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Energy Use, Economic Growth, and Carbon Dioxide Nexus in Ethiopia: An Auto Regressive Distributed Lag-Bound Test of Co-Integration Analysis

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Abstract

Understanding energy, economic growth, and carbon dioxide nexus in Ethiopia help to develop and refine contemporary policies and strategies. This study is used the Auto-Regressive Distributed Lag model to test and analyze data. The finding shows unidirectional and negative causality from the square of per capita gross domestic product to carbon dioxide emission in the short run, while the relationship between carbon dioxide emission and energy use is bidirectional and positive in the long run. Besides, energy use and the per capita gross domestic product bidirectionally related to each other in the short run. Thus, we found that energy is an engine to enhance economic growth and to reduce carbon dioxide emissions. So, it is pivotal to give an emphasis to the untouched energy sources.

Keywords: Trends; relationship; causality; CUSUM; carbon dioxide emission forecast

JEL Classification: O44, P18, Q43, Q56

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1. Introduction

Many developing countries have the ambition to meet a higher level of economic growth within the challenges of energy supply and climate change. Carbon dioxide induced climate change is an innate concern for the economic growth of these countries. It is one of the Greenhouse Gases (GHG) accountable for global warming (Houghton, 2004; IEA, 2019; Miller and Spoolman, 2009). According to the International Energy Agency (IEA), the global CO_2 emissions are contributed 30 percent of the surface temperature (IEA, 2019), which is increasing over time. For instance, in the1970s and 2012 CO_2 emissions were 24.3 and 46.4 gigatons, respectively (Janssens-Maenhout et al., 2017). The trend shows an increment of 2.3 percent per year from 2004 to 2014, with no significant growth between 2014 to 2016, and enhanced again by 1.2 percent in 2017 (UNEP, 2018). The global CO_2 emission has been increasing (Janssens-Maenhout et al., 2017; Olivier et al., 2017; Olivier et al., 2013) while showing variation between countries (Janssens-Maenhout et al., 2017) and between cities within the national boundary (Han et al., 2018; Wang and Feng, 2018).

The implications of economic activities for CO_2 emission are profound. Practically the effect of economic activities on CO_2 emission is observed during the economic lockdown following the Covid-19 pandemic in 2020. During this specific period, CO_2 emission has reduced by 7% owing to the fall in the energy demand (IEA, 2020). This phenomenon implies that the effect of economic activities on CO_2 emission is substantial. However, the level of emission varies from one nation to another based on their economic activity. For instance, economic growth contribute to CO_2 emission for lower-middle-income countries such as India (Boutabba, 2014), Ghana (Aboagye, 2017), and Pakistan (Ahmed and Long, 2012; Javid and Sharif, 2016; Shahbaz, Hooi, and Shahbaz, 2012). The same goes true for higher-income countries like Kuwait (Salahuddin, Alam, Ozturk, and Sohag, 2018), Saudi Arabia (Saad and Belloumi, 2017), and Qatar (Charfeddine, 2017). Moreover, economic growth also contribute to CO_2 emission for the upper-middle-income countries like China (Zhang and Xu, 2017) and Malaysia (Saboori et al., 2012).

Moreover, some empirical evidence shows that economic growth suppresses CO_2 emission for the case of BRICS (Brazil, Russia, India, China, and South Africa) economies (Haseeb et al., 2019), for China (Rauf et al., 2018), Sub-Saharan Africa (Inglesi-lotz and Dogan, 2018), for selected South Asian countries such as Nepal, Sir-Lanka, and Pakistan (Ahmed et al., 2017), and for 26 high income and 52 emerging OECD countries (Özokcu and Özdemir, 2017). However, CO_2 emission in Africa grows fast (Nathaniel and Iheonu, 2019) with an average rate of 3.2 percent per year from 2000 to 2005 (Canadell et al., 2009), while its average GHG emission increased from 2.9 to 3.1 percent per year between 1994 to 2014 (Tongwane and Moeletsi, 2018). Specifically, agricultural activities in the North African countries cause CO_2 emission (Jebil and Youssef, 2017).

Ethiopia is said to have one of the fastest-growing economies in the world over the last decade (FocusEconomics, 2020; IMF, 2020). The average GDP growth during the Derg regime (1974-1991) was declined by 1 percent while after government change in 1991 (Shiferaw, 2017), the average real GDP grew by 1.3 and 10.9 percent from 1992 to 2003 and 2004 to 2014, respectively (World Bank, 2016) while it shows a 9 percent increment in 2018/19 (IMF, 2020). Hence, to achieve the target of becoming a middle-income country by 2025 (FDRE, 2011), Ethiopia has planned a Climate Resilient Green Economy (CRGE) strategy to sustain economic growth and fighting climate change (FDRE, 2011). Ethiopia also ratifies the Intended Nationally Determined Contribution (INDC) to reduce GHG emission by 2030 (Gota, et al., 2016). Despite the fact that the conventional growth path is expected to increase CO_2 emission (FDRE, 2011), Ethiopia like other countries whose economies are emerging are unable to achieve the green growth strategy due to lack of technology, energy inefficiency, and poor management (OECD, 2012).

The pace at which the Ethiopian economy is growing coupled with the increasing energy consumption (Oqubay, 2015) which might cause CO_2 emission unless it is properly managed and regulated (Danyo et al., 2017). Besides, 100 % of the rural households and 68% of the urban population in Ethiopia uses energy from firewood and charcoal (Beyene et al., 2018) which favors CO_2 emission (Asumadu-Sarkodie and Owusu, 2017). Hence, population expansion is likely to increase energy use and CO_2 emission (Ahmed and Long, 2012; Ahmed et al., 2017b; Ara et al., 2015). So, it is better to assess whether the ever-increasing population exacerbate CO_2 emission in Ethiopia or not.

In addition, agriculture, the backbone of the Ethiopian economy, shares 70 percent (EPMES, 2017) to 80 percent (EEA, 2017) of the total employment. Accordingly, the agricultural land in Ethiopia shows some increment for the last four decades following population expansion and domestic and foreign direct investments (CSA, 2014, 2018; Keeley et al., 2014; Rahmato, 2011). According to the Ethiopian Economics Association (EEA), cultivated agricultural land was increased by 1.3 percent in 2016/17 as compared to 2013/14 while it accounted for

26.2 percent of the GDP for the specific year (EEA, 2017). However, its share of the GDP declines over time (Ferede and Kebede, 2015; Geda, 2001). Hence, it is healthier to search for the contribution of agricultural land expansion to CO_2 emission particularly for emerging agrarian economies like Ethiopia.

From the discussions above, it is noted that there is a significant difference in the theoretical and empirical gaps with regard to the relationship between CO_2 emission, economic growth, and energy use. Hence, it is difficult to conclude the finding in one country significantly represents the other unless addressed by empirical evidence. Even though there are few findings related to this study in Ethiopia (Adem, et al., 2020; Hundie, 2018; Mahrous, 2017; Wolde, 2015) their findings regards to the EKC is not consistent. For instance, the findings by Adem, et al. (2020) and Hundie (2018) support the existence of the EKC while Mahrous (2017) presents the otherwise. Furthermore, Wolde (2015) misinterpreted EKC, yet the displayed result of GDP and its square value is against the hypothesis. In these regards, this study tries to fill the literature gap of the applicability of the EKC theory in Ethiopia. Thus, the necessity of this study is timely and incontestable. Specifically, it intends to show the trend of CO_2 emission, energy use, and GDP, its causality and relationships considering the structural changes related to government change and environmental policy.

This study is expected to contribute its part to the motive of climate change adaptation and GHG mitigation campaign. So, the pattern of energy use and economic growth towards carbon dioxide emission expected to back governors on development plans. The outcome contributes towards the short- and long-term plans of energy use and economic growth which likely to gear the development path towards climate-smart resource use, technological adaptation, and pollution mitigation practices.

This study is organized and presented in five sections. Following the introduction section, the methodology includes the analytical framework, data type and source, and model selection strategy. The result section explains the descriptive statistics, unit root, lag length, and bound test of co-integration. In addition, trends and relationships, co-integration and long-run estimates, post-model estimation, and the robustness of the ARDL model is presented. The discussion section elaborates the result in relation to previous empirical findings. The last section, conclusion and policy implication, summarizes major findings and forwards policy recommendations.

2. Methodology

This section contains the discussions on analytical framework, data types and sources, model selection strategy, results, unit root and lag length, co-integration and long run estimates, co-integration and long run estimates and other related issues.

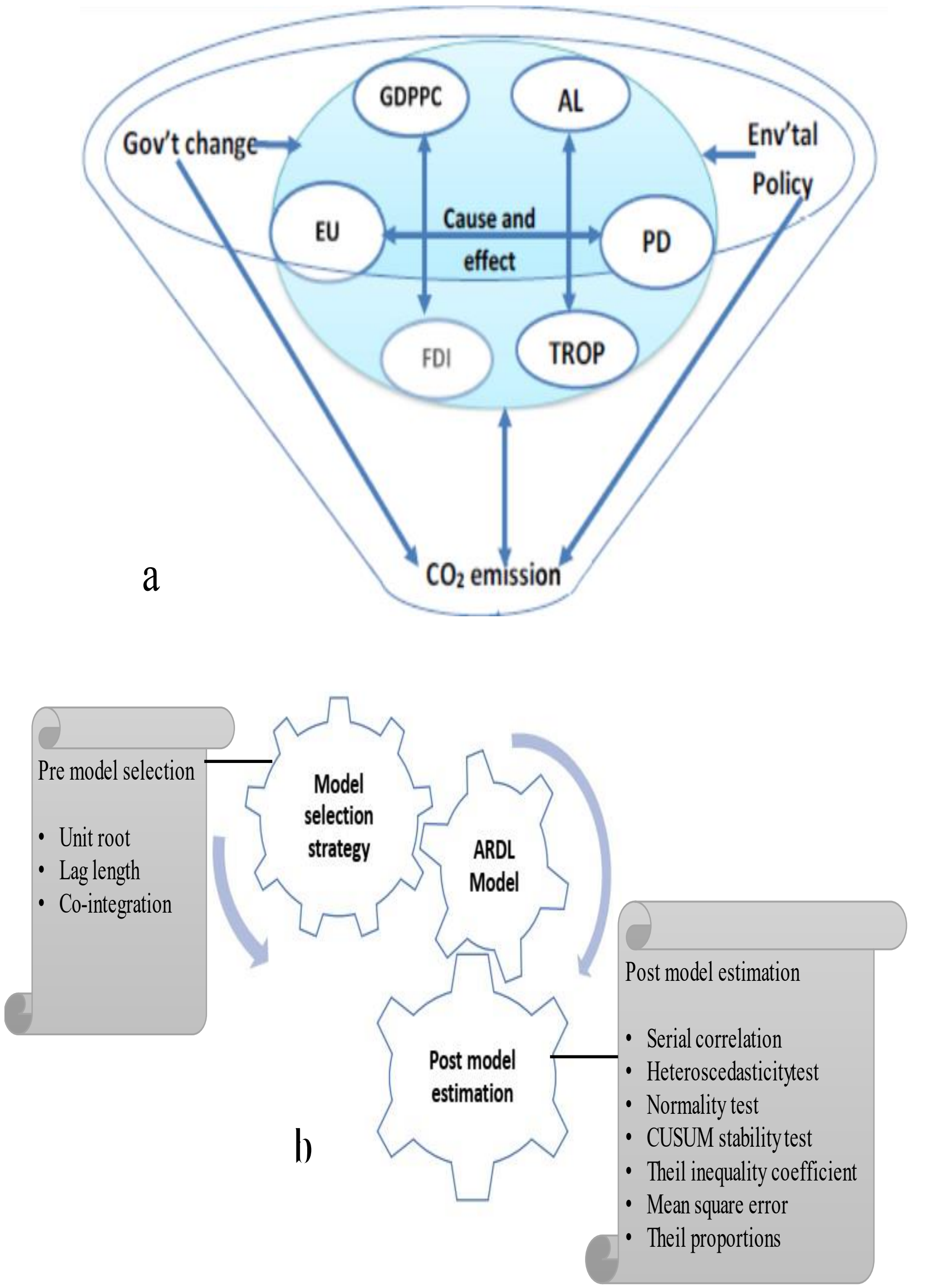
2.1 Analytical Framework

Figure 1 shows the analytical framework based on the objectives of the study. It encompasses all the stages that needs to be followed in order to address the nexus of energy use, carbon dioxide emission, and economic growth. As it is shown in Figure 1(a), all variables are expected to have either unidirectional, bi-directional or neutral relationship to one another, However, all or some of the variables can cause CO_2 emissions directly or indirectly. In turn, CO_2 emission might have an effect on other variables. At the same time exogenous variables such as government change and environmental policy are likely to have an effect on CO_2 emission and other variables.

Figure 1 (b) shows pre and post econometric model selection strategies. Nonetheless, the model selection strategy is the drive to choose the particular model based on unit root test, lag length selection criterion, and co-integration test. Accordingly, the ARDL model is proposed to this study. Again, the ARDL result would be worthless without the post model estimation. So, the post-model estimation tests such as Breusch-Godfrey LM test, Auto-Regressive Conditional Heteroscedasticity, and the Jarque-Bera normality are used to assure the absence of spurious regression, the existence of constant variance, and normal distribution of the residuals, respectively. Moreover, the cumulative sum (CUSUM) test is also used to prove the stability of the model in the long run.

Moreover, the robustness of the ARDL model is compared with other models such as Least Square (LS), Fully Modified Ordinary Least Squares (FMOLS), and Auto-Regressive Conditional Heteroscedasticity (ARCH) models. In this regard, the Theil inequality coefficient, the mean square error, and the Theil proportions such as the bias, variance, and covariance are considered.

Figure 1: Analytical framework, (a) the relationship between variables, (b) pre and post model selection strategy.



Source: Own computation, 2021

2.2 Data Types and Sources

To achieve the goals, data are used from the official web sites of World Development Indicators (WDI), United Nations Conference on Trade and Development (UNCTAD), and the national documents for the period of 1971 to 2014. The time period is restricted to 2014 because the energy use data were not released until this study is launched. Four variables, CO_2 emissions, Energy Use (EU), Population density (PD), and Agricultural land (AL) are accessed from the WDI, while Gross Domestic Product Per Capita (GDPPC) and Foreign Direct Investment (FDI) are retrieved from UNCTAD. Trade Openness (TROP) is own calculation using GDP from WDI and export and import data from UNCTAD. The values of net export and GDP are in the US dollar at the current price in millions. Then TROP is computed by the ratio of net export (export - import) to the GDP. The last two variables, Environmental policy (EP) and Government change (GC), are obtained from the ratified Ethiopian proclamations and official documents, respectively (Table 1). All continuous data are transformed to the natural logarithmic form before conducting descriptive and econometric analyses.

CO_2 emission is measured in kiloton that includes carbon dioxide produced during consumption of solid, liquid, and gas fuels. Energy use expressed in terms of the per capita per $1000 GDP measured in a kilogram of oil equivalent. It refers to the use of primary energy before transformation to other end-use fuels. Agricultural land is expressed in terms of land under temporary crops, pasture, kitchen gardens, and fallows. Population density is a midyear population divided by land area in square kilometers. Trade openness is continuous data measured in percent. Gross domestic product per capita is the annual per capita GDP at current and constant prices measured in USD. FDI is presented by the inward flow of Foreign Direct Investment measured in US Dollars at current prices in millions. The remaining variables, EP and GC are dummies that take the value of zero before the event years and one after the event. Hence, before the enforcement of EP in 1997, it is zero, while it takes one for the rest of the study periods. Similarly, GC is represented before and after the ruling party, EPRDF. For the years before 1991 it takes the value of zero, otherwise one for the rest of the study years.

Table 1: Description of variables and data sources

Variable name	Code	Unit	Nature of data	Source
Carbon Dioxide Emission	CO_2	Kilo ton	Continuous	WDI*
Energy Use	*EU*	Kg of oil equivalent per capita	Continuous	WDI
Population Density	*PD*	People per sq. km of land area	Continuous	WDI
Agricultural Land	*AL*	Square. Kilo meter	Continuous	WDI
Trade Openness	*TROP*	Percent	Continuous	UNCTAD, WDI
Gross Domestic Product Per Capita	*GDPPC*	Current and constant (2010) prices in USD	Continuous	UNCTAD*
Foreign Direct Investment	*FDI*	Inward USD at current prices in millions	Continuous	UNCTAD
Environmental Policy	*EP*	Categorical	Dummy	Official document
Government Change	*GC*	Categorical	Dummy	Official document

*https://data.worldbank.org/country/ethiopia

** https://unctadstat.unctad.org/wds/TableViewer/downloadPrompt.aspx

2.3 Model Selection Strategy

To analyze the nexus of CO_2 emission, economic growth, and energy use, the first step is specifying the econometric model before justifying the standard model (Wooldridge, 2000). Selecting the fitted model among VEC, VAR, and ARDL depends on the unit roots and cointegration results. The VEC model would be applicable when all variables are stationary at I (1) and at least one co-integration equation. Similarly, if all variables are I(0) the model would be VAR, otherwise, ARDL is appropriate in any level of variable integration.

Even though there is no perfect and unique econometric model, ARDL has an advantage over other models. First, it is best for small sample size and its computational convenience (Pesaran and Shin, 1997). Second, it is more applicable irrespective of the order of variable integration; either level, 1st difference, or mixed (Pesaran and Shin, 1997; Rauf et al., 2018). Third, it can handle endogeneity problems (Sinha and Shahbaz, 2018). Lastly, it permits dummy variables to be used in the model (Leal, Marques, & Fuinhas, 2018). ARDL is popular and used by several scholars (Boutabba, 2014; Leal et al., 2018; Rauf et al., 2018; Salahuddin et al., 2018; Sinha and Shahbaz, 2018; Ssali et al., 2019). So, due to these reasons, the ARDL model is selected and the analyses are done by an EVIEW software of version 10.

2.3.1 Unit root test and lag length selection

Unit root, non-stationary, and random walk are synonymously used terms to represent time-variant mean and/or variance of a given time series data (Planas, 1997). For instance, if the macroeconomic variable *X* depends on the lagged time, it will face non-constant mean and variance. If the consecutive *X* variable is independent of the time t, it is somehow stationary (Gujarati, 2004). Equation (1), expresses the mathematical model of the unit root test for *X* variable. If $\rho = 1$, it becomes a random walk without drift, and it faces the unit root problem. If $|\rho| < 1$, then it is at stationary (Harris and Sollis, 2003), with zero mean and constant variance.

$$X = \rho X_{(t-1)} + U_t, \text{ where } -1 \leq \rho \leq 1 \qquad \textbf{(1)}$$

When $X_{(t-1)}$ subtracted from both side of the Equation (1) become Equation (2).

$$X_{(t)} - X_{(t-1)} = \rho X_{(t-1)} - X_{(t-1)} + U_t \qquad \textbf{(2)}$$

It can be rewritten as Equation (3)

$$\Delta X_{(t)} = \delta X_{(t-1)} + U_t \qquad \textbf{(3)}$$

Where $\delta = \rho - 1$ and Δ is the 1st difference operator. It is important to note that if $\delta = 0$, then $\rho = 1$, that is a unit root, meaning the time series under consideration is non-stationary. Thus, the Equation (3) become,

$$\Delta X_{(t)} = X_{(t)} - X_{(t-1)} = U_t \qquad \textbf{(4)}$$

Where, U_t is a white noise error term, if it is at stationary, the 1st differences of a random walk time series are stationary.

It is also better to estimate Equation (3) taking the 1st difference of $X_{(t)}$ and regress on $X_{(t-1)}$ and see whether the estimated slope coefficient (δ) is zero or not. If it is zero, $X_{(t)}$ is concluded as non-stationary, otherwise, if negative, $X_{(t)}$ is stationary (Gujarati, 2004). Hence, to check whether the time series contains a unit root or not, the Augmented Dickey-Fuller (ADF) test is used. Under the null hypotheses $\delta = 0$, the estimated value of the coefficient in Equation (3) follows the tau (τ) statistic. If the null hypothesis is rejected, the time series would be stationary. However, in case U_t is correlated, the Augmented Dickey-Fuller test is applied to include lagged difference terms so that the error term (ε) in Equation (5) is serially uncorrelated.

$$\Delta X_{(t)} = B_0 + + \Sigma^{m}{}_{i=1} B_i X_{(t-i)} + \varepsilon \qquad \textbf{(5)}$$

Two steps were followed to identify the optimum lag length based on the values of SIC. First, the VAR model was employed treating one variable as an endogenous and the remaining variables as exogenous, successively for all variables. Next, from the VAR estimate lag order selection criteria for each endogenous variable was computed by Likelihood Ratio (LR), Final prediction error (FPE), Akaike information criterion (AIC), Schwarz information criterion (SIC), and Hannan-Quinn information criterion (HQ). Thus, the lag order is selected by the criterion at 5 percent level.

2.3.2 Specification of auto regressive distributed lag

ARDL model shows short-run and long-run relationships among co-integrating variables. Though the variables are co-integrated in a different order, as discussed earlier the ARDL model best in any level of relationship (Pesaran and Shin, 1997). So, the ARDL model of automatic selection criteria was used to get the maximum lag length, which is generally expressed in Equation (6) (Wooldridge, 2000).

$$\Delta ln\ Y_{(t)} = B_{n0} + \Sigma^{p}{}_{i=1} B_{n(t-i)}\, ln\ Y_{(t-i)} + \Sigma^{p}{}_{i=1} \gamma_{n\,(t-i)}\, ln\ X_{n\,(t-i)} + U_{nt} \qquad \textbf{(6)}$$

Where Y is the dependent variable and X_n represents the n^{th} variable other than the dependent (*CO_2*, *AL*, *EU*, *FDI*, *GDPPC*, *PD*, *TOP*, *GC*, and *EP*), i (i = 1 … P) is the lag length, and U is the error term of the n^{th} variable (n = 1… 9). The detail ARDL model is expressed in the form of Equation 7-16.

$$\Delta ln\ CO_{2(t)} = \beta_{10} + \beta_{1(t-i)}\ \Delta ln\ CO_{2(t-i)} + \ldots + \beta_{1p}\ \Delta ln\ CO_{2(t-p)} + \Delta ln\ AL + \Delta ln\ EU + \Delta ln\ FDI + \Delta ln\ GDPPC + \Delta ln\ PD + \Delta ln\ TOP + \Delta ln\ GC + \Delta ln\ EP + V_{1t} \quad \textbf{(7)}$$

$$\Delta ln\ AL_t = \beta_{20} + \beta_{2(t-i)}\ \Delta ln\ AL_{(t-i)} + \ldots + \beta_{2p}\ \Delta ln\ AL_{t-p} + \Delta lnCO_2 + \Delta ln\ EU + \Delta ln\ FDI + \Delta ln\ GDPPC + \Delta ln\ PD + \Delta ln\ TOP + \Delta ln\ GC + \Delta ln\ EP + V_{2t} \quad \textbf{(8)}$$

$$\Delta ln\ EU_t = \beta_{30} + \beta_{31}\Delta ln\ EU_{t-1} + \ldots + \beta_{3p}\ \Delta ln\ EU_{t-p} + \Delta ln\ AL + \Delta ln\ CO_2 + \Delta ln\ FDI + \Delta ln\ GDPPC + \Delta ln\ PD + \Delta ln\ TOP + \Delta ln\ GC + \Delta ln\ EP + V_{3t} \quad \textbf{(9)}$$

$$\Delta ln\ FDI_t = \beta_{40} + \beta_{41}\ \Delta ln\ FDI_{t-1} + \ldots + \beta_{4p}\ \Delta ln\ FDI_{t-p} + \Delta ln\ AL + \Delta ln\ EU + \Delta ln\ CO_2 + \Delta ln\ GDPPC + \Delta ln\ PD + \Delta ln\ TOP + \Delta ln\ GC + \Delta ln\ EP + V_{4t} \quad \textbf{(10)}$$

$$\Delta ln\ GDPPC_t = \beta_{50} + \beta_{51}\ \Delta ln\ GDPPC_{t-1} + \ldots + \beta_{5p}\ \Delta ln\ GDPPC_{t-p} + \Delta ln\ AL + \Delta ln\ EU + \Delta ln\ FDI + \Delta ln\ CO_2 + \Delta ln\ PD + \Delta ln\ TOP + \Delta ln\ GC + \Delta ln\ EP + V_{5t} \quad \textbf{(11)}$$

$$\Delta ln\ PD_t = \beta_{60} + \beta_{61}\ \Delta ln\ PD_{t-1} + \ldots + \beta_{6p}\ \Delta ln\ PD_{t-p} + \Delta ln\ AL + \Delta ln\ EU + \Delta ln\ FDI + \Delta ln\ GDPPC + \Delta ln\ CO_2 + \Delta ln\ TOP + \Delta ln\ GC + \Delta ln\ EP + V_{6t} \quad \textbf{(12)}$$

$$\Delta ln\ TOP_t = \beta_{70} + \beta_{71}\ \Delta ln\ TOP_{t-1} + \ldots + \beta_{7p}\ \Delta ln\ TOP_{t-p} + \Delta ln\ AL + \Delta ln\ EU + \Delta ln\ FDI + \Delta ln\ GDPPC + \Delta ln\ PD + \Delta ln\ CO_2 + \Delta ln\ GC + \Delta ln\ EP + V_{7t} \quad \textbf{(13)}$$

$$\Delta ln\ GC_t = \beta_{80} + \beta_{81}\ \Delta ln\ GC_{t-1} + \ldots + \beta_{8p}\ \Delta ln\ GC_{t-p} + \Delta ln\ AL + \Delta ln\ EU + \Delta ln\ FDI + \Delta ln\ GDPPC + \Delta ln\ PD + \Delta ln\ TOP + \Delta ln\ CO_2 + \Delta ln\ EP + V_{8t} \quad \textbf{(14)}$$

$$\Delta ln\ EP_t = \beta_{90} + \beta_{91}\ \Delta ln\ EP_{t-1} + \ldots + \beta_{9p}\ \Delta ln\ EP_{t-p} + \Delta ln\ AL + \Delta ln\ EU + \Delta ln\ FDI + \Delta ln\ GDPPC + \Delta ln\ PD + \Delta ln\ TOP + \Delta ln\ GC + \Delta ln\ CO_2 + V_{9t} \quad \textbf{(15)}$$

where the explanatory variables are expressed in the form of their lag terms,

$\Delta ln\ CO_2 = \beta_{1(t-i)}\ \Delta ln\ CO_{2(t-i)} + \ldots + \beta_{1p}\ \Delta ln\ CO_{2(t-p)} + U_{1t}$

$\Delta ln\ AL = \beta_{2(t-i)}\ \Delta ln\ AL_{(t-i)} + \ldots + \beta_{2p}\ \Delta ln\ AL_{(t-p)} + U_{2t}$

$\Delta ln\ EU = \beta_{3(t-i)}\ \Delta ln\ EU_{(t-i)} + \ldots + \beta_{3p}\ \Delta ln\ EU_{(t-p)} + U_{3t}$

$\Delta ln\ FDI = \beta_{4(t-i)}\ \Delta ln\ FDI_{(t-i)} + \ldots + \beta_{4p}\ \Delta ln\ FDI_{(t-p)} + U_{4t}$

$\Delta ln\ GDPPC = \beta_{5(t-i)}\ \Delta ln\ GDPPC_{(t-i)} + \ldots + \beta_{5p}\ \Delta ln\ GDPPC_{(t-p)} + U_{5t}$

$\Delta ln\ PD = \beta_{6(t-i)}\ \Delta ln\ PD_{(t-i)} + \ldots + \beta_{6p}\ \Delta ln\ PD_{(t-p)} + U_{6t}$

$\Delta ln\ TOP = \beta_{7(t-i)}\ \Delta ln\ TOP_{(t-i)} + \ldots + \beta_{7p}\ \Delta ln\ TOP_{(t-p)} + U_{7t}$

$\Delta ln\ GC = \beta_{8(t-i)}\ \Delta ln\ GC_{(t-i)} + \ldots + \beta_{8p}\ \Delta ln\ GC_{(t-p)} + U_{8t}$

$\Delta ln\ EP = \beta_{9(t-i)}\ \Delta ln\ EP_{(t-i)} + \ldots + \beta_{9p}\ \Delta ln\ EP_{(t-p)} + U_{9t}$

Where *'t'* is the time length, U_n is the error term of the corresponding variable, *'p'* is the lags of itself and the other entire *n–1* variable and V_{it} is the error term for the corresponding i^{th} dependent variables.

