2016	2.90	10500	110	2.72	6000	105	2.70	1850	100	2.72
2017	2.92	10900	170	2.71	7200	160	2.69	2200	150	2.72
2018	2.91	11200	210	2.70	9501	210	2.70	3000	200	2.72
AVE.	2.1	6116	82.5	1.902	4548	78.75	1.21	1590	75.83	1.674

Source: Own computation from survey data and recorded data from respective municipalities, 2022.

Note: compensation: the compensation price per one-metre square land offered to evicted; lease: the price of one metre square of land transferred to the third party through the lease system; allocation: the price of land per one square metre collected from housing cooperatives allocated for residence purposes; and average: is the average compensation price of land per one metre-square paid to evicted of all the study areas.

4.3 Econometric Estimation Results

4.3.1 Dichotomous model

Table 6 depicts the distribution of bid vectors to each respondent. The distribution of the first bid amount, or t_i, is one of the first things examined from this data set. Each respondent to the questionnaire, which included dichotomous questions with follow-up, was asked to two contingent valuation questions. Table 6 shows the initial bid vector dispersion. Three groups of observations totaling 393 observations each contain a different number of participants.

Table 6: Distribution of the Bid Vectors

Bid	Frequency	Percent
10	72	18.32
20	154	39.19
30	78	19.85
40	89	22.65

Source: Computed from survey data, 2022.

Table 7 shows the responses to the contingent valuation questions of the bid vectors. When employing contingent valuation data, it's crucial to ensure that respondents are responsive to the bid amount. In other words, the study anticipates a higher proportion of respondents to reply positively as the bid amount rises. The result of the model depicted that almost 37.4% of those interviewed answered yes to the first contingent valuation question.

Table 7: Responses to the first CV questions of the bid vectors

Answer 1	Frequency	Percent
No	246	62.60
Yes	147	37.40
Total	393	100.00

Source: Computed from survey data, 2022.

4.3.2. Single and double bounded model estimation results

The following table shows the single bounded Probit regression estimation results of the WTA compensation for the land they dispossessed in the study areas. The majority of the explanatory variables hypothesised to affect WTA compensation are as expected. The estimated regression result depicts that the probability of accepting the offered bid for compensation is significantly and positively affected by the bid price and land size of the household at 1% and 5% significant levels, respectively. However, WTA compensation is significantly and negatively affected by the age of the household head, the education level of the household head, and the total income of the household at the 5% significance level.

Table 8: Single Probit Regression Model

Dependent Variable (Answer 1)	Coefficient	Standard Error	Z-Value
Bid-1	0.1058***	0.00836	12.66
Age	-0.0146**	0.0072	-2.02
Sex	0.2264	0.2054	1.10
Education	-0.278**	0.1153	2.41
Family Size	-0.0767	0.0666	-1.15
Dependency Ratio	0.137	0.12	1.14
Land Size	0.3227**	0.0994	3.25
TLU	0.0187	0.0511	0.37
Total Income	-0.00003**	0.00001	2.09
Distance To Market	-0.031	0.049	0.63
Constant	-1.8644***	0.6946	2.68
Observations	393		
Log Likelihood	-147.8095		
Prob > CHI2	0.000		
LR CHI2(10)	248.99		

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

Source: On computation from survey data, 2022.

The yearly total income of the respondents is negatively and significantly related to the households' WTA compensation to the offered bid amount, indicating that respondents with higher incomes were either less likely to be willing to accept compensation than those with lower incomes because eviction may reduce their annual income earned from the land.

The estimated coefficient of age of the head household was found to be significant, negatively affecting the willingness to accept compensation. This implies that older household heads were less willing to accept compensation than their counterparts. This might be due to the fact that old aged household heads are less competitive to engage in other income-generating employment opportunities other than agricultural practices and earn less income from non-agriculture jobs compared to younger household heads.

Land size of the household is also another significant factor affecting the WTA compensation positively. As the size of the land holding increases, the willingness to accept compensation also increases compared to those households that own a lesser amount of agricultural land. This might be the expectation that the lump sum amount of compensation offered at a time can create the capacity to purchase other assets such as cars and buildings, which they expect to generate a better monthly income than the land itself can generate.

Likewise, the estimated coefficient of education of the household head is negative and significant. The likelihood that a household's willingness to accept compensation decreases with an increase in the household's education level because educated people can weigh the advantages and disadvantages of owning land versus losing it and can analyze the benefits and adverse effects against the compensation bid amount.

Similar to the SBDC model, the double DBDC estimation result is depicted in Table 9. Among the variables expected to influence WTA compensation, age of the household head and family size of the household affects positively while total income of the household affects negatively and significantly.

Table 9: Double bounded bivariate probit regression model

Dependent Variable (Answer 1)	Coefficient	Standard Error	Z-Value
Beta			
Age	4.274**	2.333	1.83
Sex	0.2264	0.2054	1.10
Education	0.905	5378.45	0.00
Family Size	7.3***	2.066	3.62
Dependency Ratio	0.137	0.12	1.14
Land Size	0.3227	0.199	1.62
TLU	0.0187	0.0511	0.37
Total Income	-0.00003**	0.00001	2.09
Constant	32.504***	1.432	22.69
Sigma			
Constant	54.444***	0.6224	87.741
Observations	393		
Log Likelihood	-394.55		
PROB > CHI2	0.000		
WALD CHI2(10)	248.99		

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

Source: Computed from survey data, 2022.

4.3.2 Estimation of the mean WTA compensation

Table 8 also represents the comparison of alternative estimates of the mean WTA compensation. To find out whether utilizing follow-up responses provide more efficient and robust estimation of WTA compensation or not, this section reports the estimates of the WTA from SBDC and DBDC models. It is possible to compare the effectiveness of several estimate models in estimating welfare. The primary criterion for evaluating the effectiveness of the models can be found in the precision estimates of welfare measures generated using the "doubleb" command process.

The results demonstrate that, by providing a wider confidence interval level, the DB bivariate probit model is significantly more successful than the single bounded model. As a result, the double bounded dichotomous choice CV model outperforms the single bounded model. Finally, the welfare estimate showed that, due to its wider confidence interval, the DB model's mean WTA (29.27 years) estimates are superior to those of the SBDC probit model. Therefore, we have chosen the estimated result from the double bounded bivariate probit for welfare aggregation in the study area.

Table 8: Comparison of alternative estimates of mean WTA

Models	Mean WTA	Confidence Interval 95% DOUBLEB		ASL*	Range (UB-LB)
		LB	UB		
SBCV	29.2423	27.8487	30.6358	0.000	2.7871
DBCV	29.2725	27.8777	30.6677	0.000	2.7896

*: Achieved Significance Level for testing; Ho: WTA <=0 vs H_1: WTA>0; LB: Lower Bound; UB: Upper Bound

Source: Survey Estimation Result, 2022.

4. Discussion

This study's primary goal is to determine the total WTA compensation for the land that has been taken away from the towns of Injibara, Burie, and Gish Abay in the peri-urban areas due to horizontal urban expansion. Out of the 393 respondents in this survey, 197 had been evicted and had been stripped of their possessions. A total of 619,200 square metre of their land were seized. A total of 3,349,000 birr is paid to them, computed as the ten-year total income of the land. However, taking the land from the farmers with this value of compensation, the municipalities transfer the land to the third party through the lease system at a price that is several folds higher than the price they paid to the evictees. According to the data obtained from the individual municipalities of the study areas, the average price of land per square metre that was transferred to a third party via the leasing system was 3,700 birr, with the average price varying from 300 birr to 11,200 birr per square metre of land depending on the specific location of the plot and municipality. Additionally, the municipalities transfer the land for residential purposes to those who are in need of constructing residential houses, which are organized by housing cooperatives through land allocation schemes. Simultaneously, the municipalities receive compensation from these housing cooperatives for the land they transferred from the evictees, with an average price of 183.12 birr per square metre, ranging from 30 to 500 Birr depending on spatial and temporal dynamics. The data showed that under both schemes, i.e., the leases and allocation, there is a greater disparity between the land price paid to the evicted farmers and the land price transferred to the third party. This demonstrates that the livelihood of the people is substantially affected by the existing compensation price for the land offered to evicted farmers. The average compensation price provided to evicted farmers and the lease price established by the municipalities for transferring to another entity ought not to be expected to be equal in order to ensure a win-win strategy for the evictees and the municipalities. However, minimizing the gap between the revenue generated by the government and the compensation given to the evictees can create a sustainable rural-urban growth nexus. Therefore, by combining the maximized bid value of compensation with the annual income generated by a particular piece of land the farmers are to be dispossessed of, mean WTA compensation could potentially be achieved in the peri-urban interface without having an influence on the evicted farmers. According to the results of this study, evictees are willing to accept compensation (WTA) for an average bid vector of 29.27. This means that the average output of the land three years preceding the expropriation multiplied by 29.27. However, the municipalities are paying compensation to the evictees 10 times the average output of the land prior to the expropriation.

Based on this bid vector, the sampled evictees would have been received compensation worth 9,802,523 birr, or nearly 2.9 times more than what they actually received. The result is further reinforced by the descriptive finding that municipalities (via lease and allocation schemes) and evictees (as compensation) receive greater discrepancies in revenue generated from the same plot of land (Table 5). This finding is incongruous with the finding of (Gemeda et al., 2023). Due to this significant underestimation of the compensation price of their land, the evictees are disgruntled with the government's current bid of ten years, despite the fact that the actual compensation paid to them thus far is comparable to what ought to be paid.