2.3.3 ARDL bound test of co-integration

The other important issue in a time series analysis is co-integration, the regression of a unit root time series data on another unit root time series, which may produce spurious regression (Gujarati, 2004). The bound test of cointegration was conducted by using the Pesaran et al. (2001) approaches to see whether the long-run relationship exists or not among variables. The estimation of the nine equations (Equation 7-15) are used to test for the existence of a long-run relationship among the variables. It applies the F-statistics of joint significance for the coefficients of the lagged variables, i.e.: H0: $B_{1i} = B_{2i} = B_{3i} = B_{4i} = B_{5i} = B_{6i} = B_{7i} = B_{8i} = B_{9i} = 0$ against the alternative one: H1: $B_{1i} \neq B_{2i} \neq B_{3i} \neq B_{4i} \neq B_{5i} \neq B_{6i} \neq B_{7i} \neq B_{8i} \neq B_{9i} \neq 0$. The F-statistic which is normalized on ln*CO2; F lnCO2 (lnCO2\ ln AL, ln EU, ln FDI, ln GDPPC, ln PD, ln TOP, ln GC, ln EP)* and detected by two sets of critical values, lower bound and upper bound, for the given level of significance. The lower bound, I(0), and the upper bound, I(1), were computed on the assumption that all variables included in the ARDL model integrated of order zero and order one, respectively. The null hypothesis of no cointegration is rejected when the value of the F-statistic exceeds the upper critical bounds value, while it is accepted if the F-statistic is lower than the lower bounds value. Furthermore, the existence of negative coefficient of the error correction equation was used to crosscheck the long-run relationship between variables (Gujarati, 2004).

3. Results

The discussion under this section includes description of variable characteristics, unit root and lag length, ARDL Bounds Test of co-integration, ARDL Bounds Test of co-integration, and other related concerns.

3.1 Description of Variable Characteristics

Table 2 summarizes the natural logarithmic form of variables such as; *ln* CO_2, *ln EU, ln PD, ln AL, ln TROP, ln GDPPC,* and *ln FDI*. The mean value of *ln* CO_2 is 8 units with the maximum and minimum values of 9 and 7, respectively. Similarly, *ln EU* and *ln GDPPC* have the mean value of 6 and 5 units, respectively.

The two dummy variables represent government change (before and after Ethiopian People's Revolutionary Democratic Front) and the implementation of environmental policy. The mean value of GC shows that an equal time period is used for the study period between the successive regimes. Likewise, the launch of EP represents 39 percent of the study period.

Table 2: Descriptive statistics of variables

Variables	*Mean*	*Median*	*Maximum*	*Minimum*	*Std. Dev.*	*Sum*
Ln CO	8.008953	7.976920	9.358650	6.955366	0.618404	352.3939
Ln A	12.98773	13.02244	13.29682	12.62715	0.295140	571.4600
E	0.386364	0.000000	1.000000	0.000000	0.492545	17.00000
G	0.500000	0.500000	1.000000	0.000000	0.505781	22.00000
Ln E	6.169095	6.164950	6.208217	6.153700	0.013217	271.4402
Ln FD	3.982060	3.340586	7.531043	2.002830	1.665972	175.2106
Ln GDPP	5.355824	5.338935	6.004096	4.962982	0.230594	235.6563
Ln P	3.914372	3.914263	4.578485	3.279497	0.420025	172.2323
Ln TRO	3.009338	2.945105	3.730860	1.613219	0.479906	132.4109

Source: Own computation, 2021

3.2 Unit Root and Lag Length

Table 3 shows the unit root test and lag length choice criteria. The Schwarz Information Criterion (SIC) exhibits a unit root problem at level, but they are stationary at the 1st difference. The result shows the non-existence of the unit root problem at a one percent significant level. All variables also show the optimal lag length of one by the SIC criterion at a 5% level.

Table 3: The Augmented Dickey-Fuller unit root test and lag length selection

Variables	Stationary (t-statistics)		Lag length				
	level	1st difference	LR	FPE	AIC	SC	HQ
ln CO_2	0.701144	-7.017713***	1	1	1	1	1
ln AL	-1.196010	-6.336477***	1	1	1	1	1
EP	-0.766004	-6.480741***	1	1	1	1	1
GC	-0.976467	-6.480741***	1	1	1	1	1
ln EU	1.951301	-5.749762***	1	1	1	1	1
ln FDI	-0.508102	-6.107624***	1	3	3	1	1
ln GDPPC	1.491198	-4.228584***	1	2	2	2	2
ln $GDPPC^2$	1.801313	-4.029462***	2	2	2	2	2
ln PD	0.298150	-5.135759***	1	1	1	1	1
ln TROP	-1.546170	-7.742962***	1	1	1	1	1

Source: Own computation, 2021

Significance: ***$p<0.01$

3.3 ARDL Bounds Test of Co-integration

Table 4 shows eight co-integrating equations in both criteria, by the bound test and cointegration equation coefficients (ECT_{t-1}). Their F-statistic are significantly higher than the upper bound I (1) value at 1 percent p-level of significance. So, the null hypothesis of no long-run relationships among variables is rejected. Rather the result indicates co-integration among these variables. For instance, the F- statistics of *ln* CO_2 is 7.146 which is higher than the upper bound I (1) (3.68) and the cointegration equation coefficient is negative and significant (-0.913806) at 1% *p*-level. Likewise, the F- statistics of *ln EU* is 5.545 which is higher than the upper bound (3.68) and the cointegration equation coefficient is negative and significant (-0.945768) at 1% *p*-level. In addition, the F- statistics of *ln GDPPC* is 33.507 which is higher than the upper bound (3.68) and the cointegration equation coefficient is negative and significant (-0.104839) at 1% *p*-level.

Table 4: ARDL Bounds Test of co-integration

Variables	F-statistic	ECT_{t-1}	F-bounds test		
			Sig. Level	I(0)	I(1)
ln CO2	7.146293***	-0.913806***	10%	1.8	2.8
ln AL	9.367343***	-0.078139***	5%	2.04	2.08
EP	4.449788***	-0.515336***	2.5%	2.24	3.35
GC	10.47216***	0.123342***	1%	2.5	3.68
ln EU	5.545122***	-0.945768***			
ln FDI	4.444306***	-0.840623***			
ln GDPPC	33.50720***	-0.104839***			
ln $GDPPC^2$	33.63181***	-0.058573***			
ln PD	316.4737***	-0.015424***			
ln TROP	2.543887	-0.620605***			

Source: own computation, 2021
Significance: ***p<0.01

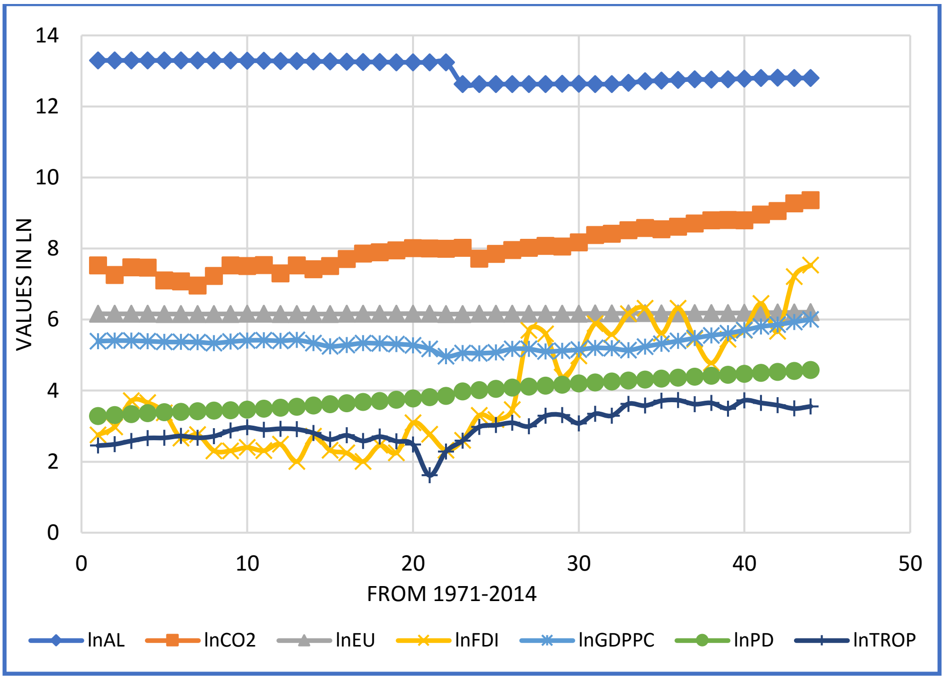
3.4 Trends and Relationships

Trends and relationships are discussed as follows.

3.4.1 Trends

Figure 2 shows trends of *ln* CO_2, *ln EU*, *ln GDPPC* and other variables from 1971 to 2014. Except for agricultural land and energy use, the trend of all other variables is unsustainable through time. For instance, *ln* CO_2 and *ln FDI* show more increment as compared to *ln GDPPC, ln PD,* and *ln TROP*. Following the government change in 1991, particularly, *ln* CO_2, *ln FDI*, and *ln TROP* have enhanced in contrast to the Derg Regime (1974-1991). Even though the *EP* being implemented since 1997, it might not show a declining trend in *ln* CO_2 after the implementation period. Besides, *ln AL* and *ln EU* seem constant for the specified period of time while *ln PD has* increased somehow in a similar fashion to *ln* CO_2. To this end, it is possible to guess the increasing trend of *ln* CO_2 is associated with *ln FDI*, *ln TROP*, and *ln PD* keeping other variables constant. It doesn't mean that *ln AL*, *ln EU*, and *ln GDPPC* has no correlation with *ln* CO_2 emission.

Figure 2: Trends of *ln CO_2*, *ln EU*, *ln GDPPC*, and other variables



Source: Own computation, 2021

3.4.2 Relationships

Table 5 reveals the relationship among *ln CO_2* emission *ln EU*, *ln GDPPC,* and other variables in terms of a correlation matrix. The result depicts *ln CO_2* has a strong relationship with all variables except *ln GDPPC*. Particularly, *ln CO_2* has a strong positive correlation with *ln EU*, *ln PD*, *ln FDI*, EP, *ln TROP*, and *ln GC*. Energy use has a strong relationship with *ln FDI*, *ln GDPPC*, *ln PD*, and *ln TROP*. Similarly, other variables also show some correlation between themselves. For instance, *ln AL* negatively correlated with *ln GC*, *ln PD*, *ln EP*, and *ln TROP*. In general, the aforementioned descriptive and trend results give some clue towards the nexus of *ln CO_2* emission, *ln EU*, and *ln GDPPC*. However, it needs an empirical evidence to conclude their relationship and causality.

Table 5: Correlation matrix

Variables	*LN AL*	*LN CO_2*	*EP*	*GC*	*LN EU*	*LN FDI*	*LN GDPPC*	*LN PD*	*LN TROP*
LN AL	1.000								
LN CO_2	-0.695	1.000							
EP	-0.722	0.834	1.000						
GC	-0.983	0.776	0.793	1.000					
LN EU	-0.536	0.920	0.776	0.659	1.000				
LN FDI	-0.745	0.837	0.889	0.820	0.835	1.000			
LN GDPPC	0.069	0.471	0.359	0.100	0.736	0.419	1.000		
LN PD	-0.858	0.942	0.859	0.909	0.822	0.850	0.292	1.000	
LN TROP	-0.706	0.721	0.846	0.790	0.719	0.806	0.425	0.785	1.000

Source: own computation, 2021

3.4.3 Causality

The discussion in the earlier subsection of the bound test of co-integration and the correlation matrix gives some clue on the relationship between variables. The F-statistics (Table 6) depicts the significance of the overall ARDL models at 1% *p*-level. As a result, *ln* CO_2 emission has a strong causal relationship with *ln EU*, *GC* and its lags, *ln PD* and its lags, lag of *ln TROP*. The *ln EU*, one-period lag of *GC*, and *ln PD* enhance *ln* CO_2 emission at 1% *p*-level of significance. In contrast, *GC* and its two-period lag, a one-period lag of *ln PD*, and a one-period lag of *ln TROP* significantly decline *ln* CO_2 emission.

Similarly, *ln EU* and its lag, *EP*, *GC* its lags, lags of *ln FDI*, *ln* $GDPPC^2$ its lags, *ln PD* and its lags, and lags of *ln TROP* significantly affect *ln GDPPC*. For instance, lag of *ln EU*, one-period lag of *EP*, *GC* and its two-period lag, *ln* $GDPPC^2$, one-period lag of *ln PD*, and lags of *ln TROP* have a positive effect while others' negatively affect *ln GDPPC*. Moreover, *ln*CO_2, *ln GDPPC*, lag of *ln* $GDPPC^2$, and lag of *ln PD* induce *ln EU* whereas the lag of *ln GDPPC*, *ln* $GDPPC^2$, *ln PD*, and a two-period lag of *ln TROP* retard *ln EU*. Generally, there is bidirectional causality between *ln*CO_2 emission and *ln EU as* well as between *ln EU* and *ln GDPPC*. Yet, the finding shows no relationship between *ln*CO_2 emission and *ln GDPPC*.

Table 6: ARDL model results

	ln CO_2		***ln GDPPC***		***ln EU***	
Selected Model:	***(1, 0, 2, 1, 0, 0, 0, 1, 2, 1)***		***(1, 0, 2, 2, 1, 1, 2, 1, 2, 2)***		***(1, 1, 0, 0, 0, 0, 0, 1, 1, 2)***	
Variable	***Coefficient***	***Std. Error***	***Coefficient***	***Std. Error***	***Coefficient***	***Std. Error***
Ln CO_2 (-1)	0.086	0.121	-	-	-	-
Ln CO_2			0.000	0.002	0.013	0.003***
Ln GDPPC (-1)	-	-	0.895	0.059***	-0.828	0.329**
Ln GDPPC	3.000	4.056	-	-	0.720	0.314**
Ln EU (-1)	-	-	0.326	0.089***	0.054	0.144
LNEU	29.621	5.664***	0.121	0.099	-	-
EP	0.063	0.076	0.002	0.002	0.000	0.002
EP (-1)	-	-	0.004	0.002**	-	-
EP (-2)	-	-	-0.002	0.001	-	-
GC	-4.354	1.166***	0.049	0.019**	0.000	0.011
GC (-1)	8.103	2.066***	-0.108	0.032***	-	-
GC (-2)	-2.757	0.814***	0.058	0.014***	-	-
Ln AL	-0.744	1.461	-0.035	0.018	0.000	0.017
Ln AL (-1)	2.818	1.861	0.035	0.026	-	-
Ln FDI	0.034	0.027	0.000	0.000	0.001	0.001
Ln FDI (-1)	-	-	-0.001	0.0005**	-	-
Ln FDI (-2)	-	-	-0.002	0.001***	-	-
Ln $GDPPC^2$	-0.284	0.380	0.094	0.001***	-0.066	0.029**

	ln CO_2		*ln GDPPC*		*ln EU*	
Selected Model:	***(1, 0, 2, 1, 0, 0, 0, 1, 2, 1)***		***(1, 0, 2, 2, 1, 1, 2, 1, 2, 2)***		***(1, 1, 0, 0, 0, 0, 0, 1, 1, 2)***	
Variable	***Coefficient***	***Std. Error***	***Coefficient***	***Std. Error***	***Coefficient***	***Std. Error***
Ln $GDPPC^2$(-1)	-0.072	0.038	-0.087	0.005***	0.079	0.032**
Ln PD	39.113	9.182***	-0.608	0.169***	-0.135	0.037***
Ln PD (-1)	-69.401	17.244***	1.224	0.316***	0.143	0.039***
Ln PD (-2)	31.117	8.446***	-0.636	0.151***	-	-
Ln TROP	0.025	0.076	-0.001	0.001	0.000	0.002
Ln TROP (-1)	-0.250	0.102**	0.007	0.001***	0.000	0.003
Ln TROP (-2)	-	-	0.007	0.002***	-0.006	0.003**
C	-211.606	41.384***	-2.359	0.833**	5.933	0.873***
R^2	0.992		0.999		0.989	
Adjusted R^2	0.986		0.999		0.984	
AIC	-2.113		-11.172		-9.608	
SC	-1.367		-10.179		-8.946	
HQ	-1.839		-10.808		-9.365	
DW	2.210		2.316		1.994	
F-statistic	172.897***		161961.2***		165.09***	

Source: Own computation, 2021

Significance: ***p<0.01, **p<0.05

3.5 Co-integration and Long Run Estimates

3.5.1 CO_2 emission

Table 7 shows the short-run co-integration form and the long-run estimates. The short-run coefficient of error correction term (ECT_{t-1}) expresses the speed of *ln* CO_2 emission adjustment in the long run. Both *GC*, *ln* $GDPPC^2$, and lag *ln PD* reduce *ln* CO_2 emission in the short run while lag in *GC* and *ln PD* increase *ln* CO_2 emission in the short run. Likewise, *ln AL*, *ln EU*, and *ln PD* increase *ln* CO_2 emission in the long run. The co-integration in Equation 16 links the short run *ln* CO_2 emission with its long run, which is corrected by the estimate of ECT_{t-1}. Hence, ECT_{t-1} represents the speed of adjustment for a one-period deviation on *ln* CO_2 emission to be at equilibrium in the long run. Accordingly, 91.4 percent of the error on *ln* CO_2 emission adjusts after one year to be equilibrium in the long run.

$$ECT_{t-1} = ln\ CO2 - (0.0685*EP + 1.0859*GC + 2.2705*ln\ AL +$$

$$32.4151*ln\ EU + 0.0373*ln\ FDI + 3.2832*ln\ GDPPC –$$

$$0.3903*ln\ GDPPC2 + 0.9074*ln\ PD - 0.2460*ln\ TROP - 231.5656) \qquad \textbf{(16)}$$

An increase in *ln* $GDPPC^2$ by one percent reduces *ln* CO_2 emission by 0.28 percent in the short run while it has no effect in the long run, keeping other variables constant, though. Similarly, *GC* reduces *ln* CO_2 emission by 4.35 units, whereas one period lag in *GC* increases *ln* CO_2 emission by 2.76 units in the short run. A one percent increase in agricultural land also increases *ln* CO_2 by 2.27 percent in the long run. Moreover, an increase in *ln PD* by one percent increases *ln* CO_2 by 39.11 and 0.91 percent in the short and long runs, respectively, while an increase in one period lag in *ln PD* by one percent decreases *ln* CO_2 emission by 31.12 in the short run. Besides, one percent increase in *ln EU* increases *ln* CO_2 by 32.42 percent in the long run.

Table 7: ARDL co-integrating and long run form (*ln* CO_2 as dependent variable): ARDL (1, 1, 0, 1, 0, 0, 0, 0, 0, 0)

Co-integrating Form			Long Run Coefficients		
Variable	**Coef.**	**Std. Err**	**Variable**	**Coef.**	**Std. Err**
D (*ln AL*)	-0.744	(0.865)	*ln AL*	2.2705	(1.0009) **
D (*GC*)	-4.354	(0.737) ***	*EP*	0.0685	(0.0825)
D (*GC*) (-1)	2.757	(0.554) ***	*GC*	1.0859	(0.6302)
D (*ln* $GDPPC^2$)	-0.284	(0.036) ***	ln EU	32.4151	(6.4174) ***
D (*ln PD*)	39.113	(5.839) ***	ln FDI	0.0373	(0.0283)
D (*ln PD*) (-1)	-31.117	(5.614) ***	*ln* $GDPPC^2$	-0.3903	(0.3910)
D (*ln TROP*)	0.025	(0.046)	*ln GDPPC*	3.2832	(4.3990)
ECT_{t-1}	-0.914	(0.087) ***	*ln PD*	0.9074	(0.2121) ***
			ln TROP	-0.2460	(0.1382)
			C	-231.5656	(45.3737) ***

Significance: ***p<0.01, **p<0.05
Source: Own computation, 2021

3.5.2 GDPPC

Table 8 presents the short run co-integration and the long run estimates of *ln GDPPC*. The co-integration equation (Equation 17) links the short-run *ln GDPPC* with its long-run by the coefficient of ECT_{t-1}. The ECT_{t-1} is the speed of adjustment for a one-period deviation in *ln GDPPC* to be at equilibrium in the long run. As represented in Table 11, its coefficient is negative and significant at one percent of *p*-levels. This implies that 11 percent of the error on *ln GDPPC* adjusts after one year to be equilibrium in the long run.

$$ECT_{t-1} = \ln GDPPC - (4.2697*\ln EU + 0.0035*\ln CO2 + 0.0386*EP - 0.0053*GC - 0.0057*\ln AL - 0.0260*\ln FDI + 0.0693*\ln GDPPC2 - 0.1896*\ln PD + 0.1252*\ln TROP - 22.4967) \quad \textbf{(17)}$$

Table 8 shows that change in *EP* and its lag, *GC*, *ln EU*, lag of *ln FDI*, *ln GDPPC2*, and lag of *ln PD* positively contribute to *ln GDPPC* increment in the short run, keeping other variables constant. In contrast, *ln AL*, lag *GC*, *ln PD*, and lag in *ln TROP* negatively affect *ln GDPPC* in the short run. An increase in *EP* and its lag, *ln EU*, lag of *ln FDI*, *ln* $GDPPC^2$, and lag of *ln PD* by 100 percent increase the *ln GDPPC* by 2, 2, 12, 2, 9, and 64 percent, respectively, in the short run. Whereas one percent increase in *ln AL*, *ln PD*, and lag in *ln TROP* reduce the *ln GDPPC* by 0.04, 0.61, and 0.01 percent, respectively, in the short-run.

Table 8: ARDL co-integrating and long run form (*ln GDPPC* as dependent variable): ARDL (1, 0, 0, 0, 0, 1, 0, 0, 0)

Co-integrating Form			Long Run Coefficients		
Variable	**Coef.**	**Std. Err**	**Variable**	**Coef.**	**Std. Err**
D (*ln AL*)	-0.035	(0.009) ***	*ln AL*	-0.006	(0.149)
D (*EP*)	0.002	(0.001) **	*ln* CO_2	0.003	(0.021)
D (*EP*) (-1)	0.002	(0.001) **	*EP*	0.039	(0.020)
D (*GC*)	0.049	(0.008) ***	*GC*	-0.005	(0.087)
D (*GC*) (-1)	-0.058	(0.006) ***	*ln EU*	4.270	(2.646)
D (*ln EU*)	0.121	(0.044) **	*ln FDI*	-0.026	(0.013)
D (*ln FDI*)	0.00002	(0.00001)	*ln* $GDPPC^2$	0.069	(0.012) ***
D (*ln FDI*) (-1)	0.002	(0.00002) ***	*ln PD*	-0.190	(0.102)
D (*ln* $GDPPC^2$)	0.094	(0.0002) ***	*ln TROP*	0.125	(0.062)
D (*ln PD*)	-0.608	(0.060) ***	C	-22.497	(15.394)
D (*ln PD*) (-1)	0.636	(0.061) ***			
D (*ln TROP*)	-0.001	(0.001)			
D (*ln TROP*) (-1)	-0.007	(0.001) ***			
ECT_{t-1}	-0.105	(0.004) ***			

Significance: ***p<0.01, **p<0.05

Source: own computation, 2021

3.5.3 Energy use

Table 9 shows the short run co-integration form and the long-run estimates of energy use. The co-integration equation (Equation 18) links the short-run *ln EU* with its long run by the coefficient of ECT_{t-1}. The ECT_{t-1} is the speed of adjustment for a one-period deviation in *ln EU to* be at equilibrium in the long run. This means *ln EU* has a long-run relationship with *ln* CO_2 and *ln TROP*. The coefficient of the ECT_{t-1} is negative and significant at one percent of *p*-levels. It implies that 95 percent of the error on *ln EU* adjusts after one year to be equilibrium in the long run.

$$EC = ln\ EU - (-0.1139*ln\ GDPPC + 0.0136*ln\ CO2 + 0.0002*EP + 0.0004*GC + 0.0004*ln\ AL + 0.0009*ln\ FDI + 0.0133*ln\ GDPPC2 + 0.0085*ln\ PD - 0.0073*ln\ TROP + 6.2734) \quad \mathbf{(18)}$$

As shown in Table 9, on the one hand, *ln GDPPC* and a lag of *ln TROP* enhance the *ln EU* while *ln* $GDPPC^2$, *ln PD* and *ln TROP* reduce the *ln EU* in the short run. Accordingly, an increase in *ln GDPPC* and one period lag in *ln TROP* by 100 percent increase *ln EU* by 72 and 0.6 percent, respectively, keeping other variables constant. Yet, a 100 percent increase in *ln* $GDPPC^2$, *ln PD* and *ln TROP* reduce the *ln EU* by 7, 13, and 0.01 percent. On the other hand, an increase in *ln* CO_2 emission by 100 percent enhances the *ln EU* by 1.4 percent while an increase in *ln TROP* by 100 percent declines the *ln EU* by 0.7 percent in the long run, keeping other variables constant.

Table 9: ARDL Co-integrating And Long Run Form (Energy use as dependent variable): ARDL (1, 1, 0, 0, 0, 0, 0, 0, 1, 0)

Co-integrating Form			Long Run Coefficients		
Variable	**Coef.**	**Std. Error**	**Variable**	**Coef.**	**Std. Error**
D (*ln GDPPC*)	0.720125	(0.127) ***	*ln AL*	0.0004	(0.018)
D (*ln* $GDPPC^2$)	-0.06634	(0.012) ***	*ln* CO_2	0.014	(0.003) ***
D (*ln PD*)	-0.13452	(0.018) ***	*ln FDI*	0.001	(0.001)
D (*ln TROP*)	-9.41E-05	(0.001)	*ln GDPPC*	-0.114	(0.104)
D (*ln TROP*) (-1)	0.006452	(0.002) ***	*ln PD*	0.008	(0.007)
ECT_{t-1}	-0.94577	(0.103) ***	*ln TROP*	-0.007	(0.003) **
			EP	0.0002	0.002
			GC	0.0003	(0.011)
			ln $GDPPC^2$	0.013	(0.009)
			C	6.273	(0.306) ***

Significance: ***p<0.01, **p<0.05

Source: Own computation, 2021

3.6 Post Model Estimation

The result in Table 10 shows serial correlation LM tests. The probability of *Obs.* R^2 is more than the 10% p-value; the null hypothesis of no serial correlation isn't rejected. So, there are no problems of spurious regression for the applied ARDL models. The variance of the residual is also checked by using the heteroscedasticity test of Auto-Regressive Conditional Heteroscedasticity (ARCH). The result in Table 11 implies that constant variance is existed, so there is no reason to reject the null hypothesis. Moreover, Table 12 also presents the Jarque-Bera normality test to strengthen the result of a normal distribution of the residual with zero mean and constant variance. As a result, since the p-value is above 10%, there is no evidence to reject the null hypothesis for the ln EU. Hence, this implies that the residual distribution is normal with zero mean and constant variance for ln EU.

Table 10: Breusch-Godfrey Serial Correlation LM Test

Dep. Var.	F-statistic	Prob.	Obs.R^2	Prob. Chi- Square
ln CO_2	0.359059	0.5549	0.645595	0.4217
ln GDPPC	0.850761	0.3692	2.001706	0.1571
ln EU	0.000351	0.9852	0.000590	0.9806

Table 11: Heteroscedasticity Test: ARCH

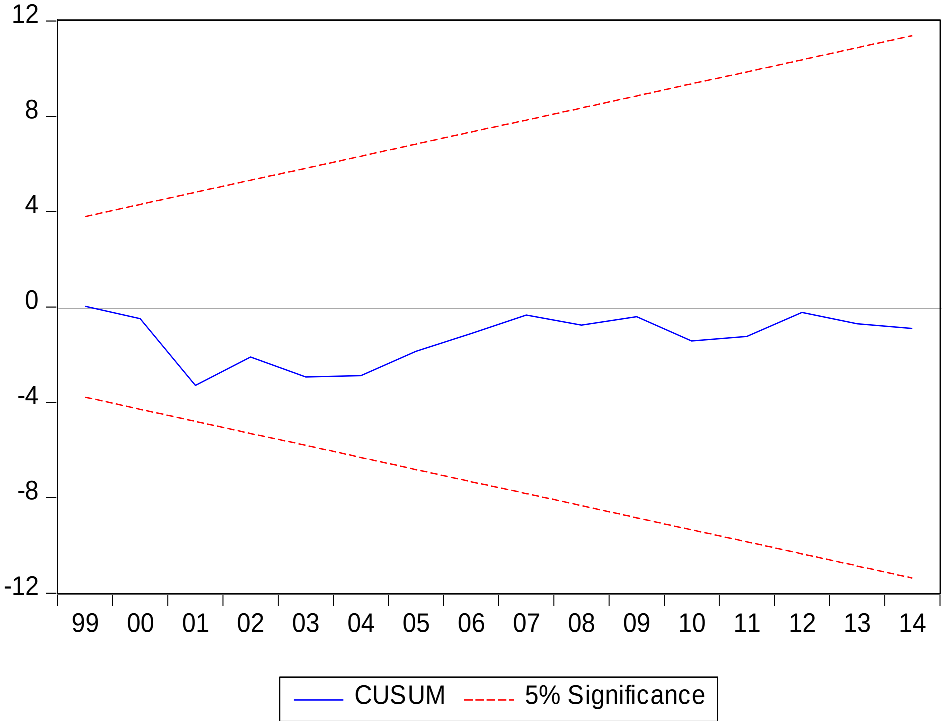
Dep. Var.	F-statistic	Prob.	Obs.R^2	Prob. Chi-Square
ln CO_2	0.427953	0.9622	9.769991	0.9130
ln GDPPC	0.415785	0.9756	14.57198	0.9093
ln EU	0.865353	0.6057	13.98585	0.5266

Table 12: Normality test

Dep. Var.	Jarque-Bera	Probability
ln CO_2	15.38712	0.000456
ln GDPPC	10.20646	0.006077
ln EU	1.396904	0.497355

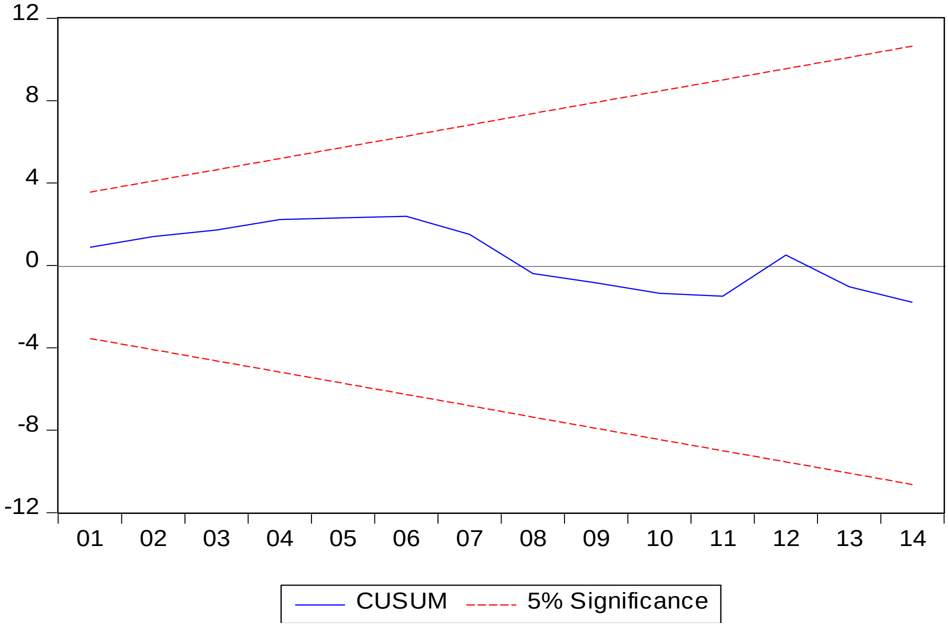
Furthermore, the CUSUM test is used to check the stability of the model. So, the stability tests for those co-integrated variables such as *ln* CO_2, *ln GDPPC*, and *ln EU* reveal that they are stable in the short and long runs. As depicted in Figure 3 (a-c), the stability lines lie between the boundaries (broken lines) at a 5% significance level. This means the coefficients are stable over the period of 1971-2014. Thus, the ARDL co-integration models are stable and consistent in the short run and long run.

Figure 3a: Stability of the models, *ln* CO_2



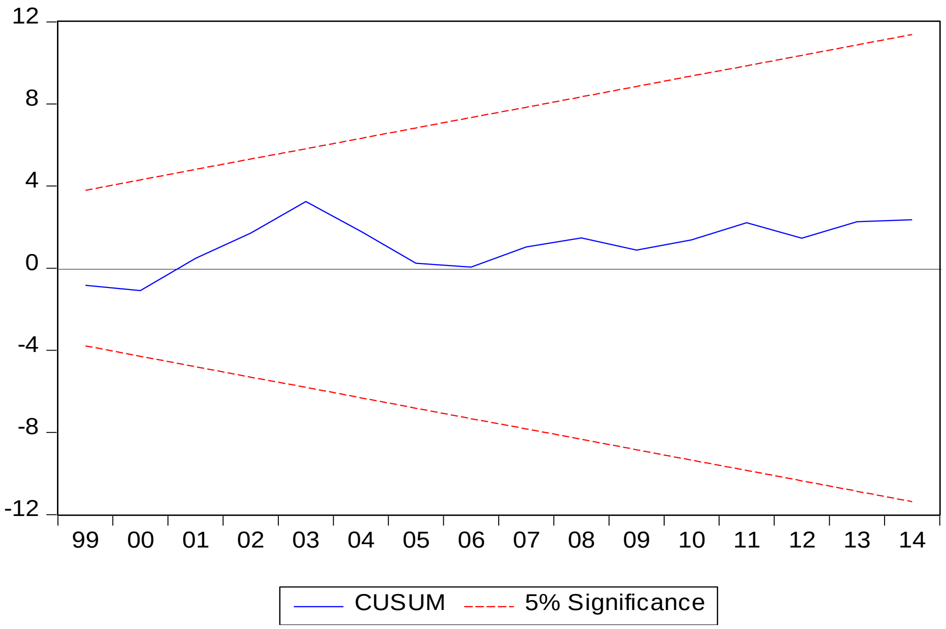
Source: Own computation, 2021

Figure 3b: Stability of the models, *ln GDPPC*



Source: Own computation, 2021

Figure 3c: Stability of the models, *ln EU*

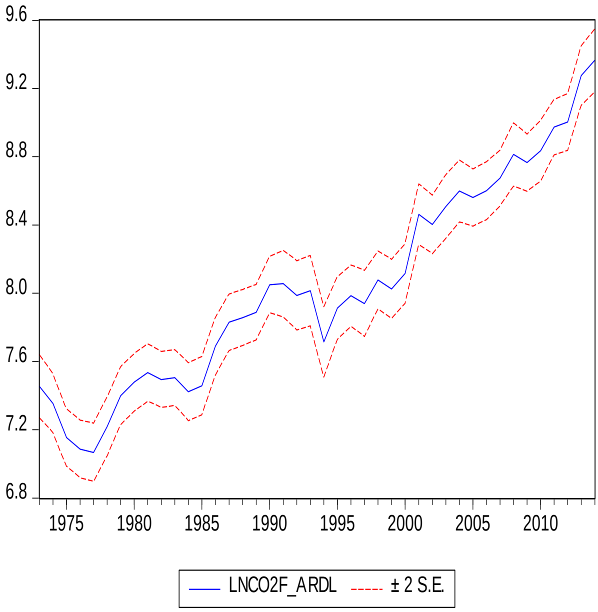


Source: Own computation, 2021

3.7 ARDL model robustness evaluation for CO_2 emission forecast

The robustness of ARDL model is also checked for CO_2 emission forecast as compared with Least Square (LS), Fully Modified Ordinary Least Squares (FMOLS), and Auto Regressive Conditional Heteroscedasticity (ARCH) models. Figure 4 (a-d) shows that ARDL (a) is the best-fit model as compare to LS (b), ARCH (c), and FMOLS (d). The Root-mean-square errors and Theil inequality coefficient in the ARDL model show the lowest value than the others. The ARDL root-mean-square error of CO_2 emission (0.0544) is preferable for forecasting since it is closest to the actual value than the rest models. The Theil inequality coefficient, often between 0 and 1, approach zero in the ARDL model (0.0033) as compare to the others. In addition, the three aspects of Theil proportions (the Bias, variance, and covariance) show ARDL is the best model. So, we can conclude that the CO_2 emission prediction based on the ARDL model is robust and best.

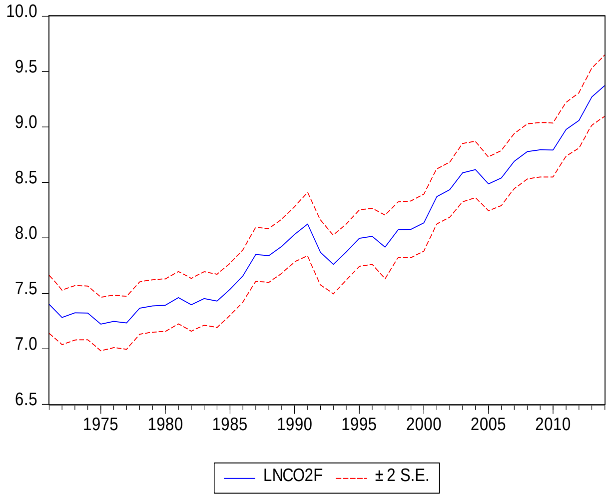
Figure 4a: *CO_2* emission forecast from the ARDL models



Forecast: LNCO2F_ARDL	
Actual: LNCO2	
Forecast sample: 1971 2014	
Adjusted sample: 1973 2014	
Included observations: 42	
Root Mean Squared Error	0.054462
Mean Absolute Error	0.037917
Mean Abs. Percent Error	0.485777
Theil Inequality Coefficient	0.003378
Bias Proportion	0.000000
Variance Proportion	0.002518
Covariance Proportion	0.997482
Theil U2 Coefficient	0.395279
Symmetric MAPE	0.485237

Source: Own computation, 2021

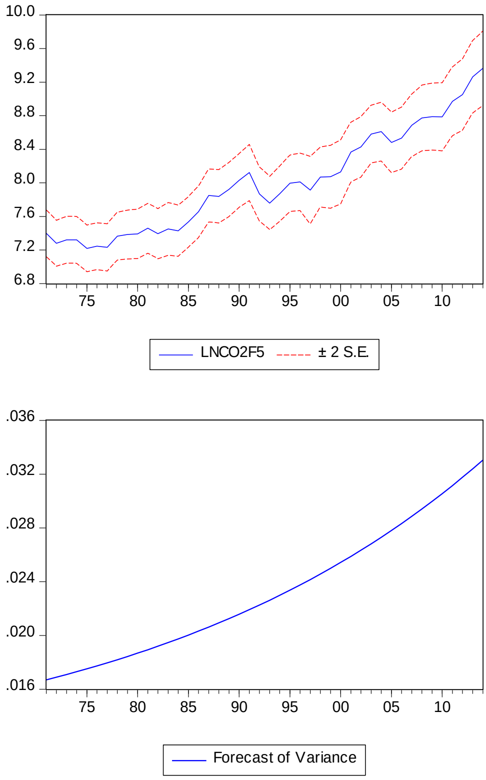
Figure 4b: CO_2 emission forecast from the LS models



Forecast: LNCO2F	
Actual: LNCO2	
Forecast sample: 1971 2014	
Included observations: 44	
Root Mean Squared Error	0.099285
Mean Absolute Error	0.072871
Mean Abs. Percent Error	0.953404
Theil Inequality Coefficient	0.006181
Bias Proportion	0.000000
Variance Proportion	0.006682
Covariance Proportion	0.993318
Theil U2 Coefficient	0.680891
Symmetric MAPE	0.952408

Source: Own computation, 2021

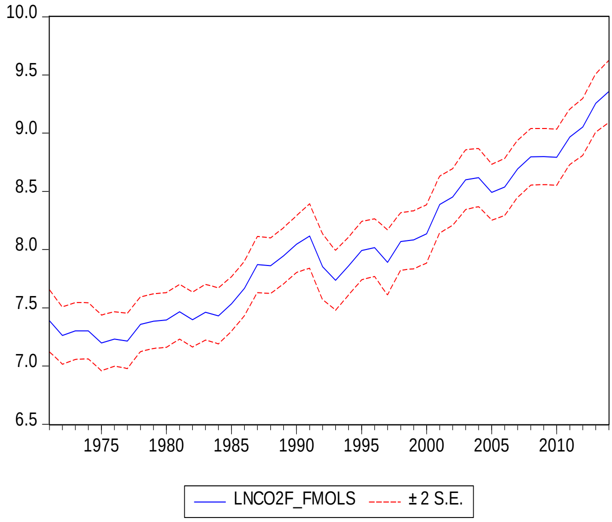
Figure 4c: CO_2 emission forecast from the ARCH models



Forecast: LNCO2F5	
Actual: LNCO2	
Forecast sample: 1971 2014	
Included observations: 44	
Root Mean Squared Error	0.099398
Mean Absolute Error	0.073494
Mean Abs. Percent Error	0.960493
Theil Inequality Coefficient	0.006189
Bias Proportion	0.001798
Variance Proportion	0.010122
Covariance Proportion	0.988080
Theil U2 Coefficient	0.680790
Symmetric MAPE	0.959870

Source: Own computation, 2021

Figure 4d: CO_2 emission forecast from the FMOLS models



Forecast: LNCO2F_FMOLS	
Actual: LNCO2	
Forecast sample: 1971 2014	
Included observations: 44	
Root Mean Squared Error	0.100226
Mean Absolute Error	0.072520
Mean Abs. Percent Error	0.946540
Theil Inequality Coefficient	0.006240
Bias Proportion	0.000761
Variance Proportion	0.002381
Covariance Proportion	0.996858
Theil U2 Coefficient	0.681365
Symmetric MAPE	0.946873

Source: Own computation, 2021

4 Discussions

The study finds that *ln* CO_2 emission has a strong relationship with *ln GDPPC*^{2}, *ln EU*, *ln PD*, *ln AL*, and with *ln GC*. An increase in ln GDPPC^2 reduces *ln* CO_2 emission in the short run. Our finding is in line with most of the studies (Ahmed and Long, 2012; Boutabba, 2014; Charfeddine, 2017; Chen et al., 2016; Hanif, 2017; Kasman and Selman, 2015; Özokcu and Özdemir, 2017; Saboori et al., 2012; Shahbaz et al., 2012) and against the findings of some authors (Alam et al., 2016; Ara et al., 2015; Inglesi-lotz and Dogan, 2018; Salahuddin et al., 2018). In fact, it is a general truth that an increase in personal-income led people to conduct quality life and shift from fossil and fuelwood energy sources to hydroelectric power, wind energy, and solar (Kebede et al., 2002) which is expected to contribute to CO_2 emission reduction. Since most Ethiopians have lived in rural areas with poor electricity infrastructure, as their personal income improves, they tend to shift from traditional energy sources to electricity from the hydropower (Kebede et al., 2002).

The other important variable which contributes to CO_2 emission, in the long run, is energy use. As explained by Erbato and Hartkopf (2011) and Beyene et al. (2018), the dominant source of energy in Ethiopia comes from fuelwood, animal dung, charcoal, and the likes. So, it is obvious that these sources have contributions to the increment of CO_2 emission. So, energy use in Ethiopia, in line with some studies (Acheampong, 2018; Ahmed and Long, 2012; Ahmed et al., 2017; Al-mulali and Ozturk, 2016; Boontome et al., 2017; Boutabba, 2014; Charfeddine, 2017; Hanif, 2017; Javid and Sharif, 2016; Jayanthakumaran et al., 2012; Kahouli, 2018; Kasman and Selman, 2015; Özokcu and Özdemir, 2017; Rauf et al., 2018; Saad and Belloumi, 2017; Sarkodie and Owusu, 2017; Shahbaz et al., 2012, 2015; Shahzad et al., 2017) came mostly from non-renewable sources and have enhancing effect on CO_2 emission (Alam et al., 2016; Asumadu-Sarkodie and Owusu, 2017).

The expansion of agricultural land also increases CO_2 emissions in the long run. It may be associated with the soil structure, crop cover, and land management (Schahczenski and Hill, 2009; Toochi, 2018). In spite of the fact that forest and bushlands have reduced the effect on the overall CO_2 emission than annual crops (Schahczenski and Hill, 2009; Wang et al., 2017), the expansion of agricultural land at the expense of forests (EPMES, 2017) enhances CO_2 emission in the long run (Di Vita et al., 2017). Furthermore, the agricultural practice might not be carbon-intensive and the use of biomass and crop residue as fuel and burning in the farmyard tend to increase CO_2 emission (Di Vita et al., 2017; Ko et al., 2017).

The anthropogenic CO_2 emission is related not only to energy use but also to population expansion (Asumadu-Sarkodie and Owusu, 2017). Like agricultural land, an increase in population density causes land use land cover change in Ethiopia. So, an increase in population enhances CO_2 emission which supports the findings of several studies (Ahmed and Long, 2012; Ara et al., 2015; Kasman and Selman, 2015; Zhu et al., 2016) among others but against the case of Brazil (Alam et al., 2016). In contrast, government change reduces the effect on CO_2 emission in the short run. In reality, government change in Ethiopia has not been in a democratic way rather through military action. Hence, in the short run government might give focus on peace and security to stabilize the country rather than encouraging people's socio-economic activities which is expected to inhibit the energy use (it is not co-integrated with CO_2 emission in the short run).

Like most agrarian countries, the GDP in Ethiopia is more dependent on the agricultural sector. Agriculture shares around 56% in 2000/01, 52% in 2005/6, and 43% in 2012/13 (Ferede and Kebede, 2015) of the GDP. In addition, the contribution of agriculture to the total export earning is almost 80 percent (EPMES, 2017). However, its contribution to GDP has been declining and overtaken by service and manufacturing sectors (IMF, 2020). So, it is not amazing that agricultural land negatively related to *ln GDPPC*. Similarly, energy also contributes to *ln GDPPC* improvement in the short run which is in line with studies done in various countries (Azam et al., 2015; Baranzini et al., 2012; Bekun et al., 2019; Bildirici, 2014; Dagher and Yacoubian, 2012; Saad and Taleb, 2018). Hence, it is better to expand the energy supply particularly from renewable sources to sustain economic growth. In addition, government change in Ethiopia brings economic reform in the country (Shiferaw, 2017) which improves the *ln GDPPC* as compared to the Derg regime. Government change is nothing by itself but the associated socio-economic reform and the stance of politicians for their commitment positively contribute to *ln GDPPC.*

Our result also shows bidirectional causality between *ln* CO_2 emission and energy use in the long run which is in agreement with the findings in Sri Lanka (Asumadu-Sarkodie and Owusu, 2016). Likewise, energy use and *ln GDPPC* have bidirectional causality in the short run in line with the findings of some studies (Bildirici, 2016; Bildirici, 2014; Wang et al., 2016). An increase in energy use enhances *ln GDPPC* and at the same time, an increase in *ln GDPPC* improves energy use. That is to say, means an increase in *ln GDPPC* encourages peoples to use more energy. So, it is a good opportunity for Ethiopia to boost the economy without affecting the environment by exploiting untouched renewable energy resources such as hydropower, the solar, wind, geothermal energies (Erbato and Hartkopf, 2011). In addition, biofuel from jatropha and castor oil also serve as alternative energy sources and at the same time, they can conserve soil and sequestrate carbon (Negash and Riera, 2014).