5. Conclusion and Recommendation

Based on the results and discussion, it can be inferred that in the peri-urban areas of Burie, Injibara, and Gish Abay towns, the willingness-to-accept (WTA) compensation among farmers stood at a bid vector of 29.27. Key determinants affecting farmers' decisions on accepting or rejecting compensation included the initial bid vector, age of the household head, household land size, education level of the household head, and annual income of the household. The displacement of farmers from their land as a result of urban expansion driven by development is unavoidable, but it should be approached in a manner that benefits both parties, ensuring that indigenous farmers are not adversely affected. This goal can be attained by utilizing empirical evidence to examine the willingness-to-accept (WTA) compensation of peri-urban farmers. Consequently, it is crucial to provide appropriate compensation to those who are displaced, and ongoing support should be provided to assist them in sustaining their livelihoods post-expropriation. This is essential because these individuals may lack the financial and administrative skills necessary to effectively manage a lump sum payment if it is offered all at once. The broader implication of addressing these issues is vital improving social justice, inform sustainable economic development, conflict mitigation, and community well-being. Therefore, the government ought to embrace multifaceted strategies in handling land valuation issues to guarantee fairness, transparency, and efficiency. Here are some policy suggestions that the government should contemplate implementing:

- Informed Property Valuation: Professional judgments and data-driven methodologies could be utilized to precisely evaluate property values. This can help to avoid undervaluation or overvaluation of properties during transactions.
- Informed Property Valuation: Utilizing expert opinions and data-driven methods to accurately assess the value of properties. This can help in preventing undervaluation or overvaluation of properties during transactions.

- Planned Expropriation: When the government needs to take private property for public objectives, a well-defined and fair expropriation procedure can assist safeguard property owners' rights.
- Comprehensive Compensation Calculations: Ensuring that when the government expropriates the land for public purpose, the owner receives appropriate and fair compensation. This entails taking into account a number of variables, including the property's market value, any upgrades performed, and any inconveniences experienced by the owner.
- Awareness Campaigns: Educating the public on property rights, valuation processes, and legal aspects of land transactions to empower landholders and encourage willingness in the industry.
- Early Provision of Residential Homes: To reduce life disruptions, it is important to make sure that communities or individuals impacted by land eviction have access to appropriate alternative housing options as soon as possible.
- Shareholdings: Investigating options such as allowing land owners to have a stake in development projects in cases of expropriation or development, thereby enabling them to benefit from the future value of the property.
- Accountable Valuation: Implementing mechanisms to hold property valuation professionals and institutions accountable for their assessments, ensuring accuracy and integrity in the valuation process.
- Property Valuation Institutions: Establishing separate institutions dedicated to property valuation that adhere to best practices and standards, thus enhancing the credibility and reliability of valuation processes.

Finally, subsidizing evicted farmers can help them sustain their livelihoods, taking inspiration from the compensation subsidy model in Kenya. Eviction often affects farmers' economic activity and can result in income loss. Governments may protect evicted farmers' livelihoods while supporting long-term growth and resilience in peri-urban communities and adjusting assistance programs to local situations. Subsidizing evicted farmers is a reasonable and compassionate way to support individuals suffering displacement. This can help farmers fill financial gaps and avoid severe economic shocks. This assistance can serve as a safety net during transitional periods, backup farmers to navigate uncertainty and sustain their livelihoods in the face of eviction.

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Financial Inclusion and Household Well-being: Evidence from Ethiopia

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Abstract

When households have equal access to affordable financial services and products, they will save money and invest it in improving their income. This is a simple concept of financial inclusion. In this study, we have investigated the impact of financial inclusion on poverty reduction using survey data from the Ethiopian socio-economic survey of round four. We employed a standard counting method to establish the financial inclusion index for the analysis and an IV probit model. In this study, we employed knowledge of financial service use as an instrumental variable to address the issue of endogeneity. The empirical result confirmed that financial inclusion positively impacts a household's well-being. We also explored the individual impacts of the financial inclusion index components on poverty and the effects of gender and location dimensions. The study examined the regional distribution of poverty headcount and financial inclusion indicators. The result revealed the average poverty line of the Ethiopian household is 25.9. percent. An increase of one unit in the Financial Inclusion Index (FII) is linked to a decrease of 0.336 percentage points in the likelihood of being poor while keeping other variables unchanged. As financial inclusion improves, the probability of people experiencing poverty decreases. Financial inclusion has more poverty-reducing effects for female-headed households and rural dwellers compared to their male-headed and urban counterparts. Governments are encouraged to work more on the accessibility of technology-driven financial services to address the exclusion problem due to knowledge of financial service use and distance to formal financial institutions.

Keywords: Financial inclusion, Poverty Reduction, Gender, and Location, Ethiopia
JEL Codes: D12, D13, D14, and I31

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1. Introduction

Financially included households have access to affordable financial services that help them meet their needs, such as paying bills, saving money, and obtaining credit (Koomson & Ibrahim, 2017). Financial inclusion (FI) also refers to both access and utilization of a limited set of financial services (Abimbola et al., 2018; Sarma, 2008). Owning a deposit or transaction account at a formal financial institution is one of these types of financial services. It became a focal point of emerging economies' development agendas, promoting and providing financial access to unbanked households to alleviate poverty (Churchill & Marisetty, 2020). The primary goal of endorsing and supporting FI implementation is to provide equal opportunities for families from all socioeconomic backgrounds to benefit from financial inclusion. As a result, FI as a policy measure can drive inclusive growth, reduce inequality, create jobs, and boost productivity through savings, benefiting households significantly. As a policy instrument, it provides access to monetary facilities at the community and government levels, which increases individuals' savings accounts, payment conveniences, access to credit, and receipt of transfers, all of which improve household welfare through an increase in commercial proclivities (Pazarbasioglu et al., 2020). For years, governments and development initiatives have focused on providing financial access to the unbanked population to effectively implement improved access to basic banking services that were previously limited to reaching out to the community. The primary goal of microfinance institutions in developing countries is FI. As a result of financial market liberalization, non-bank financial institutions have expanded rapidly, resulting in the rapid growth of microfinance. While these institutions have had a significant impact on the lives of millions of people, their reach extends beyond the poorest of the poor. They have also had a significant impact on how marginalized people borrow money and manage their credit (Koveos & Randhawa, 2004). According to the literature, poverty is primarily a rural phenomenon (Tambunan, 2009; Akhtar et al., 2015), increasing FI can be more important in improving household living standards by creating opportunities for credit and saving options that can lead households to either smooth consumption or pave the way for productive investment. FI has a significant impact not only on access but also on the financial well-being of individuals, as FI is essential for development. This is because the vast majority of people in developing countries lack access to banking; if they did, they could save and invest (Claessens, 2006). This enables them to become wealthier throughout their lives and establish a business, which increases their economic activity and, in turn, contributes to the growth of their nation. According to the aforementioned study, a microfinance program can generate an additional $1 in income for every $1 invested in a client, which can then be used to support the livelihood of a low-income client. The primary implication of the study is that formal financial institutions, such as banks and microfinance organizations, promote financial inclusion, especially by providing credit access to low-income groups. In this regard, Winters (2003) emphasizes that, since the mid-twentieth century, those developing countries have experienced tremendous economic growth in terms of trade and poverty reduction, but one of the most significant constraints to growth has been low-income households' limited access to financial markets. Several studies have shown the encouraging effect of increased availability of financial facilities on economic performance, bringing the role of FI on economic growth to the forefront for consideration (Ang, 2008; Zhuang et al., 2009; Seck et al., 2017.; Fowowe, 2020; Shen et al., 2021). Nonetheless, several factors have hampered our understanding of the full impact of FI on economic performance, including the complex and sensitive nature of the relationship between FI and economic expansion, as well as the scarcity of data on financial services access in many developing countries (Arestis & Sawyer, 2016).

Furthermore, FI has remained a challenge in Ethiopia because the financial sector is in its infancy and has low dissemination. A significant proportion of the rural population is economically excluded, and over 85 percent of the Ethiopian population resides in rural areas. Access to basic financial services also remains restricted, limiting households' ability to obtain bank accounts, pay bills, use credit, and save (Baza & Rao, 2017a; Abdu & Adem, 2021; Achew et al., 2021; Hundie & Tulu, 2021). Consequently, the "unbanked majority" must pay high transaction fees for payment services and cannot utilize cash-saving services to smooth income and build assets. Literature on the financial sector and inclusion in Ethiopia has highlighted "account ownership" as a component of financial inclusion, as well as a

determinant of financial inclusion (Baza & Rao, 2017a; Desalegn & Yemataw, 2017). Other studies have examined the Afar region (e.g., Abdu & Adem, 2021), but their sample size and geographic scope were limited. Moreover, they overlook potential endogeneity and heterogeneity issues inherent in the data.
The purpose of this study is to determine whether the function of financial inclusion has a significant impact on household poverty in Ethiopia. We use the most recent household and individual-level datasets available, covering both rural and urban households. In terms of methodology, this study accounts for endogeneity by using instrumental variable regression. It addresses heterogeneity by estimating models over household gender and household place of residence to examine how FI is related to poverty (rural vs. urban). The remainder of the paper is organized as follows: Section 2 reviews the literature, Section 3 describes the data and econometric methodology, and Section 4 reports the results and comments. Finally, Section 5 provides some closing remarks.

2. Literature Review

Recent studies have focused on financial inclusion as a driver of economic growth. For instance, Ozili (2021) explained why FI is becoming a program for both developed and developing countries, as well as the significant positive impact of the financial sector on achieving sustainable development goals and eradicating poverty and income inequality. As a result of this evidence, financial sector reforms have been implemented here and there, promoting FI as one of the primary activities of policymakers.