An increase in population density reduces the energy use in the short run against the findings of some scholars (Asumadu-Sarkodie and Owusu, 2016; Sarkodie and Owusu, 2017). While our finding is in agreement with Ji and Chen, (2017) and Osorio et al. (2017), as the population density increases it induces an energy-saving effect particularly in the urban areas. On the other hand, the negative effect of population density on energy use might be due to the incompatibility of energy supply with the population growth rate.

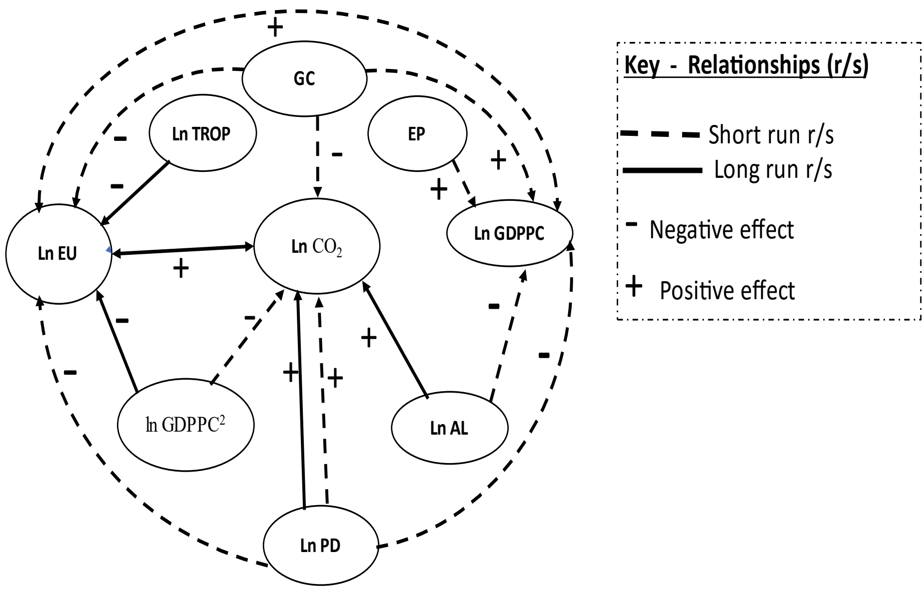
5. Conclusion and Policy Implications

5.1 Conclusion

This study identifies the nexus of CO_2 emission, economic growth, and energy use, keeping other variables constant. As summarized in Figure 5, CO_2 emission has a bidirectional positive relationship with energy use in the long run, while *ln* $GDPPC^2$ has a unidirectional and negative effect on CO_2 emission in the short run. On the one hand, *ln GDPPC* has no effect on CO_2 emission, but *ln*

$GDPPC^2$ it reduces it. This result is an evidence for the ECK hypothesis not holds true in Ethiopia. On the other hand, even though *ln GDPPC* has no direct effect on CO_2 emission, it affects CO_2 emission indirectly through energy use. Moreover, agricultural land has a negative effect on *ln GDPPC* in the short runs while its expansion enhances CO_2 emission in the long run. Similarly, an increase in population density enhances CO_2 emission in the long and short runs while it reduces energy use and *ln GDPPC* in the short run. Hence, it is possible to conclude that the energy sector is an engine towards economic growth and for CO_2 emission reduction. So, due emphasis should be given to the type and source of energy is used in the economy.

Figure 5: Nexus of CO_2 emission and macroeconomic variables



Source: Own computation, 2021

5.2 Policy Implications

To sustain the per capita economic growth and at the same time to reduce CO_2 emission government should exploit renewable energy sources like hydroelectric power, solar, wind, and geothermal energy sources. So, it is a good opportunity for Ethiopia to utilize the untouched renewable sources to meet the CRGE strategy and the SDGs. Furthermore, since agriculture is the backbone of the Ethiopian economy, mechanized and intensified agricultural practice likely to enhance its productivity by reducing the expansion of agricultural land which in turn retards CO_2 emission. So, emphasis should be given to the use of productive and environmentally friendly climate-smart agricultural technologies instead of expanding agricultural land to reduce CO_2 emissions.

An increase in $ln\ GDPPC^2$ and energy use potential tend to decline and enhance CO_2 emission, respectively, while the energy use enhances *ln GDPPC*. So, these relationships provide vibrant lessons to boost the implementation of the CRGE strategy. Furthermore, the environmental policy of Ethiopia does not have a significant effect on CO_2 emission and on energy use, so it is substantial to review and improve the policy. For the future, we recommend further studies that consider the forest resource and mining to assess the economy-environment nexus.

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Institutions, Innovation and Economic Growth in Sub-Saharan Africa: A Literature Review

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Abstract

Based on the theory of institutions and empirical literature survey from Sub-Saharan African economies, this review article examines the state of development in institutional quality, and absorptive capacity and the implication these bear for economic performance in the region. Drawing on the theory of institution by North, D.C. (1990), and Acemoglu, D., & Johnson, S. (2005), and the indigenous growth theories by Schumpeter (1934), Romer (1986) and Lucas (1988), to assess the state affairs in institutions, innovation, and economic growth in Sub-Saharan Africa. Empirical evidence points out that institutions and absorptive capacity are underdeveloped in most of the Sub-Saharan countries. However, institutions and innovative capacity of the region is gradually evolving with substantial implication over the economic growth record of the Sub–Saharan region. This study claims that if current trends of institutional development (i.e., democratic and governance institutions) and improvement in innovation infrastructure continue: Sub-Saharan Africa will become more democratic with strong rule of law in the near future; innovative capability of Sub-Saharan African states will be improved; and Africa will maintain its momentum in terms of economic growth.

Key words: Institutional Theory; Institutions; Absorptive Capacity; Innovation; Sub-Saharan Africa, Economic Growth
JEL Classification: D70, D72, O15, O30, O31, O55

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1. Introduction

In development discourse the sources of growth and development has been one of the most controversial issues. The non-state interventionist policy framework from its early root of Classical Economic Model (Harrod, 1939; Domar, 1946) to the present neo-liberal theory (Williamson J., 1990) suggests market liberalization with focus on capital formation as the rules for economic growth and development. The classical growth model focuses on formation of capital formation needed for financing productive investments in local business. The growth models of Harrod and Domar explain that capital formation raises the standard of living, which in turn results in higher growth. Criticizing the growth models proposed by Harrod and Domar on the ground of the fixed proportion of factors of production and substitutability between labor and capital, Solow (1956) argued that capital formation increases labor productivity in a dynamic process of investment growth.

Indigenous growth theories (Schumpeter, 1934; Romer, 1986; Lucas, 1988) explain growth in terms of government policy to foster the right kinds of investment in physical and human capital formation for economic expansion, growth, and development. Similarly, Romer (1990); Helpman and Grossman (1991) incorporate knowledge capital gained through research and development to explain growth along with other variables. Overall theoretical growth literature demonstrates the role of capital or changes in definition in capital (knowledge capital or human capital) in enhancing economic growth. Developing economies are poor in innovation capacity partly because institutions (i.e., economic, political, and legal institutions) are poorly developed to promote the right form of investment into human capital development through education and training. For economic development, human and physical capital formation is essential for the efficient utilization of natural resources (Schumpeter, 1934).

Institutional theory recommends the improvement of the quality of institutions for long-run economic growth and development (North, D. C., 1990; Acemoglu, D., & Johnson, S., 2005; Yao and Yueh 2008; Hasan et al. 2009; Casson et al. 2010; Huang, 2010; Angelopoulos et al. 2010; Blackburn and Forgues-Puccio, 2010; Frunza, R., 2011). The institutions represent a network of formal and informal rules meant to introduce order in the economic and social life and to improve a mechanism of applying and monitoring these rules in view of efficiently using the available national resources (North, 1990). The institutions form the environment that can influence favorably or unfavorably the itinerary of economic and social activities of a country (Frunza, R., 2011). Strong legal, political, and economic institutions are essential to promote development directly and through influencing policies including innovation policy. According to North (1990: pp.3), institutions are defined as the “rules of the game in a society, or more formally, humanly devised constraints that shape human intervention”. Among the institutions that are the most crucial to economic growth are those that enable a country to allocate capital to its most productive uses. Moreover, institutions that promote economic freedom are also essential in promoting economic productivity and efficient use of economic resources. Such institutions establish and maintain strong property rights, an effective legal system, and a sound and efficient innovation system. In recent years, the field of economic development has concluded that institutional rules are critical to economic growth. According to Ramona Frunza (2011), institutions represent a network of formal and informal rules meant to introduce order in economic and social life and to provide a mechanism for applying and monitoring these rules with a view to efficiently using the available national resources. However, empirical literature proved that the effect of institutions on economic development is also indirect through affecting policies. Accordingly, institutions help install policies targeting institutional reforms that aim to promote growth-driven innovation systems. It is clear from research in institutional economics that the levels and modes of innovative and entrepreneurial activity will be affected by the surrounding institutions (Licht and Siegel, 2006; Busenitzet.al. 2000). Effective institutions can help alter the constraints and structure of incentives in a society to direct self-interested behavior towards either more or less economically productive activity (Baumol, 1990; Nee, 1996). However, in the African context for example, extractive or predatory institutions do the opposite resulting in poor economic and social development. New opportunities arise as emerging economies undertake the shift from redistributive bureaucracy to open markets (Nee, 1996), but we still lack an understanding of which shifts are more important for increasing technological innovation.

Innovation capacity determines the level of capital formation. Similarly, the use of innovation results directly rather than innovating per se could contribute to capital accumulation. Like any other region, the economies of the Sub-Saharan African region innovation capacity development demand institutional and economic reforms to improve the performance of formal institutions and thereby to enhance economic growth. The theoretical argument for linking innovation capacity to economic development is that well-developed innovation systems improve the efficiency of capital allocation (Schumpeter, 1912; Helpman and Grossman, 1991). A modern innovation system promotes investment by identifying and funding good business opportunities, mobilizes savings, monitors the performance of managers, enables the trading, diversification of risk, and facilitates the exchange of goods and services. These functions result in a more efficient allocation of resources, in a more rapid accumulation of physical and human capital, and in faster technological progress, which in turn feed economic growth (Bagehot, 1873; Schumpeter, 1934). In the neoclassical framework, the impact of innovation is treated as part of the Solow residual and hence a key contributing factor to economic progress and long-term convergence (Solow 1957, Fagerberg, 1994). In recent decades, due to the popularity of endogenous growth theories, economists are increasingly of the view that differences in innovation capacity and potential are largely responsible for persistent variations in economic performance and hence wealth among the nations in the world (Grossman and Helpman, 1991). In the Grossman and Helpman approach innovation is viewed as a deliberate outgrowth in investments in industrial research by forward looking and profit seeking economic agents.

However, the question of what fundamental forces results in a well-developed innovation system, as well as what basic factors hinder the development of innovation capacity, are still debatable in the plethora of economic literature. One thing apparently clear, however, is the consensus that institutions which foster investment into education, training, research and development are critical for nourishing innovation systems. though there is still significant knowledge gap about the factors that ultimately determine a country's rate of innovation capacity, economists have increasingly becoming aware that institutional arrangements affect knowledge accumulation (Rodrik, 2000; Sala-i-Martin, 2002; Gradstein, 2004) and as a result, recognize that institutional arrangements affect the long-run growth of output. If one wants not only to diagnose the problem of growth, but also search for ways to stimulate growth, it is very important to understand how institutions and innovation are linked. Despite these, the existing literature reveals that political economists are still challenged by the daunting task of understanding the nexus between institutional quality and innovation capacity and to integrate institutions into the standard theoretical framework of economic growth (Huang & Xu, 1999; Sala-i-Martin, 2002). Besides, few growth models explicitly address this issue (Huang & Xu, 1999; Fedderke, 2001; Gradstein, 2004; Tebaldi & Elmslie, 2008) and little empirical cross-country analyses directly examine such a link. The existing literature on institutional and economic performance finds a positive association between institutions and levels of income (Hall and Jones, 1999; Acemoglu et al., 2001; Easterly and Levine, 2003; Alcala and Ciccone, 2004). Also, the link between institutions and the transitional growth rates of per capita income has been well explained in previous literature (Barro, 1991; Mauro, 1995; Acemoglu et.al., 2001). As far as the literature reviewed in this study an unambiguous empirical association between institutions and technical innovation has not yet been established. In addition, very little has been done in terms of theoretical explanation and empirical evaluation of the influences of institutional quality on technical innovation. This study contributes to the literature by examining empirical and theoretical literatures that provide evidence for links between technical innovation and the quality of institutional arrangement on the one hand and the link between innovation capacity and economic performance on the other hand. Following from this the author argues that institutional development is imperative to improve the innovation capacity of a nation and there by the performance of its economy.

1.2 Background to the African Social and Political Issues

The international experience in economic and institutional reform carries the central idea of the role of the state and markets in economic development. The dominant idea of the post second World War period is that the state could do better than the market and should therefore play a critical role in guiding societies that lack a strong entrepreneurial class towards a sustainable growth path. Most states directly concerned themselves with production in an attempt to accelerate capital accumulation and to acquire new technologies. The argument culminates with the conclusion that the society knows little or nothing as to how to move forward from vicious circle of poverty to virtuous cycle of wealth accumulation and therefore should be guided by the state policy makers and planners (Tipps D., 1976). According to Fenelli and Popov (2003), Norman v. Louyza and Raimundo Sotto (2003) the state policymakers in Africa experimented with tools like manipulation of relative prices, protectionism and intervention in the process of financial intermediation to influence resource allocation in the desired direction.

However,1970s began to show up the drawbacks of the model in the form of increased burden on government finance resulting from inefficient state-owned enterprises, inflated bureaucracies, low productivity, and foreign exchange shortages resulting in reducing the role of the state and increasing reliance on markets (Heidhues Franz, 2009). In the late 1980s the embrace of market-oriented development approach became widespread as many reforms were put together when the Washington Consensus (Williamson J., 1990) development policy prescriptions were in place demanding a market liberalization, privatization, and deregulation measures as the only way out of poverty for underdeveloped economies. The irony is the policy prescriptions failed in most of the cases because it exports only the sets of policy prescriptions but not the institutional array necessary for implementation of the policies. At the same time many countries moved to political systems that, at least on the surface, were more democratic than their predecessors. The 1990s saw even more dramatic institutional changes, particularly in the former socialist economies of Europe, East Asia and Africa. For Sub-Saharan Africa, economic performance in the 1970s and 1980s was very poor (Acemoglu, et al., 2002; Jerven, 2009; IMF, 2009). Much of the region was unable to break away from paths of negative or low per capita income growth (Ferguson, 2006; Thomson, 2010), high inflation and fiscal deficits (Hodges, 2004), and balance of payments difficulties, which in some countries culminated into political and social turmoil (Sender and Smith, 1986; Chabal, P. & Daloz, J., 1999).

For African economies, the historical experience is quite the same as that observed in many other developing countries. Since independence in the 1960s, Africa's development scenario was very interesting for about two decades. Sub-Saharan average economic growth was 3.4 percent between 1961 and 1981(World Bank, 1981). Over this period Ivory Coast and Nigeria outperformed Indonesia, while countries such as Congo Democratic Republic, Ghana and Uganda were in par with South Korea's development performance (Klasen, 2003). By the end of 1970s the general development prospect of Sub-Saharan African countries was unsatisfactory although some countries had experienced better economic growth (World Bank, 1981). Development motives in the region since the late 1960s have been full of controversies (Gareth Austin, 2010). During the 1970's and 1980's, almost all the countries implemented policies of self-reliance and protectionism, which entailed the state taking the leading role in national development under socialist systems (Heidhues Franz, 2009). These included extensive compulsory villagization, nationalization, and price controls. Among others, nationalization of private owned companies and creation and management of state enterprises was based on the infant industry protection and development considerations and the thinking that the state was in a better position to guide the society towards sustainable development. This process has adversely affected the then institutional development in Africa in general.

However, by the 1980's, African economies were among the world's poorest countries in terms of GDP per capita, and it seems that for the most part its problems were related to poor policies and structural weaknesses characterized by internal and external political frictions (Sender and Smith, 1986; Easterly and Levine, 1997; Heidhues Franz, 2009; Jerven, 2009; IMF, 2009). Since the demise of the socialist system at the end of 1980’s, the countries started to reorient their policies towards a free enterprise system. The governments renovated their approach to structural adjustment policies suggested by the World Bank and IMF. Structural reforms carried out by the governments in Sub – Saharan Africa have focused on realigning the incentive structure towards efficient use of scarce foreign exchange, liberalizing markets for goods and services, and reducing the involvement of the public sector in the economy and privatization of public enterprises under capitalist economic system. However, a history of little to no success was reported from the implementation of structural adjustment programs because of the weak institutional array in these economies (Acemoglu, et al., 2002; Hodges, 2004; Ferguson, 2006; Williams G., 2007; Thomson, 2010). Those economies like Ethiopia and Rwanda which realized the failure and reoriented their development policy towards the Developmental State Model (mainly imitated from the Asian economies) proved to succeed, posing critical questions on the mechanisms of institutional development for improvement of innovation capacity and thus economic and social progress (Oliver Reynolds, 2018; Ben Shepherd and Anna Twum, 2018). Hence, this study argues that lack of quality institutions and failure to mobilize support for collective action has limited the ability of African countries to influence the design of innovation policy in particular and economic growth promoting policies in general.

1.3 Stylized facts

Contrary to previous studies, Edinaldo Tebaldi & Bruce Elmslie (2008) suggest that a good way to study the role of institutions in promoting economic growth is not to study in terms of its direct effect alone, but to consider the impact of technological innovation on the nexus of institutions and economic performance. They argue that focusing only on the direct effect of institutions risks predefining the object and thus not seeing it as it really is. That means the dual effect of institutions is going to be overlooked if our analysis of the role of institutions fail to capture the indirect effect of institutions. When institutions are poorly developed such as in Sub-Saharan African economies, one must take a comprehensive view to see it clearly. This is because improvement in institutions in such a context plays significant role directly and indirectly by harnessing sectoral policies. The alternative, North (1990), Rodrik (2000), Acemoglu et al. (2001), Easterly and Levine (2003) suggests, is to consider the direct effect of institutions on economic performance.

This review article seeks to briefly explain how the findings might be important for understanding the broader picture of how technological change and various elements of political and governance institutions are related in promoting economic performance in Sub-Saharan African economies, along with policy-making implications. Understandably, it is difficult and to try to develop predictions, particularly about the future state of affairs. Nevertheless, it is important to consider some key themes and trends that have emerged through empirical examination of the role of institutions, and what might be the implications for future developments in the nexus of institutions, technological change, and economic performance in Sub-Saharan Africa.

There are significant disagreements among scholars of sub-Saharan African studies about the likely future directions of institutional development, particularly on the development of political and governance institutions in Sub-Saharan Africa (Gareth Austin, 2010; Cheeseman, 2015; Temnin John, 2018). Partly, this is because of different theoretical perspectives playing into the diversity of African countries in terms of social, political, and economic issues. Cheeseman affirms that significant portion of the African continent is democratizing by acknowledging that the large bulk of African states are still in murky ground between democracy and autocracy. Temnin John based on data from the freedom house provides evidence that democratic development in Sub-Saharan Africa has distinctive regional divergence. While southern and western Africa have shown significant improvement in the development of democratic political and governance institutions, eastern and central Africa have experienced major backlash. In general, the institutional development in Sub-Saharan African countries is relatively changing towards democratic institutionalization. Sub-Saharan African state institutions as a result are fairly complex, producing contradictory observations and conclusions on how the state politics functions (Cheeseman Nic, 2015; John Stremlau, 2016; Jakkie Cilliers, 2016). In this brief review the author aims to add another piece to the attempt to better understand state of development in political and governance institutions in Sub-Saharan

Africa and the implications of these developments on economic growth in the continent.

Scholars of African study tended to focus on the question of how to reform the politics and governance of African states so that typical African states become a liberal democracy. This review claims that this is not only wrong question, but also misguided and misinformed, and in fact focusing on this consequentialist question will obscure our understanding of contemporary African states as they actually are. This review considers that it's essential to take an objective view, to analyze the key trends in institutional development and how they might keep on developing in the future, without any presumption that a typical African state should evolve into a liberal democracy. The author of this review proposes that the relevant debate in future research should focus on what type of democracy (i.e., liberal democracy, consensus democracy or social democracy) is viable for African states. To this effect, future research need to focus on examination of specific country cases. Previous research underscored institutions in Sub-Saharan African states are indeed evolving with significant implication on innovation and economic growth that the continent witnessed in recent periods (Radelet, 2010; Africa rising, 2011; Kathleen et al., 2016; Asongu, 2017). It is clear that establishing innovation encouraging institutions require as a necessary and condition, good politics, and good governance. This is not to say that the development is uniform across Sub-Saharan Africa (see: Appendix Tables A1, A2 and A3). Also, it is not to say that institutions in Sub-Saharan Africa are developed enough. The large numbers of regimes in Africa are still quite identified as either authoritarian or hybrid. In terms of democratization, The Economist Intelligence Unit's democracy index awarded full-democracy status only to Mauritius in 2018. This signifies that there is still a long way to go for democracy to take root in Sub-Saharan Africa. A quite significant number of African states are still authoritarian and weaknesses in freedom of speech, accountability and transparency are observable. However, what are the implications if current trends of democratization continue? Based on the evidence analyzed in this research, it could be argued that. (1) Sub-Saharan Africa will become more democratic in the near future; (2) innovative capability of Sub-Saharan African states will be improved; (3) Africa will maintain its momentum in terms of economic growth.

1.4 Democratic Africa is emerging

The general popular perception that Africa's democratic deficit puts the continent behind the rest of the world in the most obscure of political terms is fading away. In spite of the fact that millions of people elsewhere in the world live under regimes that can be described as authoritarian, oppressive and undemocratic, Africa is considered as the most vulnerable to democratic deficit. Cheeseman and Klaas (2018) provide strong evidence that there is strong African bias regarding democracy and good governance. Available evidence shows that large portion of the African continent is democratizing against the odds. According to the 2008 report of The Economist intelligence unit's democracy index the number of successful "coups from within" in Sub-Saharan Africa has been dropped substantially since early 2000s. The index identifies four categories of regime types: full democracy, flawed democracy, hybrid, and authoritarian. It puts most African countries in murky ground between democracy and autocracy awarding full democracy status only to Mauritius, a country with very strong rule of law. Freedom House, a think tank based in the United States (US), reported in 1990 that only 17 out of the 50 African countries on which it reported could be classified as 'free' or 'partly free'. This classification is based on subjective measurement of democracy making it prone to measurement contaminants. In fact, that is not specific to freedom house indicator, and it is the limitations of indicators for democracy index in general (Sara Bush, 2015). Its most recent data in 2019 indicates that 32 out of 54 countries are 'free' or 'partly free'. Democratic progress in Sub-Saharan Africa is uneven (Temnin John, 2018) even though holding periodic elections is becoming common in African states (Democracy Index, 2018). The drop in number of successful coups is an indicator of the progress in development of democratic institutions in Sub-Saharan Africa; especially it signifies that peaceful transition of power is emerging in Sub-Saharan Africa. Some countries in Sub-Saharan Africa appear to defy the narrative of a democratic deficit in the continent. In 2016: Nigeria, Liberia and Ivory Coast are named among the countries with the biggest development in political rights and civil liberties by the freedom house. These countries were previously known for instability and internal conflict. For the first time in Nigerian history an opposition party obtained political power through elections in 2015. In recent reports countries such as Botswana, Ghana, Cape Verde, and Benin have also been lauded as democratic examples. Specifically, Ghana has witnessed the achievement of an established democracy by electing an opposition for 50.5% of the votes over the 49.5% to the ruling party on 7 December 2016. Senegal and Ghana are examples of relatively well-governed states as a result of repeated and successful alternations of political power.