D'Onofrio et al. (2019) investigated the relationship between resident banking expansion and inequality distribution. This study also indicated that the proponent of domestic banking expansion can mitigate disparity, but the impact on the local community may not be enhanced if the development of the financial sector is not supported by socioeconomic infrastructure. Similarly, using panel data from 2000 to 2018, Coccorese (2022) investigated whether local banking development benefits residents or exacerbates income inequality in 103 Italian municipalities. The analysis found a negative correlation between economic inequality and regional financial expansion, i.e., when provincial and local banking systems expand, income inequality declines.

To a large extent, Menttei et al. (2021) investigated the role of credit institutions in reducing income inequality by analyzing the credit market with panel data from 2001 to 2011. This study also revealed that corporate banks contribute more to reducing income inequality in local communities than their commercial counterparts. In addition, Demir et al. (2022) suggested that the impact of FinTech could support the poor in obtaining the benefits of monetary policy, contrary to the theory that market imperfections and information asymmetry would prevent them from participating in financial inclusion schemes.

Few recent studies have examined the relationship between FI and poverty reduction. Indeed, using panel data from 31 Indonesian provinces, Anwar et al. (2016) showed that FI has a significant impact on poverty and that an increase in FI reduces poverty by 8.17 percent. In a similar study, Seck et al. (2017) found that the possibility of gaining access to financial resources positively affected household consumption in Nigeria. Abdu and Adem's (2021) study, which utilized logistic regression, demonstrated that companies engaged in finance were effective tools against poverty. Consequently, age, financial literacy, and the use of mobile banking were significantly correlated with FI for low-income individuals. Access to financial services could help people promote their business ventures, assist their children's education, and reduce their chances of falling into poverty (Joan et al., 2022). In Ghana, FI has the potential to reduce the likelihood of falling into poverty by 32% and the risk of falling further into poverty by 31%. (Koomson et al., 2020). Furthermore, Schmied and Marr (2016) concluded that the inclusion of finance affected the variables that determine poverty in Peru.

In this stream, it was identified that FI is critical for poverty alleviation by improving household well-being. It was also demonstrated FI played a significant role in reducing inequalities between different groups of society living in different contexts and with varying levels of education (Adebowale & Dimova, 2017). However, some studies have demonstrated that financial progress in Africa has had little impact on poverty and inequality (Chibba, 2009; Fowowe & Abidoye, 2013; Jahan et al., 2019). In this vein, formal financing instruments have a much lower impact on household inequality than other latent variables like access to roads, whereas the presence of banks in the area and living in cities have a positive correlation with financial inclusion (Adebowale & Dimova, 2017).

FI shrinks poverty and inequality for people living in developing nations (Nelson & Nelson, 2010; Mediatrice, 2017, Omar & Inaba, 2020), particularly in Sub-Saharan Africa (Nsiah et al., 2021). Similarly, the provision of domestic credit has contributed to the reduction of poverty through its positive effects on FI (Mehry et al., 2021; Ssonko, 2010). However, several factors that can negatively impact financial inclusion have been identified, including low economic growth, a lack of employment opportunities, low adult literacy, and economic inequality. According to Kura et al. (2012), although borrowing money from local microfinance institutions to meet the needs of families has short-term benefits, many people who were unable to repay their loans were forced to sell their assets, exposing them to a variety of social and economic issues. This could be due to a lack of financial literacy and an environment in which people can use loans to start businesses that will aim at reducing poverty over time.

On the other hand, numerous scholars have identified the primary determinants of FI. In low-income populations of India, Kumar Vaid et al. (2020) identified distribution, access, affordability, technologies, financial awareness, trustworthiness, and the availability of currency to be saved in recognized financial institutions as factors that significantly affected FI. Likewise, for Kenya, adult financial illiteracy and a lack of technology experience were identified as barriers to the inclusion of financial services (Tiwari et al., 2019). Studies regarding the Afar region, on barriers to FI identified a lack of credit, problems related to collateral for credit, a high interest rate, financial illiteracy, technology, problems with trusting the institutions, low income, and difficulty accessing banks (Abdu & Abdu & Adem, 2021). On a large extent, psychological makeup, sociocultural factors, and adult financial and numerical literacy have been identified as supply-side determinants of financial inclusion, while physical infrastructure and document-related issues have been classified as demand-side barriers (Baza & Rao, 2017a; Steptoe et al., 2013). In the case of Ethiopia, insufficient income, distance from financial institutions, a fixed price structure, and a lack of documentation have been identified as obstacles to FI (Baza & Rao, 2017; Desalegn & Yemataw, 2017; Dinku, 2019).

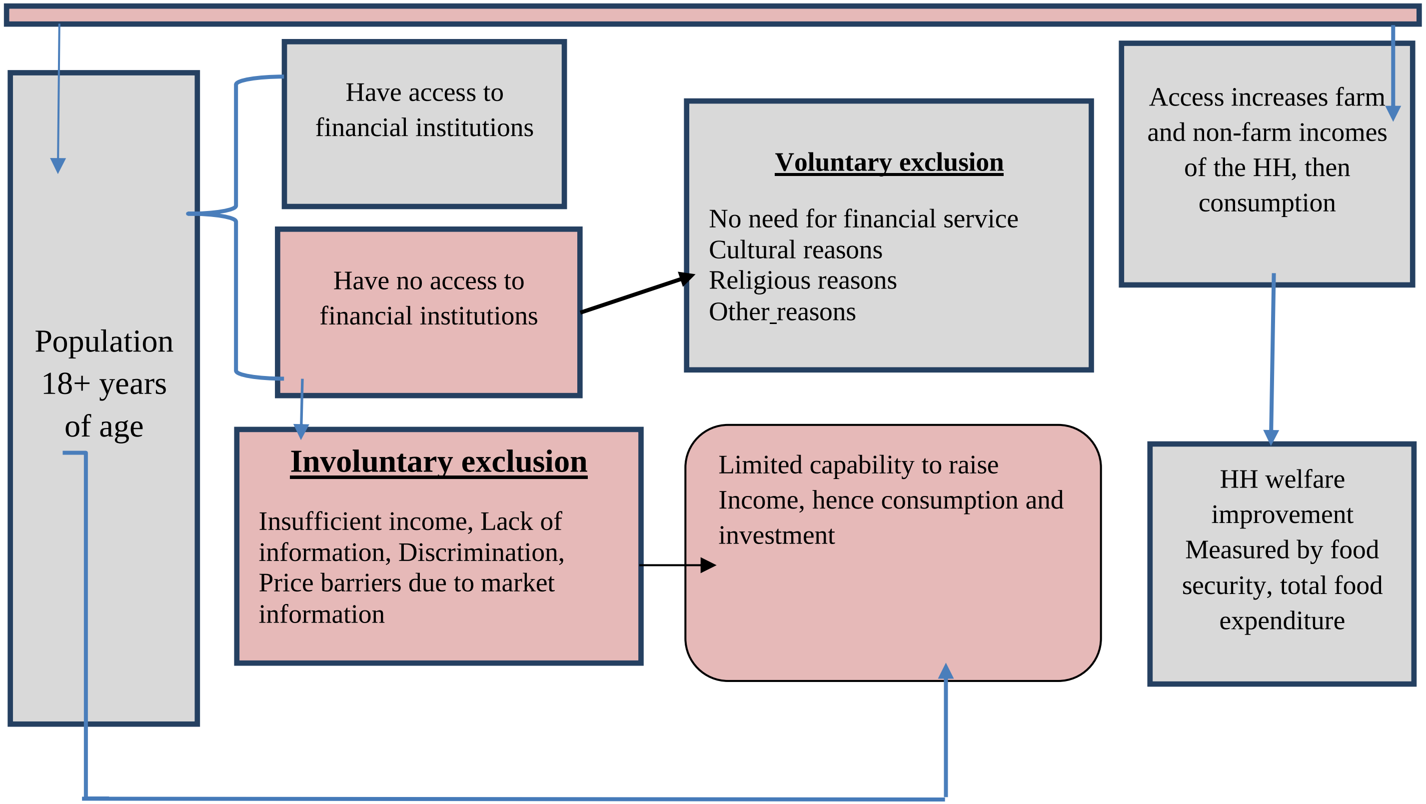
Hundie and Tulu (2021) used the Fairlie decomposition method to explore a statistically significant gender gap, with age, higher income, more advanced education, a high level of income, and employment opportunities all having a positive impact on access to credit. Regarding gender disparities in FI, women-headed households are more disadvantaged than their counterparts (Abdu & Adem, 2021; Desalegn & Yemataw, 2017; Dinku, 2021; Girón et al., 2021; Hundie & Tulu, 2021). People in Ethiopia are unbanked due to a shortage of money as well as the fact that the location of banking institutions is far away (Desalegn & Yemataw, 2017; Dinku, 2021).

Finally, the evidence suggests that low levels of income, distance from financial institutions, financial literacy, and level of education all contribute to FI. Rural communities' isolation from banks and other financial institutions has been identified as a significant barrier. However, mixed results were reported regarding the relationship between FI and age, gender, loan/credit availability, and public trust in financial institutions (Desalegn & Yemataw, 2017; Kumar Vaid et al., 2020). Even though strategies for FI implementation have been developed in Ethiopia, the issue of infrastructure has yet to be resolved. Rural residents continue to live in sparsely populated areas far from formal financial administrations. Limited access to digital and financial literacy, as well as attitudes toward credits/loans, continue to be a challenge for FI in Ethiopia. Thus, the FI strategy is not guaranteed unless the government and those with a stake in the issues unlock other enabling systems.