In east Africa the giants like Ethiopia, Kenya and Tanzania are moving towards the path of democratization. In Ethiopia for instance, a soft revolution from 2016 to 2018 has led into replacement of a very repressive regime with a relatively democratic one. Freedom house witnessed the development in Ethiopia as follows. “Following sustained protests in Ethiopia, the ruling party installed a reformist prime minister who lifted a state of emergency, released political prisoners, and permitted more open political debate” (Democracy Index, 2019). In Tanzania presidential election has already resulted in the opposition taking over the political power. In Kenya the opposition and the incumbent agreed to work together though it is after crisis in the aftermath of general elections. In central Africa a positive development is emerging as far as democratization is concerned. In democratic republic of Congo- a nation severely torn with instability and internal conflict - an opposition is elected to office in 2018 defying the conventional narratives. The 2016 polls in Central African Republic culminated to ending persistent conflict for years, and the presidential runoff was concluded peacefully in spite of months of sectarian and ethnic violence, albeit with a lower turnout. The southern African region is relatively more democratic compared with the rest of African regions (Temnin John, 2018). Electoral outcomes in this region of the continent are less contentious. Nevertheless, election is only one face of democracy. As the then UN secretary general Kofi Annan said: “Democracy is not just about one day every four or five years when elections are held, but a system of government that respects the separation of powers, fundamental freedoms like the freedom of thought, religion, expression, association and assembly and the rule of law … Any regime that rides roughshod on these principles loses its democratic legitimacy, regardless of whether it initially won an election.” As result, Sub-Saharan African governments need to promote the rule of law if furtherance of democratic governance is to be realized. Jakkie Cilliers (2016: P.1) argues that “democracy in much of Africa is constrained from delivering on its development potential for three reasons. First, governance capacity is lacking. Second, the quality of electoral democracy is thin. Finally, neopatrimonialism undermines electoral democracy in Africa”. This means Sub-Saharan African states need to focus on institutionalization of their democratic progress to avoid the risk of backlash. Cheeseman (2015) affirms that Sub-Saharan African countries are likely to continue to make democratic gains and consolidate them over time but there is a risk of backlash owing to poor institutionalization. Furthermore, Cheeseman (2018) argues that against the historical posture of African political institutions such as constitutions, legislatures, and judiciaries are weak and vulnerable to manipulation, leading some to claim that the continent is 'institution-less', recent developments including the consolidation of presidential term limits in a number of Sub-Saharan African countries demonstrate that this depiction is no longer tenable. Institutional conditions that create the rule of law and guarantee a broad range of civil liberties to all citizens are preconditions to the institutionalization of democracy. Mohamed A. El-Khawas (2001) asserts that this aspect of democratization is being implemented slowly and unevenly among African countries, because it requires institution building and huge resources to make changes and to train people to perform new roles. As Jean-Germain Gros (1998: p.3) succinctly put it, the major purpose of the institutionalization of democracy is “to make intrastate and state-society relations more balanced. Separation of power . . . checks and balances, administrative decentralization and accountability, freedom of speech, press, assembly, and . . . civilian hegemony over the military are some of the components of the second phase of democratization.” Hence, institutionalization of democracy needs to focus on the balance and exercise of power among the legislature, the executive, and the judicial bodies of the government system.

Available evidence reveals that there is impressive progress in Sub-Saharan Africa in terms of the rule of law in particular and the development of governance institutions in general. The Ibrahim Index of African Governance, an annual assessment developed by the Mo Ibrahim Foundation, focuses on what happens between elections. It conceptualizes good governance as safety and rule of law, participation by citizens and a respect for human rights, sustainable economic opportunity, and human development. The 2018 index provides strong evidence for positive development in governance institutions across Africa. At the top of the index were Mauritius, Seychelles, Cape Verde, Namibia, and Botswana, while Central African Republic, South Sudan, Eritrea, Libya, and Somalia – all nations torn by conflict – were at the bottom of the list. Chester A. Crocker (2019) attributes the prospect of governance development in Africa to macro variables such as educational access (especially for women), climate change impact and mitigation, development and income growth rates, demographic trends, internet access, urbanization rates, and conflict events. Chester A. Crocker (2019) further emphasizes on the potential influence exerted by the region's leading states, measured in terms of size, population, economic weight, and overall political clout and leadership prestige. The positive development in a critical mass of the leaders—e.g., South Africa, Nigeria, Kenya, Ethiopia, Cote d'Ivoire, Algeria, Egypt—will pull some others along in their wake; of course, with a possibility for the reverse as well. Moreover, the Afrobarometer provides strong evidence that the critical mass in Sub-Saharan Africa has strong demand for jobs, better economic management, reduced inequality and corruption and such outcome deliverables as health, education, and infrastructure (Massa Coulibaly et.al, 2019). These outcomes entail efficacious and quality governance institutions (Chester A. Crocker, 2019). Although it is difficult to claim that such institutions will consistently emerge, public choice theory suggests that it is reasonable to expect that good governance institutions will evolve over time in response to the quest by the critical mass. It is vital not to overemphasize the institutional progress and its development in Sub-Saharan African countries as it is, but if these trends continue there is potential for democracy and good governance to flourish. That is with the unfolding democratic progress and good governance in Africa, if sustained; innovation inducing institutions will be established. One basic question for further investigation at this juncture is: what is the effect of democracy on good governance? This review leaves this question to future empirical investigation.

1.5 Innovative and Growing Africa in the Making

The findings from empirical literature review suggest that sub-Saharan Africa will become more innovative. Furthermore, the continent is likely to maintain its track record of economic growth momentum. For instance, the global innovation index reports show that most countries among the group of innovation achievers' category have been from sub-Saharan Africa region (Cornell University et al., 2018). Available evidence indicates that progress in institutional development and business sophistication has played essential role in helping the region as a whole to catch up with Central and Southern Asia in terms of innovation. The substantial improvement achieved in institutional development in economies such as South Africa, Mauritius, Botswana, Namibia, Rwanda, and Burkina Faso has led into highest scores in institutions and market sophistication in Sub-Saharan Africa in 2017(Cheeseman Nic, 2015; Cornell University et al., 2018). There is difference in the approach employed by Sub-Saharan African countries to improve their innovative capability for instance, large-sized economies such as South Africa, Kenya, Botswana, and Namibia expanded their investment in infrastructure development, while others such as Mauritius, Rwanda, Senegal, and Zimbabwe are achieving progress in innovation through investment in human capital development (Cornell University et al., 2018). Kenya and Rwanda evolved as prominent examples in using technology to catalyse new areas of growth. The biggest innovations that are coming out of Sub-Saharan Africa is in the area of financial service, which has disrupted traditional financial models. Rwanda is a pioneer in digitalizing health care education and general government services. Ndubuisi Ekekwe (2015) provides strong evidence that in Sub-Saharan Africa, innovation is accelerating, and the continent is finding better ways of solving local problems, even as it attracts top technology global brands. However, Sub-Saharan Africa is the least innovative region in the world, despite the strong performance of individual countries such as South Africa, Mozambique, Mauritius, Kenya, Rwanda, Malawi, and Botswana (Cornell University et al., 2018).

The African union has a vision dubbed 2063 which aspires to transform African politics, society, and its economy. In pursuing this, African Union gives emphasis to the importance of innovation and development of technological capability. To this end, science and technology strategy has been developed (African Union, 2014). "Technology and Innovation Strategy for Africa 2024 (STISA-2024) places science, technology and innovation at the epicenter of Africa's socio-economic development and growth" (African Union, 2014). The strategy emphasizes the importance of investments in education, technical competence and training, because science, technology, research, and innovation remain critical to Africa's economic prosperity. The vision of the African union could be considered appropriate because the existing literature has affirmed the critical role of human capital formation for improvement of innovative capability (Bourdieu, 1986; Maskell and Malmberg, 1999; Dakhli & De Clercq, 2004). Concerning human capital development, the 2018 Mo Ibrahim index of African governance indicates that in Sub-Saharan Africa, there is a progress in education over the last decade. However, education quality remains poor in sub-Saharan Africa despite the growth in enrolment (Bashir Sajitha et.al, 2018). Current education quality is not matched to the growing demand for education and jobs. Mo Ibrahim index shows that half of the continent's countries (27) registered deteriorated Education scores in the last five years, meaning that for over half of Africa's citizens (51.5%) education outcomes are worsening. The poor quality of education if further deteriorates would have significant repercussions on improvement in innovative capacity. As result, the improvement of the education quality is critical. This could be done by creating industry – university linkages so that industry operators are involved in the design of educational curriculum, which could avoid mismatch between skills needed and the skills developed by educational institutions.

Development of innovative capability of Sub-Saharan African economies has a very good prospect if: 1) improvement in political and governance institutions are sustained (discussed above); 2) focus on comparative advantage of Africa guides innovation policy in the continent; 3) the financial and infrastructural challenges are addressed. Effective rule of law and institutions that guarantee protection for intellectual and private property rights are critical for innovation (Gillian K. Hadfield, 2008; Mason, O'Leary, and Vecchi 2012; Ngatat 2016, Papageorgiadis N. and Sharma A., 2016). This is because in countries where the rule of law is strong, the incentive to innovate is high since proper rule and the protection of intellectual property imply maximum rent to innovators. That means a guarantee for protection of private property such as patent rights, copy rights and trademarks serve as incentives to invest into research and development, that spurs innovation. Makhtar Diop (2017) suggests that Africa's innovation system needs to be built on sectors where it had a comparative advantage, which at least initially consisted of natural resource sectors. He further argues that Sub-Saharan Africa needs to invest into three steps of innovation policy to improve its innovation capability. These are: first include managerial and organization capabilities organizations to adopt existing innovations and piggyback on the advances that rich countries make, capturing exactly the returns that the economist Schumpeter (1934) predicted. Second, start collaborative projects with higher performing countries (like China). And third step involves investing longer term in technological programs. This means long term evolutionary process approach to absorptive capacity development is adaptable to the context of Sub-Saharan African economies if they were to grow based on their natural resource endowment. Gustavo Crespi et.al (2018) offers strong empirical evidence to support the idea that growth on the basis of natural resource-based activities should be understood as a long-term evolutionary process, from inception of the industry to maturity and internationalization. Ndubuisi Ekekwe (2015) offers evidence that innovation in Africa remains challenged by factors that indirectly stymie access to capital, including property rights, poor technical manpower, and inadequate infrastructure. That means absorptive capacity development requires the intervention of the state through government policy instruments in areas of protection for intellectual property, education provision, and funding for research and development among others. However, state intervention may generate government failure. Therefore, interventions such as these require systematic introduction to avoid possible government failure (M. G. Ukpabio et.al, 2016).

Given that institutional development and progress in innovation capacity has good prospect in Sub-Saharan Africa, the continent has a potential to maintain its economic growth record. Sub-Saharan African economies were described as hopeless in the early 2000s because of poor level of economic performance and rampant poverty (Hopeless Africa, 2002). Nevertheless, many African economies have been able to move from vicious cycle of poverty into virtuous cycle of unprecedented economic growth in just a decade (Africa rising, 2011). Radelet (2010) argues that large number of Sub-Saharan African economies exhibit the basic features of emerging economies. Moreover, Kathleen et al. (2016) provides strong evidence that Africa has enjoyed robust economic growth in over the last decade. However, evidence shows that the growth is not uniform across Sub-Saharan Africa and country level differences are significant. About seventeen countries in Sub-Saharan Africa (e.g., Angola, Chad, Equatorial Guinea, Ethiopia, Ghana, Liberia, Sierra Leone, Tanzania, Uganda, And Zambia) have experienced sustained high level of economic growth, rivaling those of rapid-growth, emerging economies in Asia (Kiertisak Toh, 2016). However, in countries such as Burundi, Central African Republic, Eritrea, Zimbabwe, Gabon, and many oil-exporting countries not only low growth rate is experienced, but also these economies remain fragile. Also, evidence suggests that emerging economies in sub-Saharan Africa are different in terms of economic fundamentals and quality of institutions and governance from none emerging slow-growth group (Garner Phillip, 2006; Kiertisak Toh, 2016; Cornell University et.al. 2018). Sub-Saharan African region has become one of the fastest growing economies in the world, albeit the need to work for structural transformation. The economic growth record is driven principally by primary exports such as fossil fuel, minerals, and unprocessed agricultural commodities and forest products.

The Global Economic Prospects report recently released by the World Bank for sub-Saharan Africa asserts that the continent will maintain its growth momentum at the rate of 3.4% in 2019. Economic growth across Sub-Saharan region varies significantly. The three largest economies of the region (i.e., Nigeria, South Africa, and Angola) are expected to grow below the regional average. Nevertheless, there are large numbers of economies which are expected to grow at over 6 percent (e.g., Ethiopia, Rwanda, Burkina Faso, Cote d'Ivoire, Ghana, Niger, Tanzania, Senegal, and Uganda. Also, the predicted economic growth for Sub-Saharan African economies is below the average of other emerging markets. This is because large sized and commodity-driven economies such as South Africa, Nigeria, Angola, and Zambia—are overwhelmed by a combination of macro-economic forces that inhibits progress and domestic challenges like unemployment, political instability, and corruption. However, countries like Ethiopia are in the spotlight. Ethiopia is on path to have nearly the highest GDP growth rate in the world, and several smaller economies like Tanzania, Kenya, Rwanda, and Ghana are growing at rates over 6 percent, a number on par or higher than China's expected growth. Moreover, these countries are also effectively attracting global capital through progressive policies aimed at diversifying their economies and growing the middle class. It is evident that Sub-Saharan African economies are growing, and they are expected to grow in the near future as well. However, the economic growth in Sub-Saharan Africa failed to result in significant progress in poverty reduction in the region (Kathleen et al., 2016; Sabina Alkire et al., 2017). Workers' productivity is still low, while the population is growing above the economic growth rate. Sluggish progress towards key business needs such as power and rail infrastructure may also hurts investor confidence. Heidhues Franz (2009) argues that many of strategies and approaches pursued to foster development in Sub-Saharan Africa since independence in the early 1960s has failed. Heidhues Franz points to two basic factors for the failure. The first is related to faulty strategies and policies propelled to Africa by international donors and development partners, and the second has to do with Africa's difficult geography and socio-cultural and institutional history, which cannot be changed in the short and need to be recognized as the given context within which development must take place. Hence, for Sub-Saharan African region to maintain its growth record these bottlenecks need to be addressed. To this end, Sub-Saharan African region needs to focus on policies that tackle corruption, invest in infrastructure development, and enhance workers' productivity if it were to maintain its growth record.

1.6 Final Remarks

This study aimed to contribute to the literature on the nexus among institutions, innovation, and economic performance in the context of developing countries. The results in prior empirical studies proved that stable democracy provides avenue for improvement in economic growth and development (North, D. C., 1990; Przeworski et al., 2000; Todaro and Smith, 2009) and stimulates countries' level of innovativeness (Hall, R. E., and C. I. Jones, 1999; Daniel, 2002; Rodrik 2007; López-Claros, A. and Yasmina Mata, 2009). Empirical literature review affirms that the impact of democratic political institutions on economic performance is more profound in underdeveloped economies than in consolidated democracies (Pereira and Teles, 2010; Acemoglu et al., 2018). This is due to the power of democratic political order in protection of fundamental political and civil rights which in turn improves economic productivity. In democracy, openness, free flows of information as well as the flow of goods fosters efficient, customized, and effective policies (Siegle, Joseph T. et.al, 2004). Similarly, quality of governance institutions contributes to economic growth and development. This means poor governance is one of the major reasons that some countries are in a vicious cycle of poverty. For instance, corruption causes low level of economic growth leading into poverty trap through misappropriation of public resources (Tanzi and Davoodi, 2002; Blackburn et al., 2006). Political instability and poor performance in freedom of speech and accountability generates low level of economic growth. On the other hand, strong rule of law provides appropriate protection for intellectual and private property rights, serving as a strong incentive for innovation and improvement in economic productivity. Haggard, S., & Tiede, L. B. (2011) argues that it is "the weakness of the government and the inability to provide law and order in the most basic sense that constitute[s] the most profound barrier to growth". Overall, the evidence analyzed suggests that developing countries in the Sub-Saharan region need to focus on development of quality institutions, improvement of innovative capacity through research and development, and investments in education and training, in order to improve their economic performance and overcome poverty traps. For institutional development, Sub-Saharan African economies need to follow an evolutionary approach because of their difficult geographic, socio-cultural and institutional history, which cannot be changed in the short run and need to be recognized as the given context within which development must take place. If countries in the region focus on development of hegemony of the civil government over the military and formal institutional check and balances in the exercise of power among the legislatures, the executive, and the judicial system, Sub-Saharan Africa has great potential to overcome poverty traps. One of the most important factors that prohibits countries from focusing on it is the involvement of the military in politics and the infiltration of party indoctrinated military commanders in the army. This is often pursued by ruling parties to ensure the military's loyalty and to remain in power. At times this has backfired, resulting in military coups as is the case in many western African countries. Hence, it is essential to focus on the professionalization of the army as well as the entire security structure of the state.

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Appendix – A:

Appendix Table A1: Lists of Countries and Mean Values of the Key Variables

Country	ID	Polity2	lnSJA	DEMO	ATR	HC
Angola	AGO	-2.2381	2.130582	1.714286	3.952381	1.361142
Benin	BEN	6.52381	4.214989	6.52381	0	1.523739
Botswana	BWA	7.952381	4.657352	7.952381	0	2.607398
Burkina Faso	BFA	-0.38095	4.436408	2	2.380952	1.131863
Burundi	BDI	2.619048	1.602067	4.333333	1.714286	1.264374
Cameron	CMR	-4	5.461935	1	5	1.803056
Central African Republic	CAF	1.190476	2.101296	-12.5238	-13.7143	1.43828
Congo Republic	COG	-4	3.85501	0.285714	4.285714	2.000335
Dem. Republic Congo	ZAR	3	2.081521	3.714286	0.714286	1.590991
Cote D’voire	CIV	0.619048	4.71709	2.238095	1.619048	1.492009
Ethiopia	ETH	-1.28571	5.647005	1.857143	3.142857	1.250761
Gabon	GAB	-1.33333	3.563768	1.52381	2.857143	2.332142
Gambia	GMB	-5.04762	3.538028	0	5.047619	1.402539
Ghana	GHA	6.285714	5.39069	6.666667	0.380952	2.210005
Kenya	KEN	5.047619	6.228357	6.238095	1.190476	2.06716
Lesotho	LSO	7.047619	1.92472	7.857143	0.714286	2.036762

Madagascar	MDG	5.714286	4.005382	6.190476	0.428571	1.594221
Malawi	MWI	5.761905	4.520296	5.952381	0.190476	1.662526
Mali	MLI	6.047619	3.655342	2.571429	-3.47619	1.196794
Mauritania	MRT	21	-3.76191	1.930861	0.190476	3.952381
Mauritius	MUS	10	3.790405	10	0	2.395448
Mozambique	MOZ	5	3.494667	5.190476	0.190476	1.161901
Namibia	NAM	6	3.606275	6	0	2.092194
Niger	NER	3.47619	3.350271	5.285714	1.809524	1.147668
Nigeria	NGA	3	7.43206	-0.38095	-3.52381	1.633099
Rwanda	RWA	-3.85714	2.755321	0	3.857143	1.508193
Senegal	SEN	5.809524	5.039578	6.380952	0.571429	1.398857
Sierra Leone	SLE	4.809524	1.937011	2	4	1.447756
South Africa	ZAF	9	8.536566	9	0	2.342954
Sudan	SDN	-4.38095	4.886726	0.333333	4.809524	1.467113
Swaziland	SWZ	-9	2.88311	0	9	1.697869
Tanzania	TZA	-0.61905	5.3801	2.190476	2.809524	1.554498
Togo	TGO	-2.47619	3.31371	1	3.47619	1.735146
Uganda	UGA	-2.28571	5.30845	0.571429	2.857143	1.863473
Zimbabwe	ZWE	-1.71429	5.03896	2	3.714286	2.276592

Appendix Table A2: Summary Statistics (1995–2015).

Variable	Obs	Mean	Std. Dev.	Min	Max	Source	Description
LnSJA	723	3.8884	1.7514	-.91629	9.1777	World Bank and Science Web Citation	Measured by the citation index of Scientific and Technical Journal Articles
POL	724	1.669	5.3035	-9	10	Polity IV Project	A codified measure of a country's political regime based on (Jaggers and Gurr 1995; Marshall and Jaggers 2002). Scores can range from -10 to 10, with 10 representing a full democracy
DEM	720	3.7111	3.2512	0	10	Polity IV Project	A codified measure of a country's level of democratization based on (Jaggers and Gurr 1995; Marshall and Jaggers 2002). Scores can range from 0 to 10, with 10 representing a full democracy
ATR	720	2.2056	2.3638	0	9	Polity IV Project	A codified measure of a country's level of democratization based on (Jaggers and Gurr 1995; Marshall and Jaggers 2002). Scores can range from -10 to 10, with 10 representing a full Autocracy
HC	724	1.692	.4022	1.0493	2.8336	Pen World Tables	A codified index of a country's level of human capital development based on (Barro, Robert J. and Jong-Wha Lee,2013) data set of educational attainment
LnGDPPC	717	6.8956	1.0298	5.1295	9.3848	Pen World Tables	the national income per person
LnPOP	724	16.099	1.1602	13.879	18.994	Pen World Tables	The total population of a country
LnEMP	724	14.993	1.293	12.207	17.855	Pen World Tables	The total number of people engaged in productive economic activities
LnCK	724	24.778	1.2917	21.889	28.435	Pen World Tables	The level of accumulated capital due to saving and investment
LnFCF	724	2.8968	.51648	-1.2280	4.3151	World Bank	Gross fixed capital formation as a percentage of GGDP
LnUPOP	724	3.4989	.48462	1.9756	4.4677	World Bank	The total size of the urban population
LnTRD	720	4.1989	.47799	2.6928	5.77341	World Bank	The ratio of the total trade (i.e., import plus export) to national GDP
MID	724	.29282	.45537	0	1	World Bank	Middle income dummy which assumes a value of 1 if the country is in the middle category as classified by the world bank, otherwise 0

Appendix B

Appendix Table B1: Lists of countries and mean values of governance institutions

Country	ID	lnSJA	GQ	VA	PSNV	GE	RQ	RL	CC	HC
Angola	AGO	2.130582	-1.26017	-1.25558	-1.13361	-1.17193	-1.25373	-1.41228	-1.33392	1.361142
Benin	BEN	4.214989	-0.1689	0.266396	0.533017	-0.44335	-0.37875	-0.39678	-0.59394	1.523739
Botswana	BWA	4.657352	0.723487	0.588086	1.067835	0.530219	0.59729	0.63274	0.924742	2.607398
Burkina Faso	BFA	4.436408	-0.36244	-0.31251	-0.24021	-0.63527	-0.24929	-0.53166	-0.20567	1.131863
Burundi	BDI	1.602067	-1.29301	-1.11427	-1.93918	-1.2981	-1.16966	-1.21238	-1.02444	1.264374
Cameron	CMR	5.461935	-0.93888	-1.02985	-0.67136	-0.8415	-0.81743	-1.12904	-1.14412	1.803056
Central African Republic	CAF	2.101296	-1.31848	-1.03554	-1.72003	-1.48014	-1.13732	-1.40755	-1.13026	1.43828
Congo Republic	COG	3.85501	-1.13691	-1.1287	-0.93726	-1.1915	-1.20148	-1.24896	-1.11355	2.000335
Dem. Republic Congo	ZAR	2.081521	-1.72009	-1.50325	-2.40868	-1.66925	-1.5958	-1.70729	-1.43628	1.590991
Cote d'Ivoire	CIV	4.71709	-0.94059	-0.89785	-1.28052	-0.89253	-0.65405	-1.11339	-0.80522	1.492009
Ethiopia	ETH	5.647005	-0.96154	-1.20963	-1.39262	-0.71713	-1.07369	-0.76243	-0.61375	1.250761
Gabon	GAB	3.563768	-0.45534	-0.72001	0.300543	-0.64961	-0.35653	-0.47674	-0.82968	2.332142
Gambia	GMB	3.538028	-0.46045	-1.02689	0.255773	-0.62091	-0.43171	-0.36929	-0.5697	1.402539
Ghana	GHA	5.39069	-0.03231	0.256717	-0.07195	-0.08106	-0.11428	-0.01895	-0.16433	2.210005
Kenya	KEN	6.228357	-0.70681	-0.40414	-1.19455	-0.52851	-0.25103	-0.85219	-1.01045	2.06716
Lesotho	LSO	1.92472	-0.14688	-0.10831	0.04302	-0.29953	-0.47992	-0.0799	0.043368	2.036762
Liberia	LBR	0.976679	-1.17278	-0.60418	-1.38274	-1.42458	-1.37997	-1.27451	-0.97067	1.667688
Madagascar	MDG	4.005382	-0.44848	-0.28006	-0.16402	-0.74452	-0.50479	-0.53208	-0.46539	1.594221

Malawi	MWI	4.520296	-0.35261	-0.20994	-0.06919	-0.53327	-0.49951	-0.26395	-0.5398	1.662526
Mali	MLI	3.655342	-0.4222	0.03993	-0.23984	-0.83272	-0.42011	-0.39116	-0.68927	1.220031
Mauritania	MRT	1.930861	-0.56742	-0.8362	-0.25649	-0.54938	-0.47002	-0.71303	-0.57941	1.589824
Mauritius	MUS	3.790405	0.749581	0.879562	0.965336	0.672197	0.66345	0.95671	0.360229	2.395448
Mozambique	MOZ	3.494667	-0.38291	-0.17179	0.069617	-0.52182	-0.43413	-0.70026	-0.53907	1.161901
Namibia	NAM	3.606275	0.330316	0.39087	0.674327	0.160789	0.14902	0.21320	0.393687	2.092194
Niger	NER	3.350271	-0.64128	-0.48319	-0.56984	-0.79688	-0.60777	-0.60747	-0.78254	1.147668
Nigeria	NGA	7.43206	-1.12578	-0.754	-1.71861	-1.02699	-0.8927	-1.18812	-1.17425	1.633099
Rwanda	RWA	2.755321	-0.68168	-1.33888	-0.99761	-0.42858	-0.54874	-0.68335	-0.09291	1.508193
Senegal	SEN	5.039578	-0.18429	0.076099	-0.38081	-0.27051	-0.19377	-0.14564	-0.19114	1.398857
Sierra Leone	SLE	1.937011	-0.93303	-0.49856	-0.84635	-1.269	-1.04609	-1.05658	-0.88162	1.447756
South Africa	ZAF	8.536566	0.330437	0.675996	-0.18655	0.554749	0.47065	0.14678	0.320986	2.342954
Sudan	SDN	4.886726	-1.5656	-1.73068	-2.35859	-1.26173	-1.3652	-1.43474	-1.24265	1.467113
Swaziland	SWZ	2.88311	-0.58437	-1.35801	-0.17518	-0.66557	-0.46464	-0.57719	-0.26563	1.697869
Tanzania	TZA	5.3801	-0.44388	-0.32305	-0.40839	-0.5229	-0.41359	-0.36132	-0.63402	1.554498
Togo	TGO	3.313712	-0.85459	-1.03103	-0.36321	-1.24999	-0.74342	-0.85099	-0.88889	1.735146
Uganda	UGA	5.308445	-0.64169	-0.68399	-1.18079	-0.50251	-0.10947	-0.47792	-0.89547	1.863473
Zambia	ZMB	4.109119	-0.37523	-0.28665	0.227111	-0.77672	-0.45509	-0.41265	-0.5474	2.208529
Zimbabwe	ZWE	5.038958	-1.27833	-1.28128	-1.00652	-1.04894	-1.71193	-1.47532	-1.14601	2.276592

Determinants of the Current Account Deficit of Ethiopia: is it Structural or Cyclical?