2.1 Conceptual Framework

Financial inclusion reduces poverty through a variety of channels. This study investigates how financial inclusion affects poverty reduction, either directly or indirectly. The direct channel, for example, is related to the distance to the nearest institutions. As illustrated in Figure 1, the study focuses on financially excluded households and attempts to suggest potential options and benefits if the marginalized group of households can become financially included. The primary channel for improving household well-being is direct farm and non-farm income growth, which leads to increased consumption as well as investment in productive activities as long as bank loans are available.

Figure 1: Conceptual Framework

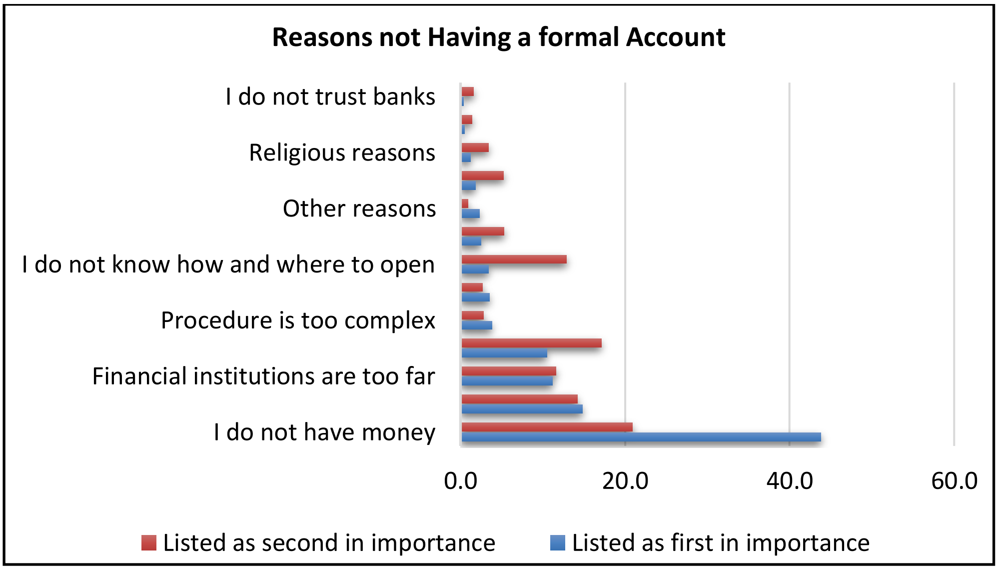


Source: Author's elaboration

2.1.1 Why are 54.1 percent of Ethiopian adults financially disadvantaged?

The FI strategy's vision was to reduce poverty in Ethiopia by ensuring universal financial access and high-quality products and services by 2025. To emphasize the importance of the issue, Ethiopia's National Council for Financial Inclusion has been established. The strategy also included methods for increasing FI by creating enabling environments such as telecommunications, electricity, and other transaction-facilitating systems (NBE, 2017). However, approximately two-thirds of adults are financially excluded due to various barriers such as the affordability of financial products, the trustworthiness of institutions providing services, and the cost of opening a formal account. Formal financial institutions in some rural areas of the country are approximately 70 kilometers away from the homes of rural dwellers.

Figure 2: Reasons for not having a formal financial institution account



Source: ESS, 2018/19 (CSA 2021).

Baza and Rao (2017b) investigated the demand and supply sides of FI factors for Ethiopian adults and observed that only 22.3 percent of adults are eligible, compared to 28.9 percent in Sub-Saharan African countries. Alemu et al. (2021) analyzed the supply and demand sides of FI limitations using decision tree analysis and the 2018-19 ESS data. The study confirmed that potential constraints included a lack of knowledge about the benefits, a lack of trust in financial service providers, a low perception of the importance of formal financial institutions, and a distance from banks. According to the same study, supply-side constraints such as poor institutional capability, inadequate private digital infrastructure, and the degree of competition and legal framework that governs bank operations act as a supply-side barrier.

3. Data and Methodology

3.1 Description of Data

We used data from the Ethiopian Socioeconomic Survey, which is conducted every three years by the Ethiopian Statistics Service and the World Bank, as it is the Ethiopian version of the Living Standard Measurement Survey[33.] Whilst survey has four waves, we use data from the fourth round, which was collected in 2018-19. This round, unlike previous surveys, includes a full-fledged module on financial inclusion. ESS4 is not a continuation of previous ESS waves and serves as a baseline for successive ESS waves. It is comprised of two administrative cities and nine regional states[34]. The ESS4 is implemented in 565 census areas, of which 316 are rural and 219 are urban. 6770 households were interviewed. The survey collected a wide range of household demographic and socioeconomic variables classified as household, agriculture, and community using multiple questionnaires and multiple visits. The FI module is included in the household questionnaire, with a focus on saving, insurance, credit, banking practice, financial knowledge, and financial capability.

3.1.1 Model specification

To analyze the impact of financial inclusion on household well-being, we employ an instrumental variable (IV) probit model. This model is suitable for estimating binary outcome variables while addressing potential endogeneity

[33] Available at Http://Microdata.Worldbank.Org/Index.Php/Catalog/3823.
[34] The Two Municipal Governments are Addis Ababa and Dire Dawa.

concerns. Then the model estimation follows using a two-step procedure. In the first stage, FI_i is regressed on the instrument Zi[35] and control variables Xi. The predicted values of FI_i are then used in the structural equation to estimate the effect of financial inclusion on household well-being.

3.1.2 Identification

The relationship between poverty and financial inclusion (FI) is fraught with endogeneity problems due to simultaneity, as highlighted by Imai et al. (2010). This simultaneity arises because financial inclusion can influence poverty, while poverty itself may affect the likelihood of being financially included. Even though FI has an effect on the reduction of poverty among households, the opposite may also be true, i.e. poverty may have an effect on whether a household has access to financial resources. Despite advancements in achieving financial sector development, financial knowledge remains one of the most significant obstacles to FI (Demirguc-Kunt & Klapper, 2012a). Consequently, it is essential to assess how the distance to banks influences the poverty-Financial Inclusion nexus. In this analysis, we used the distance to the nearest bank as an instrumental variable to control for potential endogeneity issues between poverty and FI (Imai et al., 2010; Mohammed & Scholz, 2017).

The identification strategy is determined in the first stage of the two-stage IV probit, as Cameron and Trivedi (2010) recommend using the Wald test of endogeneity and a standard F-test to test for weak instruments. The first-stage regression rejects the null hypothesis of weak instrumentation at the 0.01 significance level. Due to its theoretical relevance, we opted to utilize knowledge of financial service use as an instrument for financial inclusion.

[35] Zi is the instrumental variable which is knowledge of financial service use.

3.2 Estimation procedure

Before analyzing the mechanisms through which financial inclusion impacts poverty, it is crucial to first establish whether financial inclusion has a statistically significant effect on reducing poverty. Second, we estimate sub-sampled models that show how FI affects poverty in rural and urban households with male and female heads. The relationship between the FI index's key indicators and poverty is then investigated by looking at each of these indicators separately. Ownership of a credit card, an insurance policy, a mobile and bank account, and remittances are some of the indicators.

Specifically, we use the probit model to evaluate the deconstructed components of FI because instruments could not be identified for each. Poverty is a binary variable measured using a headcount index based on a poverty line of ETB 10,471. This figure was calculated using the following methodological approach. The data source and calculation are based on the Household Income, Consumption, and Expenditure (HICE) survey data from multiple rounds (1995/96, 2010/11, 2015/16, and 2018/19). This means households with a total consumption value more significant than the poverty line were classified as non-poor, while those falling below the line were classified as poor. The food poverty line was updated to ETB 7,178, while the total poverty line, accounting for both food and non-food expenditure, was estimated at ETB 10,471. Concerning the measurement issues this reflects the growth in consumption over time, ensuring consistency in real terms. While the methodology is consistent with the official approach used in the HICE surveys, the adjustment for inflation and growth in consumption relies on an assumed growth rate.

Financial inclusion is measured as a continuous variable ranging from 0 to 1. This score reflects the number of financial products/services a household utilizes out of a possible nine products/services. Each household reported whether they used each service (Yes/No). If a household didn't use any of the nine services, they received a score of 0. Conversely, if they used all nine services, they received a score of 1. Scores between 0 and 1 represent using some, but not all, of the financial products and services offered (i.e. the number of products/services divided by nine). This approach allows for a more nuanced understanding of financial inclusion compared to a simple yes/no indicator (see Section 2.3.7 for more detailed information on how this is done.)

Savings account, Credit/loan account, Insurance (e.g., health or life insurance), Mobile money services, Fixed deposit account, Cooperative financial services, Remittance services (receiving or sending money), Access to pension schemes, and Use of formal microfinance services. The nine services was selected to capture the broadest possible range of financial products and services typically available to households in the study area. Based on Cai et al. (2011), the IV probit method, which is a two-stage least square, was used to estimate the effects of FI on poverty reduction due to well-considered hypothetically endogenous decomposed indicators (Swamy, 2014a; Basu et al., 2018; Li et al., 2022;). Our dependent variable is poverty, and FI is the primary focus of the study, which incorporated it along with other covariates as an independent variable. In addition to financial inclusion indexes, the independent variables consist of socioeconomic and demographic variables that affect poverty.

First Stage (Reduced Form Equation - Linear Regression)

The relationship between FI and its determinants can be represented as follows. This stage explains the variation in financial inclusion (FI) using the instrumental variable (knowledge of financial services – fin knowledge) and other control variables (Xij).

$$FI_j = F(finknowledge_j, X_{ij}, \varepsilon_j) \qquad \textbf{(1)}$$

Where,

FI_j the financial inclusion score (continuous, 0 to 1) is the financial inclusion indicator,

$finknowledge_j$ is knowledge of financial services use (categorical)

X_{ij} captures a set of control variables: household demography, resource endowment, access to institutions, etc.,

ε_j is an area or regional fixed effect.

Second Stage (Structural Equation - Probit Model)

The second stage estimates the causal impact of financial inclusion (FI) on poverty (Pov) using the predicted financial inclusion (FI_hat) from the first stage and other control variables (Xs).

$$P(h_j = 1 \big| FI_j, X_{ij}) = G(\beta * FI_j, X_{ij}, \epsilon_j) \qquad \textbf{(2)}$$

Where,

$G(z) = \exp\,({}_z)/1 + exp(z)$

$P(h_j = 1 \big| FI_j, X_{ij})$ indicates the probability that poverty is 1 given financial inclusion and other central variables.

Since the FI variables are potentially endogenous and the second-stage variable is categorical, the IV probit approach is used. Following the literature, we use "distance to the nearest bank" as an IV. The proximity to a bank is considered an independent variable in the first stage of estimation, and a probit model is used to estimate the probability of poverty in the second stage.

The reduced form (1st stage) equation can be written as:

$$FI_i = \sigma_0 + \sigma_1 Knfsuse_i + \sigma_2 Age_i + \sigma_3 Hhsiz_i + \sigma_4 Hhsiz^2{}_i + \sigma_5 Gender_i + \sigma_6 Residence_i + \sigma_7 Edu_i + \sigma_8 Maritial_i + \sigma_9 Reg_i + \lambda_i \qquad \textbf{(3)}$$

Second stage Structural equation

$$P(h_j = 1 | \big| FI_j, X_{ij}) = ezp(z))/1 + exp(z) \qquad \textbf{(4)}$$

Were,

$$Z = \beta_0 + \beta_1 FI_i + \beta_2 age_i + \beta_3 hhsiz_i + \beta_4 hhsizsque_i + \beta_5 female_i + \beta_6 rural_i + \beta_7 educ_i + \beta_8 married_i + \beta_9 region_i + \lambda_i \qquad \textbf{(5)}$$

2nd stage equation expanded from the first stage

$$\Pr(PVT_i = 1|X_i) = \Phi(\beta_0 + \beta_1\widehat{FI}_i + \beta_2Ag_i + \beta_3Hhsiz_i + \beta_4Hhsiz^2{}_i + \beta_5Gender_i + \beta_6Residence_i + \beta_7Edu_i + \beta_8Maritial_i + \beta_9Reg_i) \quad (6)$$

where Φ(·)represents the cumulative distribution function (CDF) of the standard normal distribution.

4. Results and discussion

4.1. Summary of Variables

Table 1: FI index components

FI Component	Description	Proportion (%)	Dimension
ATM Banking	Access to ATM services	15	Access
Online Banking	Use of online banking	3	Usage
Mobile Banking	Use of mobile banking	6	Usage
Agent Banking	Access to agent banking	1	Access
Interest-Free Banking	Use of interest-free banking	6	Usage
Owns Account	Bank account ownership	46	Access
Credit Access	Access to credit facilities	12	Access
Remittance	Receipt of remittances	27	Usage
Savings	Regular savings	41	Usage
Insurance	Access to insurance services	36	Usage

Source: Own calculation using ESS round four data standard. ATM: Automated Teller Machine

Table 1 presents a Financial Inclusion (FI) Index constructed as a continuous variable ranging from 0 to 9, derived from nine categorical components (e.g., ATM banking, credit access). 46% of households own a bank account, indicating moderate financial inclusion in terms of formal account ownership. Furthermore, 41% of households report having a savings plan, and 36% have access to insurance services, suggesting some engagement with formal financial systems. Remittance receipt is reported by 27% of households, while only 12% have access to credit facilities, highlighting gaps in financial products that could support investment and consumption smoothing.

However, access to modern banking services remains highly constrained. Only 15% of households report using ATM services, and adoption of digital financial tools such as online banking (3%), mobile banking (6%), and agent banking (1%) is extremely limited. Similarly, interest-free banking a product designed to meet the needs of specific population segments is accessed by just 6% of households. These findings underscore significant barriers to accessing diverse financial products and services, particularly digital and convenience-driven options, which could otherwise enhance financial inclusion (Table 1). This distinction is crucial as it highlights the difference between availability (access) and active participation (usage), offering a more nuanced understanding of financial inclusion.

4.2. Measurement of the FI Index

Before examining the impact of FI on reducing poverty in representative households, we compute the FI index for poor and non-poor households. The FI index is calculated by counting the number of services used by households from a list of services that are affordable to them. The methods used to calculate the FI index are divided into two categories: access and usage[36]. It is consistent with the introduction's loose definition of FI, which states that FI reflects access to and utilization of a limited range of financial services (Sarma, 2008, p. 200; Demirguc-Kunt & Klapper, 2018). The figure below depicts the difference in usage of the components of the FI indicators before normalization between the two categories.

The t-test result shows a statistically significant difference in financial inclusion (FI) between non-poor and poor households. Specifically, Non-poor households have significantly greater financial inclusion (mean FI index = 2.2137) compared to poor households (mean FI index = 0.8881).The mean

[36] **Usage Dimensions**: Savings, remittance, insurance, mobile banking, online banking, interest-free banking. **Access Dimensions**: Owns account, credit access, ATM banking, agent banking. Demirgüç-Kunt, A., Klapper, L., Singer, D., Ansar, S., & Hess, J. (2018).

difference of 1.3257 suggests that non-poor households, on average, use more financial services than poor households, reflecting disparities in access and usage of financial services.

The large t-statistic (t=28.2721t = 28.2721t=28.2721) and small p-value (p<0.01p < 0.01p<0.01) confirm that this difference is not due to random chance but is statistically robust. This finding underscores the need for targeted policies to improve financial inclusion among poor households, which may help reduce poverty and promote equitable access to financial services.

Table 2: Two-sample t-test with equal variances for FI index used by poor and non-poor households

Group	Obs.	Mean	Std. err.	Std. dev.	[95% conf. interval]	
Non poor	4,946	2.214	0.026	1.835	2.162	2.264
Poor	1,733	0.888	0.027	1.125	.835	.941
Combined	6,679	1.870	0.022	1.777	1.827	1.912
diff		1.326	0.047		1.233	1.417
diff = mean(Non poor) - mean(Poor)					t = 28.2721	
H0: diff = 0		Degrees of freedom = 6677				
Ha: diff < 0 Ha: diff != 0					Ha: diff > 0	
Pr(T < t) = 1.0000 Pr(T > t) = 0.0000					Pr(T > t) = 0.0000	

4.3. Estimating the Poverty Headcount Index

Although there are several methods for determining a country's poverty line, the most prevalent is to use the cost of basic needs that are sufficient to provide the minimum number of calories necessary for a healthy life. The price of this food basket is referred to as the "food poverty line." A non-food component is typically determined based on the observed percentage of non-food consumption in low-income households (Akhtar et al., 2015). Finally, the overall poverty line can be calculated by combining the food and non-food poverty lines (Fritzell et al., 2012). The poverty data is derived from the aggregate consumption dataset for round four of the socioeconomic survey in 2018–19.

This study utilized the MoF[37]-estimated national poverty line from the HICE[38] survey conducted by CSA[39]. We made some adjustments and accounted for inflation to determine the 2018–19 poverty line level and we calculated consumption per adult equivalent. Using the 2018/19 adjusted poverty line, we applied it to the ESS consumption data to calculate the headcount index. For instance, if the poverty line is 10,000 Birr, we determine the number of people below this threshold. Using survey data, we determined the annual per capita consumption expenditure by calculating the consumption expenditure per adult equivalent from the aggregate household consumption expenditure data. The adjusted 2018–19 poverty line was then applied to the ESS consumption data to calculate the headcount index. To ensure transparency, the magnitude of these adjustments, the methodological approach, and justifications for using this poverty line adjustment are detailed below. However, we acknowledge the limitations of relying on externally estimated poverty lines and recommend future studies explore independent, scientific methods for estimating poverty levels. To clarify, the response variable Poverty is represented in this study by the poverty headcount, which determines the number of people who are defined as poor because their consumption expenditure is less than the cutoff point[40], poverty line at the national level (National Poverty Report, 2016). Based on the most recent national poverty line report, we calculated the poverty head count by using the annual CPI growth rate[41] and updated the older poverty lines to account for inflation. The poverty line, or the annual consumption expenditure per adult person per year, increased from 7,184 birr in 2015/16 to 10,470 birr in 2018/19[42] (See Appendix 1).

[37] Ministry of Finance
[38] Household Income and Consumption Expenditures.
[39] Central Statistics Agency.
[40] The Cutoff Point for Poverty Headcount is about 10,200 Birr per year in the Adult Equivalent Term.
[41] CPI (Consumer Price Index).
[42] According to this Estimate, the Country's Absolute Poverty Line for 2018/19 is 29.5.

4.4. Summary Statistics

This study revealed that Ethiopia's updated poverty rate is approximately 25.9 percent. Poverty appears to be more prevalent in rural areas than in urban areas, with 48 percent of rural residents living in poverty compared to 14 percent of urban residents. Likewise, households headed by women are less prosperous than those headed by men (Table 2).

The ownership disparity between male- and female-headed households is approximately 48% for male-headed households and 40% for female-headed households. The location also revealed a significant difference, with rural households owning accounts at a rate of 21% while urban households owning accounts at a rate of 66%, indicating a 45 percent difference in urban areas due to factors such as affordability and accessibility of financial institutions and financial products. Female-headed households receive more remittances than male-headed households. As expected, urban households receive more remittances than their rural counterparts. In addition to owning insurance policies, families headed by men are more likely to save money and have bank accounts, but they receive less remittance.