Getaneh Mihret Ayele[1]

Abstract

This study examines whether and the extent to which structural and cyclical factors explain the Ethiopian current account imbalance over the period 1985-2017. The results of four filtering methods generally suggest that the structural factors explain most of the variations in the current account deficit in the long-run though the cyclical factors are found to have some contributions to further deterioration of the current account balance in the post-crisis period. The structural determinants of the current account are examined using cointegration techniques, and the results using Fully Modified OLS and Canonical Cointegration Regression (CCR) have revealed that the current account balance worsens the increase in the initial net foreign asset position, the relative income, the financial deepening, and the effective exchange rate depreciation. The vector error correction (VEC) based Granger causality tests have also revealed that trade openness and real effective exchange rate Granger causes current account balance, but current account balance Granger causes only trade openness and neither of the variables Granger causes initial net foreign asset, fiscal balance, and relative income in the system.

JEL Code: F32

Keywords: Ethiopia, External imbalance, structural, cyclical factors, and filtering methods

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1. Introduction

External imbalance remains a pronounced policy issue for Ethiopia despite its recent significant development in macroeconomic policies and its considerable record in economic performance. The country runs an average of the current account deficit of not less than five percent for decades. The deficit worsens many sectors, such as external sustainability with rising external debt accumulation, constant public deficits, real exchange rate overvaluation and foreign exchange crunch especially in the post-crisis period. Indeed, based on the balance of payment constraints theory (Thirlwall, 1979), the current account deficits may be vindicated if the deficit is consistently associated with the growing capital formation including an increased share of export-oriented manufacturing industries that could guarantee the future repayment of external liabilities. However, export diversification and industrialization remain a major challenge, and the country's export has remained concentrated in a few primary commodities whose prices are volatile and exposed to global price swings. According to the National Bank of Ethiopia annual report (NBE, 2020), a few primary commodities such as coffee, oilseeds, cut flowers and chat account about 75 percent of total value of exports in 2019.

The persistent current account deficit and continued fiscal deficits with the increased spending on basic public infrastructures and social needs are reflected in the accumulation of foreign liabilities. Recent deteriorations generally are reflected in heavy infrastructure investments under the country's public investment-led development strategy, alongside the weak domestic resource mobilization. The resulting saving gap is filled by external debt and aid. As a result, the debt position of the country has been deteriorated resulting increased risk of external debt distress. The debt sustainability assessment report (IMF, 2020) has shown that Ethiopia remains at high risk of external and overall debt distress. The public and publicly-guaranteed debt accounts 57 percent of GDP in 2019 that confirms the elevated debt servicing burden relative to exports. Such chronic external imbalances produce currency instability and continued currency overvaluation, volatile capital flows and arbitrary redistribution of resources, and considerably constrain full employment growth.

Accordingly, Ethiopia's government announced a 'Home-Grown Economic Reform (HGER)' agenda in September 2019, with a private sector focus, consisting of a wide-range of macroeconomic, structural and sectoral policies to correct external imbalances, control inflation, ensure debt sustainability, and address institutional and structural bottlenecks to private sector productivity. The agenda aims to improve the foreign exchange position and current account balance and reduce external debt vulnerability with increasing exports and strengthening production of import substituting industries.

This study, thus, examines the structural and cyclical sensitivity as well as determinants of the current account imbalance of Ethiopia using four filtering techniques and regression methods. The determining factors of the current account imbalance may vary across different economic activities due to their difference in macroeconomic, political, social and institutional arrangements. Thus, it is plausible to examine the country's specific determinants of current account deficit as it would have important policy implications under the HGER agenda to address the chronic current account deficit going forward.

The research questions would be important for Ethiopia for two main reasons. First, the persisting current account deficit has been reduced during the global financial crisis but has dramatically increased in the post financial crisis period that result in a question of whether cyclical or structural factors drive such an inverse imbalance. Second, the steadily growing external debt and net inflow of FDI to finance current account deficit can raise the issue of sustainability in the external sector.

The rest of the paper is organized as follows. The second section offers empirical literature reviews about the structural and cyclical determinants of external imbalance. The econometric model and data used will be delt with under section three. Section four presents empirical results using different filtering techniques and regression methods. The last section presents conclusions and recommendations derived from the study.

2. Literature Reviews

The determinants of the current account balance have been intensively discussed in both theoretical and empirical literature using the intertemporal approach (Obstfeld & Rogoff, 1995) that views the current account balance as the difference between domestic saving and investment. However, the existing empirical studies have overlooked the least developed economies and the findings remain inconclusive regardless of the economy studied and methodological approach used. The literature offers mixed results for the structural and cyclical factors behind current account imbalance in both developed and developing countries.

The empirical works have examined the structural and cyclical determinants of external imbalance since the overture of intertemporal approach to the current account include (Chinn & Prasad, 2003), (Cheung, Furceri, & Rusticelli, 2010), (Osakwe & Verick, 2009),(Yang, 2011), (Barnes, Lawson, & Radziwill, 2010), (Sadiku, Fetahi-Vehapi, Sadiku, & Berisha, 2015), (Oshota & Badejo, 2015), (Kandil & Greene, 2015), (Bardakas, 2016), (Das, 2016),(Chuku, Atan, Obioesio, & Onye, 2017) and (Kovacevic, 2018). The empirical evidences generally suggest that structural factors are more significant than cyclical factors to explain the current account variation particularly in the pre-crisis period. (Bardakas, 2016) and (Kovacevic, 2018), using different filtering methods on annual data of Greece and Serbia, respectively, shows that the current account variations are largely explained by structural components of current account though the contributions of cyclical factors cannot be ignored in the post-crisis period.

Many studies (Chinn & Prasad, 2003; Cheung, Furceri, & Rusticelli, 2010; Das, 2016) have confirmed that structural factors such as initial net foreign assets, level of economic development, financial deepening and trade openness significantly affects external imbalances of developed and developing countries. Using a large panel of industrial and developing economies, (Chinn & Prasad, 2003) have examined the structural determinants and the results has revealed that increase government budget balance, initial stocks of net foreign asset and financial development improves current account balance for both developing and developed countries. Current account balance of developing countries including Africa also improves for increase in relative income but worsens for trade openness. (Cheung, Furceri, & Rusticelli, 2010) also examined the structural and cyclical determinants using a panel of 94 countries, and the findings show that the medium-term global imbalance is positively affected by net foreign assets, level of economic development and oil intensity, and negatively related with fiscal deficits, financial development, youth dependency ratio and regulatory quality. Cyclical factors including output growth, oil prices and real exchange rate changes are also found important to explain the narrowing external imbalance in the post-crisis period. Besides, using a dynamic panel GMM model on a large panel of developed, emerging and developing countries, (Das, 2016) suggested quite different results for developed and emerging economies. The current account balance is positively affected by net foreign assets and trade openness while negatively affected by commodity prices, real GDP growth and increase in real effective exchange rate for developed economies. For emerging economies, the balance is positively related with commodity price, real GDP growth and trade openness while it is negatively related with net foreign assets.

A region or country specific studies (Kandil & Greene, 2015; Barnes, Lawson, & Radziwill, 2010; Sadiku, Fetahi-Vehapi, Sadiku, & Berisha, 2015; Yang, 2011; Osakwe & Verick, 2009; Oshota & Badejo, 2015) also provide the structural and cyclical determinants of external imbalances with mixed results. In industrialized countries, (Kandil & Greene, 2015) have examined cyclical determinants using U.S balance of payments data, and the results have revealed that the current account balance worsens real GDP, real effective exchange rate and energy prices level. Using a panel of OECD countries, (Barnes, Lawson, & Radziwill, 2010) have shown that current account balance is positively related with demographic variables, level of economic development (real GDP per capita), initial net foreign assets, trade openness and real interest rates, while negatively related with oil prices and housing investments. (Sadiku, Fetahi-Vehapi, Sadiku, & Berisha, 2015), using ARDL approach on quarterly data, also suggested that financial development, fiscal deficit and terms of trade have a positive impact while trade openness has a negative impact on the current account balance of FYROM.

For developing countries, Yang has investigated the long-run and short run determinants of the current account, and the results of his study has revealed that initial stock of net foreign assets and trade openness explains the long-run behavior of current account balance in emerging Asian economies except China (Yang, 2011). In Africa, Osakwe & Verick have examined the determinants and sustainability of the current account deficits of Sub-Saharan African countries that have above five percent deficit with sluggish economic growth and investment (Osakwe & Verick, 2009). The results have revealed that an increase in resource exports as a ratio of merchandise exports leads to the probability of higher deficit while an increase in real GDP growth, trade openness and democratic regime may reduce the probability of deficit. Oshota & Badejo also have examined current account imbalance of West African countries (Oshota & Badejo, 2015).The findings show that level of economic development (GDP per capital), financial deepening and dependency ratio have a positive impact while real effective exchange rate appreciation has a negative effect on the long-run balance of the current account. But, in the same region (West Africa), the empirical results of the studies by Chuku, Atan, Obioesio, & Onye have shown that depreciation of real exchange rate and increasing national income worsens the current account balance in the long run (Chuku, Atan, Obioesio, & Onye, 2017).

The issue of external imbalance, thus, has no a unanimous answer yet due to a structural heterogeneity of countries studied. The existing empirical literature relatively overlooked the least developed nations including Ethiopia, and it is plausible to examine the main determinants of current account balance. This study addresses whether and the extent to which structural and cyclical factors have driven the incessantly widening current account imbalance of Ethiopia, which would be crucial to scrutinize the current account imbalance going forward and the likely policy change for potential adjustment in the external balances.

3. Empirical Model and Data

3.1 Detrending and Filtering Techniques

To examine the relative importance of structural and cyclical determinants of the current account balance of Ethiopia, four filtering methods, including Hodrick-Prescott (HP), Baxter-King (BK), Christiano-Fitzerald fixed-length symmetric (CF Symmetric) and Christiano-Fitzerald full-length asymmetric (CF Asymmetric), are used to isolate cyclical components from long-term trend of current account balance.

First, the HP (Hodrick & Prescott, 1997) is the most commonly used filtering technique in time series data to separate cyclical components from its long term trend. It is a two-sided linear filter that computes the trend component that minimizes the variance of the actual series y around trend growth g. The y series can be given as:

$$y_t = g_t + c_t, for\ t = 1, \dots, T \qquad \textbf{(1)}$$

Where, g_t is the trend component and c_t is the cyclical component (i.e. $c_t = y_t - g_t$). Then, g_t can be minimized as:

$$\sum_{t=1}^{T} C_t^2 + \lambda \sum_{t=1}^{T} [(g_t - g_{t-1}) - (g_{t-1} - g_{t-2})]^2 \qquad \textbf{(2)}$$

The solution is a linear transformation that removes the trend component, and the remaining is a detrended cycle series. The average values of the sum of squared deviations of y_t from the trend (i.e. c_t) over long periods is close to zero.

A smoother trend is generated through a larger value of λ, and the trend component corresponds to a linear time trend as λ approaches to infinity. A smoothing parameter λ controls the volatility of the cyclical component of the actual series and penalizes changes in trend growth. Hence, the filtering results are very sensitive to the value of λ because it is set arbitrarily as a rule of thumb. In fact, HP suggest λ value of 100 for annual data and 1600 for quarterly data.

Second, the BK (Baxter & King, 1999) is a linear filter to isolate the cyclical component of time series using a two-sided weighted moving average based on an assumed business cycle lasting between 1.5 to 8 years for annual data. It removes all frequencies that are not associated with the business cycle. When a finite symmetric average is applied to a time series y_t with annual frequency, the new series can be obtained as:

$$y_t^* = \sum_{k=-K}^{K} \alpha_k y_{t-k} \qquad \textbf{(3)}$$

Where, α_k is fixed weights and K is the maximum lag length.

The moving average may be represented as a polynomial in the lag operator L as,

$$\alpha(L) = \sum_{k=-K}^{K} \alpha_k L^K \qquad \textbf{(4)}$$

Where, L is defined so that $L^k x_t = x_{t-k}$ for positive and negative values of K. To extract the stationary series of a cyclical component, the symmetric moving average has a sum of weights equal to zero, $\sum_{k=-K}^{K} \alpha_k = 0$, and this is a 'trend elimination property'. As the BK filter is symmetric, it is time invariant that makes the series stationary. But, filtering through moving average in the time domain using the same number of leads and lags results the loss of $2K$ data values (Baxter & King, 1999).

Third, the CF filter (Christiano & Fitzgerald, 2003) has two models: fixed-length symmetric and fixed-length asymmetric. Fixed-length symmetric has the same characteristics as the BK filter, while full length asymmetric is the most general type of band pass filter and it is time varying with the weights change for each observation. Unlike the CF Symmetric and BK filter, CF Asymmetric filter does not use the same number of lags and leads so that the filtered series does not lose observations from the actual series. To isolate the component of x_t with a period of fluctuation between p_l and p_u (where, $2 \leq p_l < p_u < \infty$), the recommended approximation of y_t, $\hat{y}_t$, is given as follows.

$$\hat{y}_t = B_0 x_t + B_1 x_{t+1} + \cdots + B_{T-1-t} x_{T-1} + \tilde{B}_{T-t} x_T + B_1 x_{t-1} + \cdots + B_{t-2} x_2 + \tilde{B}_{t-t} x_1 \quad \textbf{(5)}$$

for $t = 3,4, \ldots, T-2$.

Where, $B_j = \frac{\sin(jb) - \sin(ja)}{\pi j}, j \geq 1$

$$B_0 = \frac{b-a}{\pi}, a = \frac{2\pi}{p_u}, b = \frac{2\pi}{p_l}$$

$$\tilde{B}_{T-t} = -\frac{1}{2} B_0 - \sum_{j=1}^{T-t-1} B_j$$

p_l and p_u are the cut-offs with a business cycle assumed to last between 1.5 and 8 years. The cyclical component p_l is a cycle that is longer than p_l and shorter than p_u. Although both the BK and CF filters approximate the ideal infinite band pass filter, the CF filter outperforms the BK filter as it works well on larger classes of time series and converges to the optimal filter in the long-run (Christiano & Fitzgerald, 2003). As the approximation error for the weights diminishes with increasing sample size, the CF is consistent compared to the BK and it converges to an ideal band pass filter (Haug & Dewald, 2004).

3.2 Empirical Model

To empirically examine structural determinants of the current accounts, Chinn and Prasad (2003) approach is used that regressed the current account balance on a set of macroeconomic variables, which is stated as:

$$CA_t = \alpha + \beta X_t + \theta F_t + \gamma P_t + \varepsilon_t \quad \textbf{(6)}$$

Where, CA is the current-account balance, and X, $F$and P are a vector of macroeconomic, financial development, and institutional variables, respectively, and ε_t is the error term.

Thus, the general empirical model estimated is stated as:

$$CA_t = \alpha + \beta_1 NFA_t + \beta_2 FBAL_t + \beta_3 RGDCAP_t + \beta_4 BMON_t + \beta_5 TOPEN_t + \beta_6 lnREER_t + \beta_7 BURQUA_t + \varepsilon_t \quad \textbf{(7)}$$

Where, CA is current account balance to GDP ratio, NFA is initial net foreign asset to GDP ratio, $FBAL$ is fiscal balance to GDP ratio, $RGDCAP$ is real GDP per capita, $BMON$ is broad money to GDP ratio, $TOPEN$ is trade openness, $lnREER$ is log of real effective exchange rate, $BURQUA$ is bureaucratic quality, and ε_t is white noise error term.

The current account balance, the dependent variable is proxied as the sum of net exports of goods and services, net income, and net current transfers as a ratio of GDP. The study has used fundamental macroeconomic regressors. The first independent variable is net foreign asset position proxied as the initial (lagged) stock level as a ratio of GDP to avoid potential endogeneity problem since the stock of NFA is determined by the sum past current account balances. A Country's NFA can positively affect the current account balance either directly through a change on net investment income or indirectly due to persistence of balances that led to the earlier accumulation of assets. Indeed, under floating exchange rate regime, the sum of the current account and capital account must be equal to zero that leads to a negative link between NFA and current account balance. But the positive effect is empirically expected to outweigh (Cheung, Furceri, & Rusticelli, 2010). A fiscal balance, which is the second regressor, is proxied as fiscal deficit to GDP ratio. The Keynesian cross states that a higher fiscal deficit, due to high government spending especially in developing countries, may increase disposable income and consumption and decrease the private saving so that the current account balance gets worsened (Brissimis, Hondroyiannis, Papazoglou, Tsaveas, & Vasardani, 2010).

The third variable is level of economic development is proxied as relative (to the USA) real income per capita. Under standard neo-classical theory, countries with lower capital-labour ratio will have external financing requirement and import capital from developed economies that result a current account deficit for years until the country reaches a higher level of development through the economic catching-up process. But, the 'Lucas Paradox' (Lucas, 1990) has stated that cross-border capital would flow uphill because of domestic distortions such as undeveloped financial markets and weak institutions in poor countries. Thus, the level of economic development have unclear coefficient.

The fourth variable is financial deepening, which is proxied as broad money (M2) as ratio of GDP. The developed financial market traditionally viewed to encourage saving and improve current account balance due to lower transaction costs and better risk management. However, financial deepening may lower saving rate in emerging economies because they commonly export their excess capital to countries with more sophisticated financial markets (Ju & Wei, 2016). This implies that there is a negative link between financial deepening and the current-account balances.

The other important variables include trade openness, real effective exchange rate and institutional quality. Trade openness, which is measured as total exports and imports as a share of GDP, may reflect liberalized international trade, accessibility of foreign technology, and ability to service external debt through export earnings. It is likely to be associated negatively with the current account balance (Yang, 2011). Real currency depreciation, under intertemporal approach, reduces purchasing power on imports, then tends to lower consumption and increase propensity to save, which improves current account balance. But, under the consumption smoothing hypothesis, current account acts as a buffer to smooth consumption during shocks to national cash flow. Real exchange rate appreciation may lead an economy to run current account surplus rather than allowing consumption to increase (Herrmann & Jochem, 2005), and real effective exchange rate have unclear coefficient. Indeed, currency devaluation may not have significant effect on current account balance of East African nations including Ethiopia (Ayele, 2019). Moreover, weak institutions may lower the risk adjusted return to capital in developing economies encouraging uphill capital flow that result worsens the current account balance (Alfaro, K-Ozcan, & Volosovych, 2005). Bureaucratic quality is used as a proxy of institutional quality, and is expected to have a positive link with the current account balance.

3.3 Data and Testing Tools

To examine the structural and cyclical determinants of the current account imbalance, annual data over a period 1985 – 2017 is used. The study period is selected based on data availability for all variables in the empirical model including institutional factors. The data is retrieved from the databases of World Development Indicators, World Economic Outlook, BRUEGEL, and International Country Risk Guide. The descriptive statistics and correlation results for the variables used for regression analysis are presented in Tables 1 and 2, respectively. The relative income and trade openness and bureaucratic quality have a relatively strong negative correlation while only real effective exchange rate have positive but insignificant correlation with current account balance.

Table 1: Descriptive Summary Statistics

	CAB	NFA	FBAL	RGDPCAP	BMON	TOPEN	LNREER	BURQUA
Mean	-4.05	6.43	-3.76	0.60	30.31	35.10	4.85	2.10
Median	-3.30	5.32	-3.57	0.55	29.14	36.71	4.75	2.50
Maximum	1.81	17.91	-0.93	1.03	41.46	57.14	5.66	3.75
Minimum	-12.64	-0.36	-8.88	0.42	20.16	8.95	4.40	0.00
Std. Dev.	4.11	5.04	1.89	0.17	5.58	13.96	0.36	1.52

Table 2: Correlation Results

	CAB	NFA	FBAL	RGDPCAP	BMON	TOPEN	LNREER	BURQUA
CAB	1.00							
NFA	-0.08	1.00						
FBAL	-0.36	-0.05	1.00					
RGDPCAP	-0.50	-0.48	0.54	1.00				
BMON	-0.17	0.82	-0.34	-0.45	1.00			
TOPEN	-0.61	0.63	0.39	0.16	0.45	1.00		
LNREER	0.20	-0.86	-0.04	0.32	-0.74	-0.72	1.00	
BURQUA	-0.61	0.37	0.46	0.46	0.28	0.83	-0.59	1.00

Moreover, to provide non-spurious regression results, a stationarity test is critical for time series data. Unit root tests are conducted using Augmented Dickey-Fuller (ADF), Phillips and Perron (PP), Kwiatkowski, and Phillips, Schmidt, and Shin (KPSS) tests. The unit root results are presented in Table 3, and it is suggested that all data series have unit root at level, stationary at first difference, and neither of the variables are integrated order two, I(2).

Table 3: Unit Root Tests using Augmented Dickey Fuller, PP and KPSS tests

	Unit root	Variables							
		CAB	***NFA***	***FBAL***	***RGDPCAP***	***BMON***	***lnREER***	***TOPEN***	***BURQUA***
ADF	Level	-2.47	-1.92	-2.89*	0.82	-2.03	-2.40	-1.40	-1.29
	1st Diff.	-5.38***	-4.22***	-5.84***	-2.85*	-5.16***	-4.21***	-5.27***	-3.57**
PP	Level	-2.44	-1.73	-2.84*	1.18	-2.10	-2.35	-1.41	-0.99
	1st Diff.	-7.43***	-4.05***	-8.06***	-2.95*	-5.20***	-4.21***	-5.27***	-3.29**
KPSS	Level	-5.66***	7.32***	-11.45***	20.36***	31.22***	78.46***	14.44***	7.93***
	1st Diff.	-0.46	0.09	0.13	2.10**	0.76	-0.85	0.49	1.93*

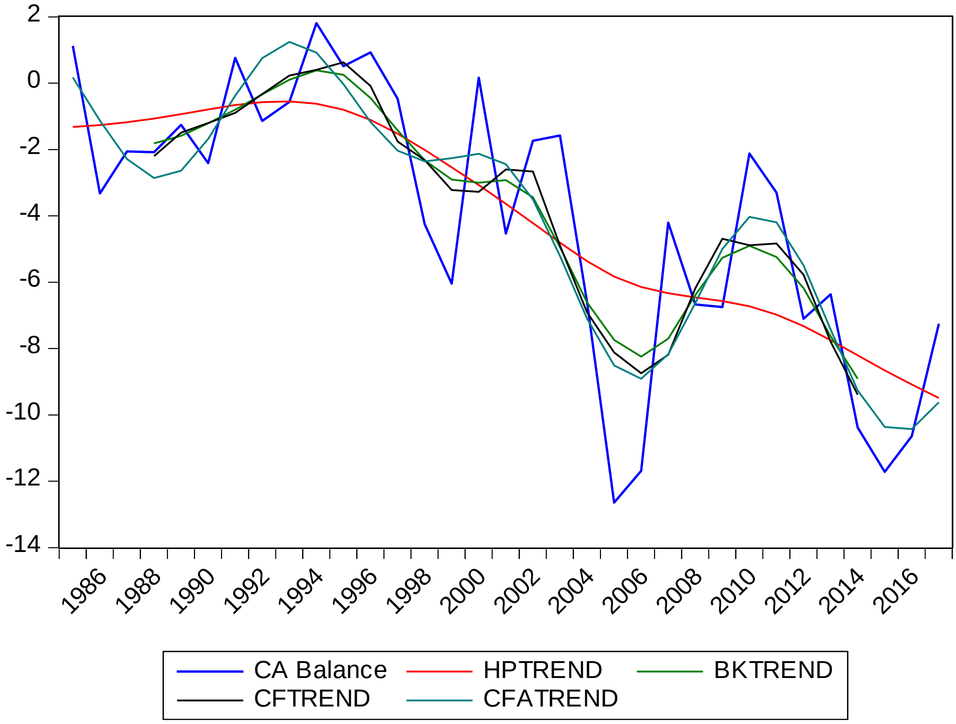
***, **, * are 1%, 5%, and 10% unit root rejection levels, respectively. SIC used for Max-lag selection.