4.5. Characteristics of Selected Indicators across Regions

HHs in Afar and Somalia region are supposed to travel on average 2.48 and 2.8 km to access formal financial institutions. While HHs from Addis Ababa travel around half a km, HHs from Dire Dawa administration cities, on average, travel 0.77 km for financial access.

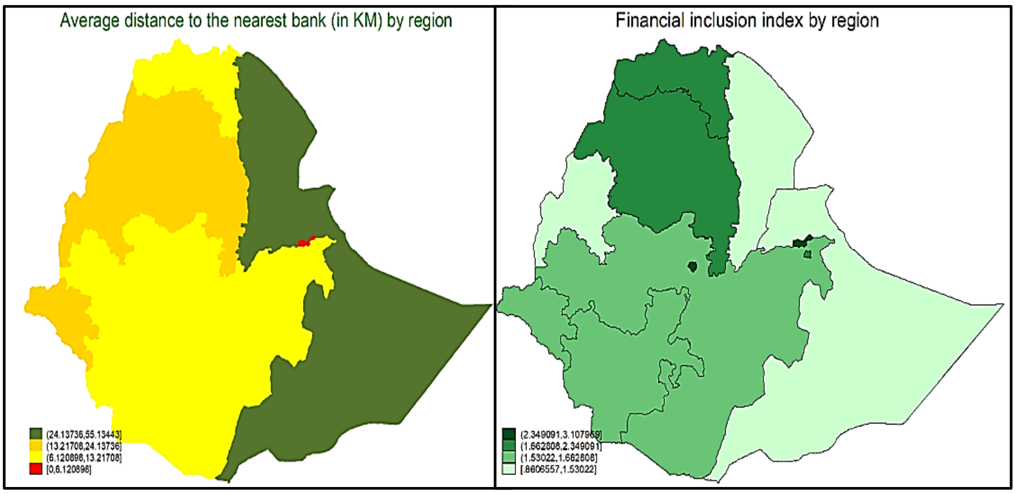
Table 3: Average distance to the nearest commercial bank across regional states

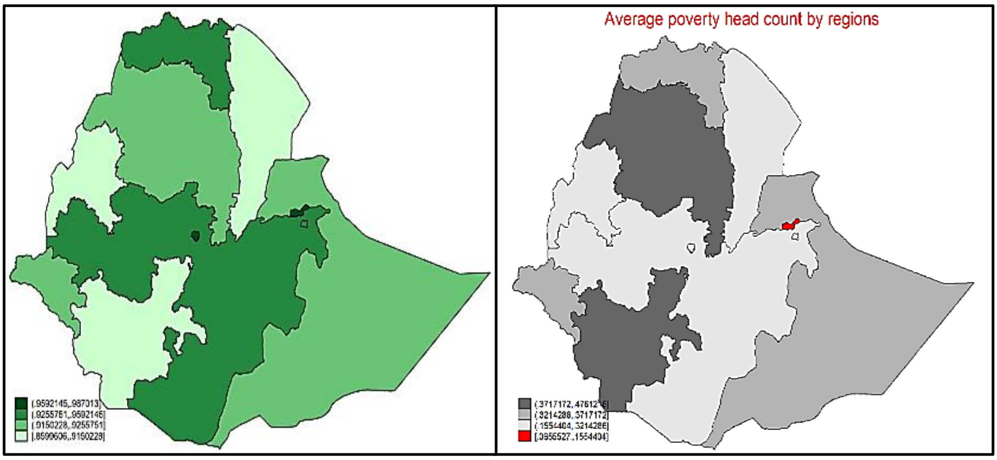
Region	Mean	Std.Err.	[95%_Conf	Interval]
Tigray	1.547032	.0549921	1.43923	1.654834
Afar	2.48744	.0778287	2.334872	2.640009
Amhara	2.238503	.053491	2.133644	2.343362
Oromia	1.478664	.0516118	1.377489	1.57984
Somali	2.804146	.0790735	2.649137	2.959155
Benishangul	2.290993	.0799446	2.134277	2.44771
SNNP	2.049175	.0487505	1.953608	2.144741
Gambela	1.479003	.0748144	1.332343	1.625663
Harar	1.052589	.0409231	.9723672	1.132812
Addis Ababa	0 (Omitted)			
Dire Dewa	.771998	.0558038	.6626049	.881391

Source: Author's computation

The regional distribution of financial inclusion measured by the number of financial products used by HHs looks more concentrated in city administrations. Harari, Amhara, and Tigray regions have better financial inclusions compared to the other regions.

Figures 3: Correlation between financial inclusion and poverty across regions





The correlations between the three indicators show that a household far from a financial institution tends to be poor. The more the household in each region is less financially included, the more they are more likely to be vulnerable to poverty. Based on the correlations between the three indicators, it can be concluded that a household located far from a financial institution is more likely to be poor. In each region, the likelihood of a household being vulnerable to poverty increases in proportion to the degree to which it is less financially involved in the population.

The proportion of households with bank accounts owned by urban households appears to be higher than that of rural families, which indicates that urban households have more formal bank accounts. People living in rural areas may have access to credit on average which is slightly higher than those living in towns and cities. Based on the mean values, it appears that residents of rural households are more likely to get money via remittances than residents of urban families. Taking into consideration the data, it appears that the average amount of savings made by rural and urban households is comparable. When it comes to insurance coverage, there does not appear to be a major difference between rural and urban households based on the means. This is rather similar to the situation with savings. A higher average poverty score appears to be associated with rural homes, which suggests that the prevalence of poverty is higher in rural households compared to urban ones.

Mean Difference: The analysis reveals a statistically significant difference in poverty rates between male-headed and female-headed households. Male-headed households exhibit a higher mean poverty rate (0.2686) compared to female-headed households (0.2399), with a mean difference of 0.0287 (t=2.50,p=0.0126t = 2.50, p = 0.0126t=2.50,p=0.0126). This finding underscores a notable gender disparity in poverty levels. Similarly, male-headed households demonstrate significantly higher levels of financial inclusion, with a mean score of 2.0039 compared to 1.5823 for female-headed households. The mean difference of 0.4216 (t=9.08,p<0.0000t = 9.08, p < 0.0000t=9.08,p<0.0000) indicates that gender plays a critical role in determining financial inclusion, with males having greater access to and utilization of financial services. These results highlight the importance of addressing gender-specific barriers to financial inclusion and poverty alleviation.

Table 4: Gender mean differences in poverty and financial inclusion

Variable	Group	Mean	Mean Difference	t-Statistic	p-Value	Conclusion
Poverty	Male	0.2686	0.0287	2.5	0.0126	Significant difference (p < 0.05)
	Female	0.2399				
Financial Inclusion	Male	2.0039	0.4216	9.08	0	Significant difference (p < 0.01)
	Female	1.5823				

Source: Author’s elaboration

Table 5: Descriptive summary presents the descriptive statistics of the key variables used in the analysis

Variable	Full Sample	Male	Female	Rural	Urban	p-value (Gender)	p-value (Location)
Poverty	25.9	30.5	26.7	48	14	0.03	0.01
Account ownership	45.7	48.1	40.6	21	66	0.05	<0.01
Access to credit	12.1	12.4	11.5	13	12	0.08	0.12
Remittance	26.6	22.5	35.8	24	29	0.01	0.08
Saving	40.5	43.6	33.3	22	55	0.04	<0.01
Insurance	35.9	40.1	26.8	18	50	0.02	<0.01
Married	66.7	84	29.6	73	61	0.01	0.04
Access to Radio & TV	45.9	47.6	42.1	23	65	0.02	<0.01
Agriculture sector	85	86	82.7	98	74	0.1	<0.01
Weekly market access	67.8	66.7	70.1	55	78	0.06	<0.01
Land area (hectares)	0.197	0.206	0.165	0.16	0.22	0.07	0.05
Livestock (count)	1.427	1.631	0.953	2.5	0.51	0.01	0.02
Age of household head (years)	42.2	41.9	42.9	44.4	40.3	0.12	0.1
Education (years)	1.2	1.2	1.2	0.3	2	0.15	<0.01
Household size (count)	4.2	4.6	3.4	4.8	3.8	0.04	<0.01

The result provides evidence of demographic disparities by different variables such as households. these differences could have implications for poverty or financial inclusion, as larger households may face more significant financial pressures or different resource allocation challenges.

Empirical results

Before examining the effect of FI on poverty reduction, we conducted the weak instrument and endogeneity test, which confirmed endogeneity at a 5% level. Therefore, the rejection of the null hypothesis of endogeneity supports the incompatibility of the Probit model for analyzing the effects of FI on poverty reduction. Compared to the simple Probit model used to examine the role of FI in reducing poverty in Ethiopia, the IV probit model demonstrates that a standard probit model places significantly less emphasis on the impact of FI. Moreover, all F statistics exceed 10, indicating a problem with the instrument's reliability (Balanay et al., 2014).