4. Empirical Results

4.1 Structural and Cyclical Estimates of Current Account Balance

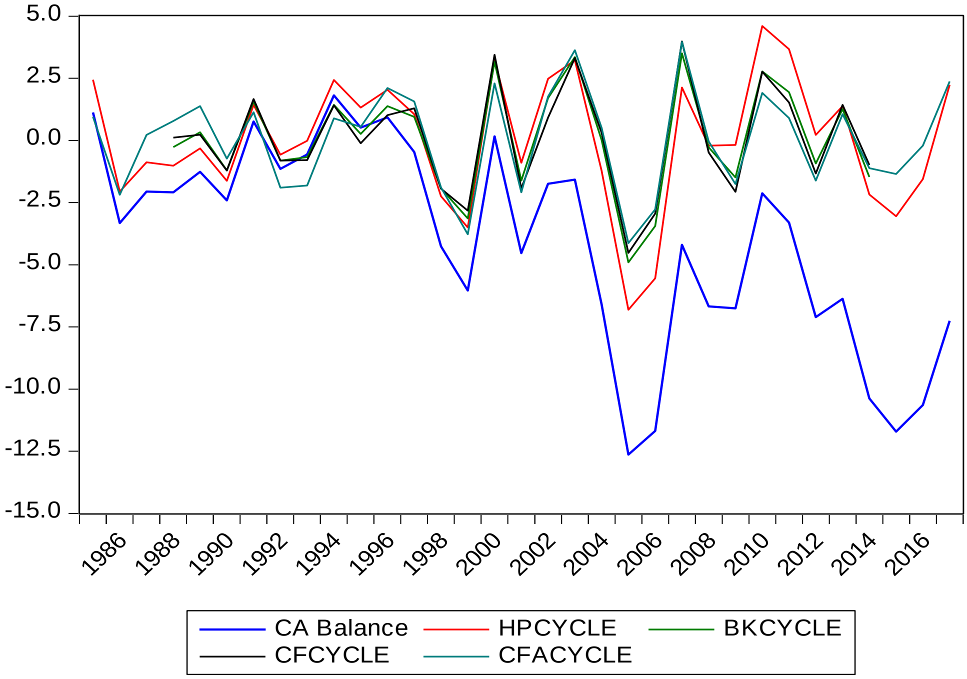
The filtering results using four methods for both structural and cyclical estimates of the current account balance are presented in Figures 1 and 2 with the actual current account value. The results have indicated that structural components have incessantly been worsened along with the path of the actual current account balance over the full sample period.

Figure 1: The Current Account Balance (%GDP) and its Structural Components



Note: CA Balance is current account balance, HPTREND is the Hodrick-Prescott filter, BKTREND is Baxter-King filter, CFTREND is Christiano-Fitzerald fixed-length symmetric filter, and CFATREND is Christiano-Fitzerald full-length asymmetric filter.

Figure 2: The Current Account Balance (%GDP) and its Cyclical Components



Note: CA Balance is current account balance, HPCYCLE is the Hodrick-Prescott filter, BKCYCLE is Baxter-King filter, CFCYCLE is Christiano-Fitzerald fixed-length symmetric filter, and CFACYCLE is Christiano-Fitzerald full-length asymmetric filter.

The mean value of the current account balance and its filtering components are presented in Table 4 for both the full sample and post-crisis period (2010 – 2017). The results show that the mean value of structural components (-3.90) is close to the mean value of actual current account balance (-4.05) for the full sample, while the structural deficit was 0.43 percentage points higher than the actual current account deficit for the post-crisis period. During the post-crisis period, both the mean value of actual current account deficit and its structural estimates have been worsened with 3.31 and 3.89 percentage points respectively, which indicate that the current account deficit is largely affected by structural components for both the full sample and post-crisis period. The persisting and recent widening of the current account deficit has a long-term or structural nature. Regarding the cyclical components, the mean values show a surplus of 0.03 and a deficit of 0.34 for the full sample and post-crisis period, respectively, indicating that cyclical factors may have some contributions to the further deterioration of current account balance in recent years.

Table 4: Average Value for Actual Current Account Balance and its Components

Sample Period	**1985 – 2017**		**2010 – 2017**	
Current Account Balance (% of GDP)	-4.05		-7.36	
Filters	***Structural***	***Cyclical***	***Structural***	***Cyclical***
Hodrick-Prescott	-4.05	0.00	-7.36	0.00
Baxter-King	-3.75	0.06	-8.15	-0.75
Christiano-Fitzerald Full Length Asymmetric	-4.07	0.02	-7.48	0.12
Christiano-Fitzerald Fixed Length symmetric	-3.75	0.05	-8.16	-0.73
Average*	-3.90	0.03	-7.79	-0.34

** Average values of four filtering results (components) for the sample period indicated. The smoothing parameter λ for Hodrick-Prescott filter is set to 100. For other frequency filters, the frequency length (lead/lags), low and high values cycle period are 3, 2 and 8 respectively. The current account series is also specified as a unit root process and a detrending adjustment is applied for both Christiano-Fitzerald filters.*

Moreover, the correlation results are presented in Table 5 to examine the relative importance of components of current account balance. The structural estimates track the actual current account with an average coefficient of 0.81, while the cyclical estimates follow the actual series with an average coefficient of 0.65. This indicates that the structural component is relatively more important than cyclical component for the full sample period. The average correlation coefficients has increased to 0.84 and 0.80 for structural and cyclical components, respectively, during the post-crisis period over which both cyclical and structural factors are almost equally important to interpret the further deterioration of current account balance.

Table 5: Correlation Coefficients between Actual Current Account and its Components

Sample period	1985-2017		2010-2017	
Filters	***Structural***	***Cyclical***	***Structural***	***Cyclical***
Hodrick-Prescott	0.72	0.71	0.89	0.90
Baxter-King	0.84	0.66	0.82	0.75
Christiano-Fitzerald Full Length Asymmetric	0.84	0.59	0.82	0.82
Christiano-Fitzerald Fixed Length symmetric	0.84	0.62	0.83	0.75
Average	0.81	0.65	0.84	0.80

Source: Eviews Results

Thus, the filtering estimation results generally suggest that structural components are the main determinants of the chronic current account deficit than cyclical components in Ethiopia. The trend of current account deficit is largely explained by the structural factors in the long-run.

4.2 Cointegration Estimation Results

Variables with unit root process generally offer spurious regression results, unless they are cointegrated and produce stationary residuals. The cointegration results using Engle-Granger (EG) and Johansen Cointegration estimation techniques are presented in Table 6 below and they can indicate all variables in equation (7) are cointegrated and have long-run association.

Table 6: Cointegration Test results

		t-Statistic	Prob.
Engle-Granger (EG) Test:			
ADF	At level	-5.0488	0.0003
PP	At level	-6.7232	0.0000
Johansen Cointegration Test:			
Trace test	None	326.8474	0.0000
	At most 1	239.4007	0.0000
Max-Eigen test	None	87.4466	0.0000
	At most 1	83.4691	0.0000

Source: Eviews Results

4.3 Long-run Estimation and VEC Granger Causality

As the long-run association among variables is prevailed with cointegration tests, the long-run relationship is estimated using Fully Modified OLS (FMOLS) and Canonical Cointegration Regression (CCR) estimators which are followed by the vector error correction based on short-run Granger causality tests. FMOLS and CCR generally offer a check for the robustness of long-run associations and provide reliable estimates under small sample sizes. FMOLS is appropriate for a long-run estimation as it modifies least squares to explain serial correlation effects and endogeneity in the regressors that arise from the existence of long-run relationship (Phillips & Hansen, 1990) while the CCR removes the second-order bias of least square estimator by transforming variables in the cointegrating regression(Park, 1992). Indeed, the CCR estimator, which is similar to FMOLS, performs much better than OLS estimator (Montalvo, 1995).

The long-run estimation results are presented in Table 7, and both the FMOLS and CCR offers relatively similar results. The findings generally suggest that the current account balance is negatively associated with initial net foreign asset position, real effective exchange rate depreciation, relative income (real GDP per capita) and level of financial development. The results have also proved those findings, though statistically insignificant. The current account balance is positively related with fiscal deficit while negatively associated with trade openness and bureaucratic quality. Moreover, the coefficient with relative income and real effective exchange rate are higher than other variables suggesting relative income (level of economic development) and exchange rate as a strong indicator of the behavior of the current account imbalances in the long-run.

The negative coefficient of NFA, which is supported by (Das, 2016), is robust for developing countries. Persistent larger net foreign assets may reduce imports through wealth erosion, and the negative link may hold for highly indebted countries due to more deep concerns about sustainability (Phillips, et al., 2013). Similarly, the negative effect of real exchange rate and relative income are supported by (Chuku, Atan, Obioesio, & Onye, 2017). The results of the exchange rate depreciation may be due to the country’s poorly diversified and inelastic exports, high trade costs with poor trade logistics and infrastructure, incessantly rising external debt service burden, high demand for imported capital goods for public investment in infrastructures, and a large dependence on non-substitutable consumption imports. Indeed, the annual report of NBE (2020) has shown that few primary commodities (coffee, oilseeds, chat and cut flowers) account about 75 percent of the country's export in 2019. Similarly, the imports of capital and consumer goods account for about 30 percent and 29 percent of total value of imports, respectively. According to the World Bank data, Ethiopia has poor trade logistics and it is ranked 126th in the world with an overall logistics performance index (LPI) score of 2.38 out of 5 points in 2016, which is even dropped from a LPI of 2.41 in 2010.

Table 7: Long-run Estimation Results

Dependent Variable: CAB

Sample (adjusted): 1986: 2017

Cointegrating equation deterministic: C

Method	**FMOLS**			**CCR**		
Variable	**Coefficient**	**Std. Error**	**Prob.**	**Coefficient**	**Std. Error**	**Prob.**
NFA	-0.5065	0.1178	0.0003	-0.4486	0.1441	0.0049
FBAL	0.0727	0.1879	0.7023	0.0434	0.2799	0.8781
RGDPCAP	-12.8764	3.4184	0.0010	-12.2801	4.9376	0.0206
BMON	-0.1689	0.0828	0.0530	-0.1910	0.1101	0.0962
TOPEN	-0.0897	0.0467	0.0674	-0.0718	0.0631	0.2669
LNREER	-7.0443	2.0849	0.0026	-6.5006	3.2269	0.0558
BURQUA	-0.2722	0.4496	0.5508	-0.2105	0.5129	0.6853
C	50.2335	10.5252	0.0001	46.6260	15.5762	0.0065
Adjusted R^2	0.5711			0.5577		
S.E. of regression	2.7042			2.7460		
Long-run variance	1.8511			1.8511		

Long-run covariance estimate (Pre-whitening with lag=1, Bartlett kernel, Newey-West fixed bandwidth = 4.0)

As all non-stationary variables are cointegrated, the dynamic causal interactions can be expressed in a vector error correction (VEC) form to show the short-run Granger causality among the variables. The short-run Granger causality tests are useful in determining potential predictability among variables, and can indicate whether lagged values of one variable conditionally help to predict the current value of another variable in the empirical model. As shown in Table 8, both trade openness and real effective exchange rate Granger causes (predicts) the current account balance, but current account balance Granger causes only openness to trade. Trade openness also Granger causes level of financial development. All variables except initial net foreign asset and level of financial development Granger can cause trade openness, but neither of the variables Granger can cause initial net foreign asset, fiscal balance and relative income in the system.

Table 8: VEC Granger Causality Results

Dep. Var.	Independent Variables							ECT_{t-1} Coeff (t-ratio)
	ΔCAB	ΔNFA	$\Delta FBAL$	$\Delta RGDPC$	$\Delta BMON$	$\Delta TOPEN$	$\Delta lnREER$	
ΔCAB	-	0.013 (0.910)	0.540 (0.463)	0.001 (0.980)	1.111 (0.292)	3.864 (0.049)	5.454 (0.019)	-0.425 [-1.910]
ΔNFA	0.001 (0.982)	-	2.142 (0.143)	1.238 (0.266)	0.709 (0.399)	0.696 (0.404)	0.214 (0.644)	0.309 [2.585]
$FBAL$	1.850 (0.174)	0.105 (0.746)	-	0.093 (0.760)	0.881 (0.348)	0.044 (0.834)	1.188 (0.276)	0.094 [0.692]
$\Delta RGDPC$	0.952 (0.329)	0.013 (0.909)	0.008 (0.930)	-	0.889 (0.346)	1.696 (0.193)	0.041 (0.839)	-0.002 [-1.179]
$\Delta BMON$	3.823 (0.051)	0.217 (0.641)	0.253 (0.615)	0.043 (0.836)	-	6.168 (0.013)	0.161 (0.689)	0.407 [2.306]
$\Delta TOPEN$	4.724 (0.030)	0.154 (0.694)	8.107 (0.004)	10.211 (0.001)	0.061 (0.805)	-	9.867 (0.002)	-0.201 [-0.695]
$\Delta lnREER$	0.015 (0.903)	0.048 (0.826)	1.949 (0.163)	5.437 (0.020)	0.296 (0.586)	1.224 (0.269)	-	0.003 [0.312]

NB: The figures in the parenthesis (…) and square brackets […] indicate p-values and t-statistics, respectively.

5. Conclusions

External imbalance with continued fiscal deficit, rising external debt accumulation, real exchange rate overvaluation, and shortage of foreign exchange remains a great policy concern for Ethiopia. The study has examined whether and the extent to which structural and cyclical factors behind the current account imbalance in Ethiopia. The results using various filtering methods generally suggest that structural components of current account balance explain most of the variations in current account deficit in the long-run though cyclical factors may have some contribution to the further deterioration of current account balance in the post-crisis period. The correlation among the current account balance and its components during the post-crisis period indicates that both cyclical and structural factors are almost equally important to interpret the further deterioration of the current account balance. The regression results using FMOLS and CCR have indicated that current account balance worsens with an increase in initial net foreign asset position, relative income, financial deepening and real effective exchange rate depreciation. The results have also shown that both trade openness and real effective exchange rate Granger causes the current account balance, but the current account balance Granger causes only openness to trade and neither of the variables Granger causes initial net foreign asset, fiscal balance and relative income in the system.

Thus, the main implication of the findings is that emphasis should be given for structural factors for any improvement in current account balance. To correct the continuous current account deficit and make it sustainable, policy measures should focus on structural changes. The change must focus on diversification of exports towards value-added products, comprehensive support and incentives for export sectors including small and medium-sized firms, promotion of innovation and technology in manufacturing sector, and enhancing government effectiveness with better institutions.

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The Importance of Human Capital Resources for Sustainable Economic Growth in East African

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Abstract

This study examines the important contributions of human capital resources for sustainable economic growth in East African over the period 1980–2018. Even if there is a rapid growth in the number of schools and students' enrolment in the education system in East Africa, the reality on the ground shows that the lowest level of human capital development raises the issues of employment challenges. In this regard, the estimation results reveal that the growth rates of human capital resources (HCR) and the physical capital stock (PCS) have long-run effects on the growth rate of gross national income (GNI). In addition, the short–term transmission mechanism of the vector autoregressive (VAR) system also indicates that HCR growth hugely contributes to the development of PCS through GNI.

Keywords: Economic Growth, Dynamic Panel, Human Capital Resource, and Wavelet Analyses
JEL Classification: J00, J24

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Disclaimer: The views expressed and arguments employed in this research study are exclusively the responsibility of the author and do not necessarily reflect the institution to which he is affiliated

1. Introduction

The underlying concept of human capital is traced back to Adam Smith, though the term was first used as applications by Pigou (1928), and followed by Becker (1964) and Mincer (1974). According to Becker, investment in human capital could be analogous to investment in physical capital. By investing in education, a potential employee is able to achieve a higher level of productivity that can be reflected in a higher wage or salary pay. However, early criticisms of human capital theory pointed out that the probability of earning differentials would result in various factors such as innate ability, motivation, social class and gender (Merrett, 1966). The crucial underlying assumption of labour market works in such a way that higher productivity reflects higher wage and that the effect of education on human productivity can be separated from other factors.

Human capital endowment, skills and capacities of the people in the productive sectors can be important determinants of long-term economic development. For an individual, or a community, investing in human capital is more crucial than any economic resources (World Economic Forum, 2013). Human capital is an essential element to the economic growth since better educated people are more likely to innovate, adopt new technology and enhance productivity (Lucas, 1993; Romer, 1993 and Fishlow, 1966). Moreover, advancement in technology and more income generation and accumulation of wealth can be created in countries where high levels of human capital resources are available than those that do not have (UNHD, 2014). In addition, good governance, institutional reform and improvement in the educational system can play a more important role in raising economic output and efficiency of a country (Gylfason and Hochreiter, 2008).

According to the studies by UNDP (1997, 2013) and World Economic Forum (2013), a sustained improvement in Sub–Saharan Africa human development is found to be very low. This problem is common to East African countries as they are part of the Sub-Saharan Africa, facing similar economic, social and environmental challenges in the development process. The potential challenges include inequality and equity concerns, high rates of poverty, unemployment and inflation rates (United Nations, 2013). Even though the low level of human development in East Africa, there has been a rapid growth of some aspects of human capital, particularly the expansion of education in terms of the number of schools and students' enrollments. However, the growth of the human capital stock itself has not been matched with a commensurate rise in physical capital due to the low level of income growth and the low returns to the education investment as the study shown by Simon and Francis (1998).

Most scholars argue that considering only the physical capital is impossible for the poor countries to sustainable growth. Poor countries must concentrate first on technological progress generated and easily adopted by human capital. Second, they gradually need to accumulate physical capital as the economy depends more on technological progress than the physical capital. In this sense, this study seeks to examine the importance of human capital resources for sustainable economic growth in East Africa.

Thoroughly studying several related empirical literature, an attempt has been made to develop a unique approach to the economic analysis. This study begins with a transformed original data into demeaned dataset (the difference between the individual and the common average in the series of date), to make sure the non–violating classical econometric assumptions of no autocorrelation and cross–sectional independence among panel countries. In fact, it has been checked by these and others issues with the help of their respective standard methods of tests. Calculating some indices is used as explanatory variables along with human capital resources (HCR), taking GDP growth rate as a dependent variable over–time. The human capital resources are sought by applying geometric mean associated with index composite of life expectancy, education, income and school enrolment mean indices. The physical capital stock is calculated using an inventory method.

It is also intended to make a methodological contribution to the economic analysis by designing a new approach called *panel time scaling wavelet*. The panel time scaling wavelet analysis enables us to separate a long timeseries into different layers. It is applicable to make the bivariate analyses by extending the traditional standard methods of the panel multivariate VAR transmission channel method to ensure the dynamic intertemporal causal effects and estimation coefficients of the main determinants and the real GDP growth rate in the short, medium and long term. These kinds of methodological analyses are new in the academic arena as they have never been used in macroeconomic panel data. Thus, it is possible to say that a new insight has been added as a significant contribution to the development of existing knowledge on the economic analysis, by identifying a gap in the statement of the problem that ultimately makes this study a different one.

Understanding and addressing the challenges related to human capital is thus a fundamental to overcome the problems of short-term stability and the long-term growth, providing prosperity and competitiveness of the nations in the region. In this regard, the purpose of this study is to analyze empirically the main determinants of economic growth while the general objective is to examine the importance of HCR to the economic growth in the short, medium and long run. Thus, this kind of study conducted in this area is of the most significant one in order to provide tangible information for the policymakers to take some actions and to serve as a foundation for motivating other researchers to conduct further studies on related areas.

Following is section two that describes the reviewed related literature. The subsequent sections are intended to deal with the methodological issues and empirical findings and discussions. Finally, the main findings of the study are presented with a conclusion Provided.

2. Review of the Related Literature

In this section, an attempt has been made to carefully review the related empirical literature to human capital resources and physical capital stocks development and their relationship with economic growth from different studies. Among others, the studies by Kanu and Ozurumba (2014), Rakotoarisoa, Shapouri and Trueblood (2014), Orla et al., (2013), and Ndambiri et al., (2012) are examined. Furthermore, empirical studies of Richard and Blessing (2010), Daniel and Marc (2004), Paula, John and Goddard (2001), Freddy et al., (2003), Jess and Mark (1994), Jorgenson and Fraumeni, (1989, 1992), and Wei (2004) have been explored. Out of these empirical studies, the most comprehensive are Jorgenson and Fraumeni, (1989, 1992) as they have used income-based approach on the US economy and Wei (2004) based on a lifetime labor income and gross human capital formation on Australian economy since both of them reveal that investment in education and training are used to measuring human capital.

Despite the fact that various kinds of human capital stocks measurement are developed, estimating the relationship between educational attainment and enrolment in primary, secondary and tertiary education in terms of human capital investment are the most important variables to be considered (see Kyriacou, 1991). Mankiw, Romer and Weil (1992) also added to the views of estimating the coefficients of production function using flows of investment as a proxy for capital stocks. Barro and Lee (1993) and Wossmann (2003) also showed the positive effect of human capital on macroeconomic performance using indicators such as number of educational facilities, ratio of government expenditure on training to GDP and per capita expenditure on education. Some other studies like Barro (1991) and Mankiw, Romer and Weil (1992) took school enrolment as a proxy for human capital and Benhabib and Spiegel (1994) and Krueger and Lindahl, (2001) used the average years of schooling of workers for human capital. The per capita wealth is used as a proxy for human capital in various regions of the world by disaggregating several factors into human capital, physical capital and natural resources (for detailed see Barro, 1998).

The contribution of human capital formation to economic growth has been described in many studies by Urélien and Yannick (2015), Sahbi and Jaleleddine (2015), Wendy and Umar (2013), Catia (2013), and Edgar, Alexander and Axel (2012). Similarliy, studies by Alexandra and Jacob (2011), Andrew, Robert and Fabio (2007), Verma, Wilson and Pahlavani (2007), Wang and Yao (2002), and Schultz (1998) are also included in the study because of their studies on the contribution of human capital to the economic growth.

It is observed that the empirical study of Yasmina and Stephen (2004) that emphasized the cross-country patterns of economic growth in estimating stochastic frontier production function for the eighty developed and developing countries have been assessed. Omolola (2013) also shows the benefits from migration aspects. There is also one important work by Mohsen and Maysam (2013) that investigates the causal relationship between gross domestic investment and GDP for the Middle East and North African countries using panel cointegration analysis over the period of 1970–2010. The studies result show that there is a strong causality from economic growth to investment. Furthermore, Kanayo, (2013) has empirically shown the evidence from the developing countries perspective and his study suggests that the importance of human capital formation to economic growth has been the major drive of the nation's development process.

The panel data econometrics has been used for estimating and forecasting purposes as cited by (Baltagi, 2005). Dynamic panel estimators have increasingly been used in growth theory (Baltagi, 2005, Easterly, 1997 Islam, 1995 and Arellano and Bond, 1991). The dynamic relationships are characterized by the presence of lagged dependent variable that appears as independent variable with other regressors. The long-run estimation under dynamic panel econometric models explains macroeconomic events by specifying preferences, technology and institutions and predicts as well as what is actually produced, traded and consumed and how these variables respond to various shocks (William, 2010).

Bichaka and Christian (2008) use unbalanced panel data from1980 to 2004 for thirty-seven African countries. They also tried to show that the aggregate impact of remittances that are related to human capital resources of a given country have impacts on economic growth. In this regard, the study reveals that remittances are boosting growth in countries where financial systems are less developed as they send money to their home country. However, Valeriia (2009) investigated the impact of capital flight on economic growth from one hundred thirty-nine countries in the year interval of 2002 to 2006 that displayed a negative impact on GDP growth. This presentation is because of the fact that even if in a country where high level of human capital resources is secured, the growth rate of GDP can be influenced by other factors such as capital withdrawal. Bangake and Eggoh (2010) studied the international capital mobility of thirty-seven African countries with panel cointegration methods over the period of 1979–2006. The findings indicated that the lowest are non-oil producing countries as opposed to that of oil producing ones.

Khaled and Willi (2006) studied the role of education and human capital in Egyptian economic growth from the year 1959 to 2002 using the Solow residual. They came to conclude that education and human have not been able to form a consensus of the causality between human capital and growth. Similarly, Mohamed and Nassima (2003) have made an assessment on the labor outcomes in Algeria and they came up with the conclusion that the main problems behind the low contribution of labor market lie on inefficient labor market institutions, absence of economic diversification and low participation of the private sector in the economy.