In line with the literature, when a household is financially included (when access to and/or use of finance increases), its likelihood of being poor decreases by about 42.3%; thereby, households benefit from the expansion of FI (Swamy, 2014b, and Mohammed and Scholz, 2017). In accordance with Alemu (2006), the results show the importance of demand- and supply-side constraints on digital payment services in Ethiopia. Indeed, they prove that isolation from nearby financial institutions has a substantial effect on the effect of financial inclusion on the poverty status of households. If substantial public efforts are made to increase FI supply and demand indicators, the Ethiopian National Bank's strategic plan to reduce poverty may be strengthened. The findings of this study regarding the impact of FI on reducing poverty are consistent with theories of financial development and the Maya Declaration of 2010 (Pazarbasioglu et al.,1998; King & Levine, 1993). There is also a spillover effect of improved FI on individuals, which can enhance the business capability of households, increase revenue and consumption, and assist individuals in escaping poverty. The educational system is one of the channels through which poverty can be influenced. Indeed, skilled heads of households are 1% more likely to be poor than their uneducated counterparts. Furthermore, the number of households has an effect on poverty reduction because a larger number of household members, particularly those employed in various sectors, can generate income when compared to households with fewer households; as the number of households increases, the probability of being poor decreases by about 15%.

Table 6: IV probit regression of the effect (ME) of FI on poverty

VARIABLES	PROBIT	IV PROBIT
POVERTY	**(1)**	**(2)**
FI Index	-0.336***	-0.423***
	(-0.103)	(-0.1)
Gender (1 if female, otherwise 0)	0.23**	-0.17**
	(-0.09)	(-0.08)
Age of HH head	0.06***	0.03***
	(-0.01)	(-0.01)
Age of HH head squared	-0.00***	-0.00***
	(0.00)	(0.00)
Household head education (in years)	-0.09***	0.01
	(-0.02)	(-0.01)
Married (no=0; yes=1)	-0.04	-0.05
	(-0.09)	(-0.05)
Household size	0.39***	0.15***
	(-0.02)	(-0.03)
Access to Radio & Television	-0.74***	0.05
	(-0.08)	(-0.12)
Agriculture sector	0.2	-0.13
	(-0.16)	(-0.08)
Rural (urban=0; rural=1)	0.85***	0.05
	(-0.09)	(-0.12)
Weekly market access	-0.01	0.08*
	(-0.07)	(-0.04)
Land area in hectare	0.06	0.03
	(-0.05)	(-0.02)
Livestock	-0.07**	-0.05***
	(-0.03)	(-0.01)
Regional Dummy	YES	YES
Wald chi2(23)	2237.27 ***	2849.48***

Source: Authors estimates

A robustness check was performed to ensure consistency with prior studies and econometric methodologies. We employ an identification strategy based on heteroscedasticity and apply our external instrument to MHHs, FHHs, and distinct rural and urban samples. We found that financial inclusion reduces poverty significantly across all estimation methods. In addition, we independently utilized each type of financial inclusion and conducted the same analysis. Whether or not a person has a bank account, uses internet banking, or utilizes an ATM are examples of the independent financial products used here. We include some estimates and test the robustness of the results by analyzing a few financial inclusion index components with poverty and evaluating the model's robustness (see Appendix 2).

Heterogeneity analysis

In the previous section, it has been shown that FI can reduce poverty in Ethiopia. In the following section, we analyzed heterogeneity by comparing the impact of FI indexes on rural and urban MHH and FHH households. Tables 6 and 7 show the results.

Gender gap

In developing nations, it is generally believed that FHHs are more financially excluded than MHHs. However, female-headed households are more likely to be productive and effective to benefit from the FI impact on poverty reduction if they can be financially included. The findings on the gender component of FI versus poverty reduction are astounding. A rise in the likelihood of being financially included for MHHs can reduce the likelihood of being impoverished by nearly 56%. In contrast, a decline in the likelihood of being impoverished can reduce the likelihood of being poor by almost 70% for FHHs. As a result, when compared to male heads, FI has a 14 percent greater impact on poverty reduction for female heads. FI reduces poverty by providing entrepreneurial opportunities through credit access and receiving remittances from various sources; improved FI strengthens the productive state of poor households.

Table 7: Role of FI on poverty in FHH and MHH – IV probit and probit estimations

Poverty	Male		Female	
	Probit	IV Probit	Probit	IV Probit
Variables	**(1)**	**(2)**	**(3)**	**(4)**
FI Index	-0.37*** (-0.03)	-0.56*** (-0.09)	-0.38*** (-0.06)	-0.70*** (-0.09)
Age of household head	0.03** (-0.02)	0.02*** (-0.01)	0.11*** (-0.02)	0.04*** (-0.01)
Age of household head squared	-0.00* (0.00)	-0.00*** (0.00)	-0.00*** (0.00)	-0.00*** (0.00)
Education in years	-0.08*** (-0.03)	0.00 (-0.02)	-0.12*** (-0.04)	0.01 (-0.03)
Married (no=0; yes=1)	0.08 (-0.13)	-0.03 (-0.07)	-0.22 (-0.15)	-0.09 (-0.07)
Household size	0.37*** (-0.02)	0.16*** (-0.03)	0.48*** (-0.04)	0.16*** (-0.05)
Access to radio & TV	-0.62*** (-0.1)	0.02 (-0.14)	-1.09*** (-0.17)	0.02 (-0.21)
Sector (Agriculture=1; other=0)	0.38* (-0.21)	0.01 (-0.11)	0.00 (-0.25)	-0.31** (-0.13)
Residence (1 if Rural, otherwise 0)	0.83*** (-0.12)	0.06 (-0.16)	0.94*** (-0.16)	0.12 (-0.16)
Access to weekly market	0.02 (-0.09)	0.09* (-0.05)	-0.08 (-0.14)	0.01 (-0.07)
Area of land in ha	0.05 (-0.06)	0.03 (-0.03)	0.08 (-0.09)	0.03 (-0.05)
livestock	-0.05 (-0.03)	-0.04** (-0.02)	-0.11** (-0.05)	-0.06** (-0.03)
Region (Base=Tigray)				
Other ten regional dummies	Yes	Yes	Yes	Yes
Distance to the nearest bank		-0.12*** (-0.02)		-0.12*** (-0.03)
Observation	4263	1978	4263	1978

Instrumented: FI index Instrument: Distance to the nearest bank (km)

Robust standard errors in parentheses *, ** and *** level of significance at 10%, 5% and 1 respectively. ME: Marginal effect IV Probit: Instrumental Variable Probit, Source: own computation

In line with the literature on household participation in non-agricultural enterprises, it was observed that in the case of Ethiopia, women are more involved in entrepreneurial activity than men (King & Levine, 1993; Rijkers & Costa, 2012). Our findings support the conclusion of Swamy (2014a) that female-headed households are more likely to reduce poverty than male-headed households. This is because FHH[43] use available resources to improve the well-being of their families while contributing more to household savings than their counterparts. According to Demirgüc-Kunt (2018), closing the gender gap to achieve FI's goals will benefit society by reducing poverty more rapidly.

Does where HHs live affect how financial inclusion helps reduce poverty?

Formal financial organizations, such as commercial banks and microfinance institutions, are concentrated in Ethiopia's urban areas. Our findings suggest that increasing FI accessibility and affordability in rural and urban regions reduces poverty in Ethiopia. The IV probit model's conclusions (Table 7) indicate that increasing FI can lower a household's likelihood of being deprived by about 66 percent. In comparison, FI's reduction effect on urban households is about 60 percent. Rural households benefit from FI improvement by five percentage points more than urban households. In most developing countries, including Ethiopia, poverty is primarily a rural phenomenon; accordingly, working to raise awareness among rural households about the affordability and accessibility of financial inclusion reforms that allow households to gain access to financial products and services can go a long way toward improving the living conditions of rural residents. This conclusion is supported by research on India (Burgess & Pande, 2005), which noticed that expanding the number of state-owned bank branches significantly reduced poverty among rural households by providing access to formal credit and savings opportunities. In Malawi, the availability of credit to rural households provides access to the agricultural industry for disadvantaged parties. This ought to significantly affect the livelihoods that influence the accessibility of funding for agricultural inputs (Brune et al., 2011).

[43] FHH STANDS for Female Headed Households, while MHH refers to Male Headed Households.

Table 8: Probit estimations of the impact of poverty in rural and urban households

	Rural		Urban	
Poverty	**Probit**	**IV Probit**	**Probit**	**IV Probit**
Variables	**(1)**	**(2)**	**(3)**	**(4)**
FI Index	-0.28***	-0.66***	-0.47***	-0.61***
	(-0.04)	(-0.15)	(-0.05)	(-0.06)
Age of household head	0.05**	0.03***	0.08**	0.04***
	(-0.02)	(-0.01)	(-0.02)	(-0.01)
Age of household head squared	-0.00*	-0.00***	-0.00*	-0.00***
	(0.00)	(0.00)	(0.00)	(0.00)
Education in years	-0.09**	0.02	-0.09***	0.00
	(-0.04)	(-0.04)	(-0.03)	(-0.02)
Married (no=0; yes=1)	-0.14	-0.07	-0.12	-0.00
	(-0.12)	(-0.07)	(-0.16)	(-0.07)
Household size	0.42***	0.19***	0.37***	0.13***
	(-0.03)	(-0.04)	(-0.03)	(-0.03)
Access to radio and TV	-0.50***	0.09	-0.19***	0.04
	(-0.11)	(-0.07)	(-0.14)	(-0.17)
Sector (Agriculture=1; other=0)	0.82*	0.09	0.08*	0.20
	(-0.25)	(-0.26)	(-0.19)	(-0.08)
Access to a weekly market	0.02	0.09*	0.14	0.17**
	(-0.09)	(-0.16)	(-0.16)	(-0.07)
Area of land in ha	-0.12	0.04	-0.18	0.06*
	(-0.08)	(-0.04)	(-0.06)	(-0.03)
Livestock	-0.13	-0.07***	-0.03	-0.02
	(-0.04)	(-0.02)	(-0.05)	(-0.03)
Region (Base=Tigray) Other ten regional dummies	Yes	Yes	Yes	Yes
Distance to the nearest bank		-0.12***		-0.12***
		(-0.03)		(-0.02)
Observation	3311	2930	3311	2930

Source: own computation

FI indicators and poverty in Ethiopia

This study examines the relationship between financial inclusion (FI) indicators—such as mobile banking ownership, formal bank accounts, access to credit, and remittances—and poverty. Financial inclusion is widely recognized as a vital element of inclusive development, particularly for disadvantaged groups, as it facilitates access to financial resources that support long-term investments and consumption decisions. By enabling households to participate in productive economic activities, FI plays a crucial role in reducing poverty and fostering economic empowerment. Understanding these relationships provides valuable insights for policymakers in designing and implementing anti-poverty programs that ensure rural and underserved populations have unrestricted access to and effective use of financial services (Park & Mercado, 2015). Consistent with prior studies such as Mohammed and Scholz (2017), this analysis reveals that mobile banking ownership significantly reduces the likelihood of poverty, as does owning a formal bank account and receiving remittances, highlighting the transformative potential of financial inclusion for poverty alleviation.

The findings further emphasize the importance of demographic and household characteristics in shaping poverty outcomes. Female-headed households, larger households, and rural households are more likely to experience poverty, reflecting structural disparities in access to economic opportunities and resources. On the other hand, education emerges as a key factor in poverty alleviation, as an additional year of education for the household head significantly reduces the probability of being poor. Similarly, marital status plays a role in reducing poverty, with married household heads benefiting from shared economic resources. While access to credit showed no significant effect on poverty, the availability of remittances and ownership of financial tools like mobile banking services and formal bank accounts contribute significantly to reducing poverty risks. These results underscore the need for targeted policy interventions that prioritize financial inclusion, promote education, and address gender and rural-urban disparities to achieve sustainable poverty reduction.

Table 9: Result from Regression on the Effects of FI indicators on poverty

Poverty	ME	Std. Err.
Mobile Banking ownership	-0.269***	0.067
Bank Account Ownership	-0.13***	0.012
Access to Credit	-0.015	0.015
Receipt of Remittance	-0.056***	0.012
Age of HH head	0.001**	0
HH Size	0.113***	0.007
HH Size Square	-0.005***	0.001
Gender	0.058***	0.014
Residence	0.101***	0.013
Education in years	-0.015***	0.003
Marital status	-0.028*	0.014
Region (Base=Tigray)		
Observation	6130	
LR chi2(22)	2148.03	
Prob>chi2	0	
Pseudo R2	0.2869	

Source: own computation

5. Conclusion and Recommendations

Financial inclusion has recently emerged as a key pillar for economic development, with the goal of reducing income disparities and poverty through channels such as access, usage, infrastructure, and affordability. Using round-four Ethiopian socioeconomic survey data, we used an instrumental variable probit model to examine how the FI index affects poverty. To collect financial data at the household and individual levels, the Ethiopian socioeconomic survey data uses an FI module developed in collaboration with the National Bank of Ethiopia. The data collected through the ESS-FI Module will be used to track progress in account ownership and usage indicators for the Ethiopia National FI Strategy. Over 6,700 households were surveyed across the country for the study, which is representative at the national, rural, urban, and regional levels. Individual socioeconomic questions were answered by all adults 18 and older, a total of 14,500 people. According to our findings, Ethiopia, like other African developing countries, has a low FI. The findings indicated that increasing the accessibility of formal financial institutions and focusing on making financial regulations more affordable can help rural people escape poverty. Currently, FI has the potential to reduce poverty by approximately 42.3%, with rural communities having a higher likelihood than urban communities. Male-headed households have a lower financial impact on reducing poverty than their female counterparts. Greater financial inclusion strengthens the productive assets of disadvantaged households and boosts their entrepreneurial activity. Our findings are also consistent with those of Swamy (2014b), who found that females have a greater capacity to reduce poverty because, compared to households headed by men, households headed by women use their resources to improve the financial security and well-being of the entire family. The research findings demonstrate the effectiveness of financial inclusion as a policy tool in eradicating reducing poverty and provide solid justification for the National Bank of Ethiopia's financial strategy to achieve this goal. The government must strive to accelerate the rate of FI to serve every region of the country. Given that FI is one of the policy pillars for reducing inequality, it is far more prudent to emphasize removing the barriers that prevent the community from adopting financial products. In addition to increasing the accessibility of financial institutions, it is recommended that financial products be integrated with digital applications such as mobile banking.

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Appendix.1: Poverty headcount calculation

Year	CPI	Based on the annual baseline	2018/19 baseline	
2009/10	42.9	43.4	29.7	**Inflation**
2010/11	59.2	59.8	41.0	38.0
2011/12	71.5	72.3	49.6	20.8
2012/13	76.8	77.6	53.2	7.4
2013/14	83.3	84.2	57.7	8.5
2014/15	92.0	93.0	63.8	10.4
2015/16	98.9	100.0	68.6	7.5
2016/17	107.2	108.4	74.3	8.4
2017/18	125.2	126.5	86.7	16.8
2018/19	144.3	145.9	100.0	15.3
2019/20	175.8	177.7	121.8	21.8

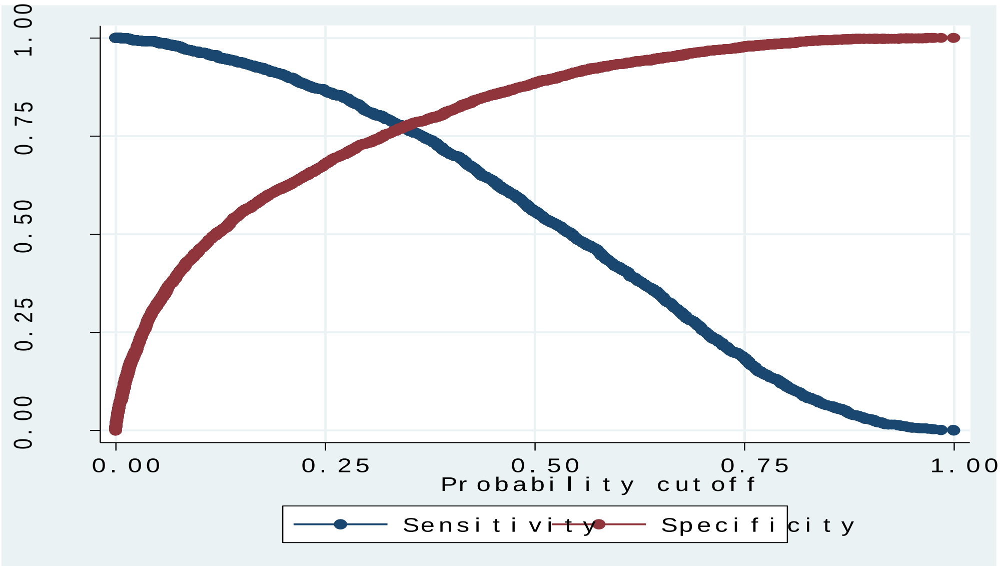
	2015/16	2018/19
Poverty line	3,781	5,515.49
Absolute Poverty line	7,178	10,470.82

Source; Own computation

Appendix 2: chi 2 test of the financial inclusion index by location

FI index	Urban	Rural	Total
0	575	1,350	1,925
1	605	895	1,500
2	626	406	1,032
3	695	229	924
4	608	102	710
5	302	43	345
6	142	10	152
7	57	3	60
8	24	0	24
9	6	1	7
Total	3,640	3,039	6,679
	Pearson chi2(9) = 1,400		Pr = 0.000

Appendix 2: Sensitivity analysis



Appendix 3: Endogeneity tests

	(1)		(2)		(3)	
	Ownership of Bank Account		Ownership of Mobile Banking		ATM Banking	
Poverty						
Gender (1 If Female)	0.24***	(0.06)	0.25***	(0.05)	0.21***	(0.06)
Age_ Head of Hh	0.01***	(0.00)	0.01***	(0.00)	0.01***	(0.00)
Education_ Head of Hh (In Years)	-0.04***	(0.01)	-0.04***	(0.01)	-0.03***	(0.01)
Married (No=0; Yes=1)	0.02	(0.06)	0.02	(0.06)	0.01	(0.06)
Household Size	0.25***	(0.01)	0.24***	(0.01)	0.24***	(0.01)
Agriculture Sector	0.10	(0.09)	0.08	(0.09)	0.07	(0.09)
Residence (1 If Rural, Otherwise 0)	0.31***	(0.06)	0.31***	(0.06)	0.29***	(0.06)
Weekly Market Access	-0.06	(0.04)	-0.06	(0.04)	-0.06	(0.04)
Land Area In Hectare	-0.01	(0.03)	-0.00	(0.03)	-0.01	(0.03)
Livestock	-0.09***	(0.02)	-0.09***	(0.02)	-0.09***	(0.02)
Asset Index	-0.26***	(0.02)	-0.27***	(0.02)	-0.26***	(0.02)
Regional Dummy	YES		YES		YES	
Ownership Of Bank Account	-0.12	(0.13)				
Fowns	-0.11**	(0.06)				
Ownership Of Mobile Banking			-0.70*	(0.36)		
Fmobank			-0.05	(0.06)		
ATM Banking					-0.68***	(0.19)
Fatmbank					0.06	(0.05)
_Cons	-2.21***	(0.21)	-2.24***	(0.17)	-2.07***	(0.18)
N	6116.00		6116.00		6116.00	

Standard errors in parentheses

Source: own calculation using 2018/19 LSMS-ISA ESS data

*, ** and *** level of significance at 10%, 5% and 1 respectively