Comparing the Sub–Saharan Africa countries with the South East Asian countries on the economic growth potential, Michael (2011) pointed out that in the 1950s and1960s most Asian countries economy were destined for prolonged poverty, while Africa was totally engaged in independence victory that ultimately encouraged great optimism. However, the East Asian economic performance has given rise to a large literature in studying the so-called growth ‘miracle’, while the Sub–Saharan Africa has attracted attention for exactly the opposite reason. The failure of many countries in the region led to the failure in maintaining sustainable per-capita income growth after the 1970s (Robin, 2011). This is due to the fact that sustainable per-capita income growth causes high growth rate of GDP.

According to the study by Oleg, Daniel and Romain (2012), in the decomposition of labor productivity growth, physical capital accumulation is the largest share in economic growth. On the other hand, Jeffrey and Andrew (1997) suggested that the slow growth in Africa is the result of poor economic policies due to lack of openness to international markets and geographical factors such as lack of access to the sea and the tropical climate. Arthur and Maxime (2014) empirically tried to show the influence of macroeconomic volatile on physical capital accumulation in the Sub-Saharan economies. This study indicated that a one-unit increase in the conditional standard deviation of the real effective exchange rate led to a 0.011 percentage decrease in the stock of physical capital.

Coming to East Africa, regardless of the economic theory that postulates that an increase in investment in human capital and physical capital leads to an increase in economic growth. However, the specifically the Kenyan case doesn't show the stated fact (see Nelson and Fredrick, 2006). Moreover, a significant decline in domestic savings over the years, there is an increase in the growth of fixed capital formation in Ethiopia. This is due to the low level of per capita income, potentially one major factor of the low level in savings (EEA, 20003/04). This is true because saving rate, income and economic growth have positively related. It is also observed that the empirical work of Khadharoo and Seetanah (2006) on the relationship between public capital and economic growth of the Mauritius economy over the period 1950–2000, using the vector error correction model which to indicate that public capital had significantly contributed to the economic performance.

In summary, the reviewed empirical studies show the importance of human capital resources for sustainable economic growth. The study looks into the analysis in depth for the important contributions of human capital resources to economic growth with certain combined methods. The methods are dynamic panel transmission channels of the VAR system, and they have been further extended to the bivariate panel wavelet time scale analysis.

3. Methodology of the Study

3.1 Data Sources and Variables descriptions

Panel datasets of nine selected East African countries including Burundi, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Rwanda, Tanzania and Uganda are used to undertake the panel analyses over the period of 1980–2018. The sources of data for this study are from the World Bank development indicators, the United Nations aggregate databases and International Monetary Fund Economic outlook. It is considered that data on gross national income (GNI) at constant 2005 USD price, (which has been recently available on the series of dataset) is the dependent variable while other are explanatory variables. The explanatory variables comprise of a total factor productivity (TFP), human capital resources (HCR) that uses a proxy for human development and physical capital stock (PCS) are the author's calculated indices. The indexed variables are calculated by the author based on the economic theory as it can be seen under specification of dynamic panel econometric model.

3.2 Measuring Physical Capital Stock and Human Capital Resources

In economics, physical capital is a factor of production consisting of machinery, buildings, computers among others. Marshall and Mariam (2005) have estimated a fixed capital consumption as a part of measurements for the net national income and multi-factor productivity changes. Physical capital is the difference between gross investment and fixed capital consumption as it is pointed out by (Berlemann and Wesselhoft, 2014) in their study.

Human capital measures are sensitive to alternative assumptions about income growth and discount rates, smoothing and imputation of labor force and school enrolment data (Michael, 2011). In addition, conventional measurement of human capital focuses neglecting the importance of its non-monetary aspects such as creating added-values and social networks. Therefore, a direct measurement of human capital resources is a difficult task (Kwon, 2009). However, the United Nations (2008) study emphasises that an accurate measure of labor and capital inputs is based on the breakdown of aggregate hours worked and aggregate capital stocks into various components are essential. The hours worked are cross–classified by educational attainment gender and age with the aim to proxy for differences in work experience. Thus, human capital is increasingly believed to play an important role in the growth process, even if adequate measuring of its stock remains controversial as the evidence is supported by the economic theory cited in (Trinh et. al., 2002).

Human capital resource may be measured either by human capital index or human development index. Human capital index is a new measure for capturing and tracking the state of human capital development around the world while human development index is a summary measure for assessing long-term progress in three basic dimensions of human development such as long and healthy life, access to knowledge and decent standard of living (UNDP, 2013).

3.3 Specification of Dynamic Panel Econometric Model

Countries endowed with large stock of human capital eventually emerge as technological leader in a specific time and maintain the leadership as long as human capital advantage is sustained (Jess and Mark, 1994). Fairly strong positive association exists between the gross income and the life expectancy across developing countries, even though the associations do not reveal causality (Oded, 1993).

In order to calculate human development index used as a proxy for human capital stock, it is considered that the (UNDP, 2013) minimum and maximum values of the goalposts of the observed values in the time series interval 1980–2012. The justification for choosing these values as a reference time period is that there is no any other dataset which refers about human development index set by UNDP. The values are set in order to transform indicators into indices between 0 and 1. The maximum value is set at 83.6 years for life expectancy of Japan in 2012 (since this value has not been determined on the yearly basis) the expected years of schooling at 18 years. The combined education index of 0.971 from New Zealand in 2010 and the gross national income GNI of 87,478 USD in purchasing power parity of Qatar in 2012 are also considered. While the minimum values are set at 20 years for life expectancy, at 0 years for education variables and at $100 for the national income per capita NIPC (UNDP, 2013 and CIA, 2006, 2015).

Therefore, by defining human capital accumulation (HCR) as human development index, the geometric mean of normalized indices of life expectancy index (LEI), school mean enrolment Index (SMEI), education index (EI) and income index (II) are calculated in the following way:

$$\mathrm{HCR} \equiv \mathrm{HDI} = (\mathrm{LEI} \times \mathrm{EI} \times \mathrm{II})^{\frac{2}{3}} \qquad \textbf{(1)}$$

where LEI is the ratio of the difference between life expectancy at birth in years and minimum value to the difference between maximum and minimum values, SMEI denotes the ratio of the difference between mean of school enrolment and minimum value, EI represents the ratio of the difference between the square root of the LEI and SMEI product and observed minimum value to the difference between maximum and minimum values and II is the ratio of the difference between GNI and minimum value in logarithmic term to the difference between the maximum and minimum values in logarithmic term.

The school life expectancy is the total number of years of schooling from primary to tertiary level that a child can expect to receive, assuming that the probability of his or her being enrolled in school at any particular future age is equal to the current enrolment ratio at that age (CIA, 2006, 2015).

Under perpetual inventory method as Berlemann and Wesselhoft (2014) have mentioned the net physical capital stock at the beginning of the current period (PCS_t) can be expressed as the sum of one period lag in physical capital stock (PCS_{t-1}) and total investment (TI_{t-1}) minus fixed capital consumption (FCC_{t-1}) which causes depreciation. Thus, it can be calculated that the current physical capital stock based on this perpetual inventory theory as:

$$PCS_t = PCS_{t-1} + \mathrm{TI}_{t-1} - \mathrm{FCC}_{t-1} \quad \textbf{(2)}$$

This implies that the change in physical capital stock (ΔPCS_t) is given by

$$\Delta PCS_t = PCS_t - PCS_{t-1} = \mathrm{TI}_{t-1} - \mathrm{FCC}_{t-1} \quad \textbf{(3)}$$

The initial capital stock based on Harberger (1978) approach of the neoclassical growth theory can be employed which relies on the assumption that the economy is in its steady state. As a consequence of output grows at the same rate as capital stock would be given as:

$$g_{GDP} = g_{PCS} = \frac{\mathrm{TI}_{t-1}}{PCS_{t-1}} - \delta = \frac{PCS_t - PCS_{t-1}}{PCS_{t-1}} \;\Rightarrow\; PCS_{t-1} = \frac{PCS_t - PCS_{t-1}}{g_{GDP}} \quad \textbf{(4)}$$

Plug Equations (4) and (3) into Equation (2), then the result looks (**5**)

$$PCS_t = \frac{\mathrm{TI}_{t-1} - \mathrm{FCC}_{t-1}}{gGDP_t} + \mathrm{TI}_{t-1} - \mathrm{FCC}_{t-1} \quad \textbf{(5)}$$

In the actual context, the production function tends to be increasing returns to scale according to neoclassical model (Schmidt-Hebbel.1994 and Easterly and Levine, 1994). Adding to this, in the model specification of the classical theory, there exist technological spillovers and increasing returns to scale (Barro and Sala-i-Martin, 2003). Accordingly, it can be expressed as a gross national income (GNI) as dependent variable whereas technological level of total factor productivity (TFP), human capital resources (HCR), and physical capital stock (PCS) and total labor forces (TLF) as explanatory factors; following the endogenous model specification in the Cobb-Douglas production function as

$$\mathrm{GNI}_t = \mathrm{A_t}(\mathrm{HCR_t})^{\alpha_t}(\mathrm{PCS})_t^{\beta_t}(\mathrm{TLF})_t^{\gamma_t}\mathrm{e}^{\varepsilon_t} \quad , \alpha+\beta+\gamma>1 \qquad \textbf{(6)}$$

It is possible to0 take log differences of Equation (6) to set up the relationship for long-term growth from time t-1 to time t can be specified as

$$(\mathrm{lnGNI_t} - \mathrm{lnGNI_{t-1}}) = \alpha_t \mathrm{lnA_t}(\mathrm{HCR_t}) - \mathrm{lnA_{t-1}}(\mathrm{HCR_{t-1}}) + \beta_t(\mathrm{lnPCS_t} - \mathrm{lnPCS_{t-1}}) + \gamma_t(\mathrm{lnTLF_t} - \mathrm{lnTLF_{t-1}}) + (\mathrm{ln}\varepsilon_t - \mathrm{ln}\varepsilon_{t-1}) \qquad \textbf{(7)}$$

Specifying the first term in Equation (7), $\mathrm{TFP_t}$ depends on the level of human capital, reflecting the effect of domestic endogenous innovation. Take the expected value in both sides of Equation (7) and divide by $\frac{1}{\alpha_t}$ then it can be done as the expected total factor productivity $\mathrm{TFP_t}$ depending on the level of human capital resources given by

$$\begin{aligned} &\mathrm{E}[\mathrm{lnA_t}(\mathrm{HCR_t}) - \mathrm{lnA_{t-1}}(\mathrm{HCR_{t-1}})] \\ &= \mathrm{E}\left(\frac{\mathrm{lnGNI_t} - \mathrm{lnGNI_{t-1}}}{\alpha_t}\right) - \mathrm{E}\left(\frac{\beta_t}{\alpha_t}(\mathrm{lnPCS_t} - \mathrm{lnPCS_{t-1}})\right) \\ &\qquad - \mathrm{E}\left(\frac{\gamma_t}{\alpha_t}(\mathrm{nTLF_t} - \mathrm{lnTLF_{t-1}})\right) - \mathrm{E}\left(\frac{(\mathrm{ln}\varepsilon_t - \mathrm{ln}\varepsilon_{t-1})}{\alpha_t}\right) \end{aligned}$$

Since the expected value of error term $E(ln\varepsilon_t - ln\varepsilon_{t-1})$ is zero, TFP_t augmented with human capital can be, thus

$$\begin{aligned} \mathrm{TFP_t} &= \left(\frac{\mathrm{lnGNI_t} - \mathrm{lnGNI_{t-1}}}{\alpha_t}\right) - \left(\frac{\beta_t}{\alpha_t}\right)(\mathrm{lnPCS_t} - \mathrm{lnPCS_{t-1}}) \\ &\qquad - \left(\frac{\gamma_t}{\alpha_t}\right)(\mathrm{lnTLF_t} - \mathrm{lnTLF_{t-1}}) \end{aligned}$$

$$\mathrm{TFP_t} = \left(\frac{\Delta\mathrm{lnGNI_t}}{\alpha_t}\right) - \left(\frac{\beta_t}{\alpha_t}\right)\Delta\mathrm{lnPCS_t} - \left(\frac{\gamma_t}{\alpha_t}\right)\Delta\mathrm{lnTLF_t} \qquad \textbf{(8)}$$

where $\frac{\alpha_t}{\alpha_t+\beta_t+\gamma_t}$, $\frac{\beta_t}{\alpha_t+\beta_t+\gamma_t}$ and $\frac{\gamma_t}{\alpha_t+\beta_t+\gamma_t}$ are the share of human capital resources, physical capital stock and total labour force in total costs derived from (6). Their respective elasticity in continuous and discrete form in each are given as

$$\alpha_t = \left(\frac{\partial lnGNI_t}{\partial lnHCR_t}\right)\left(\frac{lnHCR_t}{lnGNI_t}\right),\ \beta_t = \left(\frac{\partial lnGNI_t}{\partial lnPCS_t}\right)\left(\frac{lnPCS_t}{lnGNI_t}\right) \text{ and } \gamma_t = \left(\frac{\partial lnGNI_t}{\partial lnTLF_t}\right)\left(\frac{lnTLF_t}{lnGNI_t}\right)\ \&\ \alpha_t = \left(\frac{\Delta lnGNI_t}{\Delta lnHCR_t}\right)\left(\frac{lnHCR_t}{lnGDP_t}\right),$$

$$\beta_t = \left(\frac{\Delta lnGNI_t}{\Delta lnPCS_t}\right)\left(\frac{lnPCS_t}{lnGNI_t}\right) \text{and } \gamma_t = \left(\frac{\Delta lnGNI_t}{\Delta lnTLF_t}\right)\left(\frac{lnTLF_t}{lnGNI_t}\right).$$

Therefore, based on the idea of Baltagi (2005), it can be expressed as $\mathrm{lnGNI_{it}}$ as a function of total factor productivity ($\mathrm{TFP_{it}}$), human capital resources ($\mathrm{HCR_{it}}$) and physical capital stock ($\mathrm{PCS_{it}}$). These explanatory variables are the most influential determinants, which potentially affect the economic or GDP growth rate of a country. The dynamic panel form including lagged dependent variable can be expressed in terms of panel vector autoregressive VAR system contains a set of n variables plus error term is given by

$$\mathrm{lnGNI_{it}} = \pi_0 + \pi_{1p}\sum_{l=1}^{P}\mathrm{lnGNI_{i,t-l}} + \pi_{2q}\sum_{l=0}^{q}\mathrm{TFP_{i,t-l}} + \pi_{3m}\sum_{m=0}^{r}\mathrm{HCR_{i,t-m}} + \pi_{4n}\sum_{n=0}^{s}\mathrm{PCS_{i,t-n}} + \varepsilon_{it} \qquad \textbf{(9)}$$

Where π are parameters to be estimated and p, q, r and s denote optimal lag length. $\boldsymbol{\varepsilon_{it}}$ are white noise random disturbances. In dynamic panel data regression described in Equation (9), it is not possible to apply the OLS, GLS, Fixed and Random effects methods because $\mathrm{lnGNI_{i,t-1}}$ is correlated with $\boldsymbol{\varepsilon_{it}}$ so that the results will be inconsistent. If $\boldsymbol{\varepsilon_{it}}$ is independently identical distribution iid, it will be correlated with $\mathrm{lnNIPC_{i,t-1}}$. It is supposed that GNI_{it} be a p ×1 vector of cross-section i in period t, follows a non-stationary VAR (p) process.π_0 is a k ×1 vector with the j-th element representing the deterministic component of the model ϑ_{it} are a k ×1 vector of disturbances and are independent N (0, $\Omega_{i,t}$) for t=1, T (see Anderson et al. ,2006).

Based on lagged observations used as the explanatory variables, dynamic estimators are designed to address the problems of the unobserved specific effects and the joint endogeneity of explanatory variables (Alonso-Borrego and Arellano, 1996). In dynamic panel estimators, it is possible to apply the differenced equation to remove any bias and potential parameter inconsistency arising from simultaneity bias created by the unobserved country-specific effects and use lagged values of the original regressors. In cases where the cross-sectional dimension is small- and the-time dimension is relatively large, the standard time series techniques are applied to the systems of equations and the panel aspect of the data should not pose new technical difficulties (Breitung and Pesaram ,2005).

The importance of time scale wavelet analysis is desirable one to find the local orthonormal bases consisting of small waves that dissect a function into layers of different scale. The segmentation of time series into different layers makes a very powerful wavelet analysis in the short, medium and long run and now it has been become popular and increasingly used in economic literature (see Ramsey and Lampart, 1998; Almasri and Shukur, 2003 Hacker, Karlsson, and Månsson, 2012 and Reboredo and Rivera–Castro, 2014). The maximal overlap discrete wavelet decomposition in the methodology that it is used to allow for moving averages at every scale level and avoids the problems of calculating the moving averages consistently throughout the series by reusing observations in a circular loop. The last value of the original series is simply the first value of that series (Hacker, Karlsson and Månsson, 2012). Since wavelets are local orthonormal bases consisting of small waves that dissect a function into layers of different scale. Given the Haar function with the domain [0,1], the wavelet transformation is

$$f(x) = C_0 + \sum_{\lambda=1}^{n} \sum_{k=0}^{n\,2^{\lambda-1}} C_{\lambda k\psi}\,(\lambda, k, \psi) \qquad (\mathbf{10})$$

where C_0 is the overall mean of the data and it along with the $C_{\lambda k\psi}$values are the wavelet coefficients?

Suppose there is a vector of actual time series observations y, with its elements ordered according to uniform units of time, as are the vectors with the level–λ smooth and detail series,S_λ and D_λ. Let the level-zero smooth series $s_0$is defined to be the same as the vector of actual observations y. The following two formulae describe how the smooth and detail series are calculated at scale levels of 1 and higher,

$$S_{\lambda,t} = \frac{S_{\lambda-1,t-2^{\lambda-1}} + 2S_{\lambda-1,t} + S_{\lambda-1,t+2^{\lambda-1}}}{4} \text{ and } D_{\lambda,t} = \frac{-S_{\lambda-1,t-2^{\lambda-1}} + 2S_{\lambda-1,t} - S_{\lambda-1,t+2^{\lambda-1}}}{4}$$

It is always the case that the original series may be reconstructed by adding to the smooth series of the largest scale level consider dΛ, the sum of the detail series from level 1 to level Λ is given by

$$y = S_{\Lambda} + \sum_{\lambda=1}^{\Lambda} D_{\lambda} \qquad \mathbf{(11)}$$

Where below are demonstrated the patterns on how these equations work for three scale levels, keeping in mind that $S_{0,t} = y_t$ at scale level, 1 it is calculated as:

$S_{1,t} = \frac{y_{t-1}+2y_t+y_{t+1}}{4}$, $D_{1,t} = \frac{-y_{t-1}+2y_t-y_{t+1}}{4}$, $S_{2,t} = \frac{S_{1,t-2}+2S_{1,t}+S_{1,t+2}}{4}$, $D_{2,t} = \frac{-S_{1,t-2}+2S_{1,t}-S_{1,t+2}}{4}$,$S_{3,t} = \frac{S_{2,t-4}+2S_{2,t}+S_{2,t+4}}{4}$, $D_{3,t} = \frac{-S_{2,t-4}+2S_{2,t}-S_{1,t+4}}{4}$ & $S_{4,t} = \frac{S_{3,t-8}+2S_{3,t}+S_{3,t+8}}{4}$, $D_{4,t} = \frac{-S_{3,t-8}+2S_{3,t}-S_{3,t+8}}{4}$.

The associated wavelet details, D_1 to D_{Λ} are the decompositions of the two data at different timescales and S_{Λ} represents the long-term trend at scale level Λ, which corresponds to zooming out the camera lens and looking at the broad land scape (Hacker, Karlsson, and Månsson, 2012).

In this kind of method, the estimation is clearly made not at a time, but one after another by taking others explanatory variables remain constant. This means when the estimation of the inter–temporal causal relationship of the growth rate of real GNI–HCR is made, while others are assumed to be unchanged and panel wavelet time scaling of the bivariate analysis which are jointly determined by the panel VAR method, it is possible to use Equation (9) as:

$$lnGNI_{it}^{D_{j,t}} = \Gamma_0 + \sum_{k=1,D_{j=1}}^{K,j=h} \Gamma_1^{(k)} lnGNI_{i,t-k}^{D_{j,t}} + \sum_{k=1,D_{j=1}}^{K,j=h} \Gamma_2^{(k)} HCR_{i,t-k}^{D_{j,t}} + \sum_{k=1,D_{j=1}}^{K,j=h} \Gamma_4^{(k)} PCS_{i,t-k}^{D_{j,t}} + \varepsilon_{it}$$

where D stands for the differences, K for the number of lag length, i for the cross-sectional dimension, and t for time dimension, are respectively. j=1, …, h, denotes time scale decomposition into different layers of the entire panel datasets.

4. Discussions and Empirical Findings

4.1 Optimum Lag-length Determination

Lag-length determination is the key point in the process of testing and estimation. The Akakie information and other criteria are often used to choose the optimal lag length distributed-lag models. In the estimation of optimum lag-length, it is possible to compute log-likelihood function and various types of information criteria for each choice used in accordance with the analyses made in the studies by (Johansen,1988,1991,1995). Thus, for pre-estimation of an VAR model selection to be used, together with the final prediction error (FPE), Akaike information criteria (AIC), Schwarz information criteria (SiC) and Hannan-Quinn information criteria (HQic) with the least values indicating (see Akakie, 1974) as shown below (in Table 4.1). Therefore, the optimum lag length of three that is going to be used for the entire analysis is chosen.

Table 4.1 Choosing of Optimum Lag Length

VAR Lag Order Selection Criteria
Endogenous variables: $lnGNI_{it}, HCR_{it}, TFP_{it}, PCS_{it}$

Lag	LogL	FPE	AIC	SIC	HQIC
0	-16117.31	3.46e+13	48.2012	48.2416	48.2169
1	-10617.12	2781676	31.8658	32.1487	31.9754
2	-10489.88	2117686	31.6931	32.1184	31.7966
3	-10470.57	2026137*	31.6429*	32.0907*	31.6404*
4	-10442.37	2278941	31.6663	32.6765	32.0576

* indicates lag order selected by the criterion with the least values

4.2 Panel and Individual Cointegration T-tests

It is necessary to take into account the panel cointegration methodology developed by Johansen (1988,1991,1995) which highlights that one can be confident when eigenvalues problem is solved and inferences of the test hypothesis about cointegrating relationship among the variables are confirmed. Like panel unit root tests, panel cointegration tests can be interested as it is more powerful than the individual time series cointegration tests. The interactions of short-run dynamics between the cross-sections influence of other members in a panel of the cross-section brings a long-run equilibrium. These differences can make ranks in the cross-sectional cointegration (Anderson, Qian and Rasch, 2006).

Accordingly, conducting the Johansen cointegration tests for a panel of ten countries a priority and following that it is possible to obtain the number of cointegration equation which is found to be four. The test for individual separately at the 5% level of significance is calculated using the trace and the maximum eigenvalue tests. Thus, Burundi, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Rwanda, Tanzania, Uganda and Zambia have shown number of equations as (3,1) ;(4,1) ;(1,0) ;(1,1) ;(1,1) ;(2,1) ;(2,0) ;(1,0) ;(1,1) and (0,0), respectively. The numbers in the brackets are the trace and the maximum eigenvalues in their order of respect. Out of ten countries, Zambia is rejected since there is no cointegrating equation in both cases of tests. When the trace and the maximum eigenvalue is statistically different, it is necessary to take trace test (Alexander, 2001). that is the reason why nine countries have passed with cointegrations. Finally, a test is conducted for a panel of nine countries, excluding Zambia. The test results are shown in (Table 4.2).

Table 4.2: Johansen test of Panel Cointegration for HCR- Economic Growth

Dependent Variable: ln (GNI)							
Hypothesized No of CE(s)	**Trace Test**				**Maximum Eigenvalue Tests**		
	Eigenvalue	**Statistic**	**5% C. Value**	**P. Value**	**Eigenvalue**	**5% C.V.**	**P. Value**
None	0.2187	119.75	47.856	0.0000*	64.413	27.584	0.0000*
At most 1	0.1043	55.339	29.797	0.0000*	28.758	21.132	0.0035*
At most 2	0.0752	26.581	15.495	0.0007*	20.417	14.265	0.0047*
At most 3	0.0233	6.1638	3.8415	0.0130*	6.1638	3.8415	0.0130*

The Johansen test of Panel Cointegration performed for unrestricted Rank(r). * denotes rejection of the null hypothesis at the 5% level of significance. The trend assumption is linear deterministic with optimum lag-length of 3.

The results in (Table 4.2) show that the Johansen test for cointegration for a panel of nine countries in the unrestricted rank multivariate analyses do exist. The null hypothesis of no cointegration is rejected, at most one, two and three cointegrations. Since the trace and maximum eigenvalue statistics exceed their respective critical values conventionally at the 5% level of significance. Both tests indicate there are four cointegrating equations.

Both the trace and the maximum eigenvalue tests in the first column of (Table 4.2) indicate that the number of cointegrating vectors, in which the hypotheses of the variables are non-cointegrated (r$=0$) against the alternative of one or more cointegrating vectors (r>0). Since the values of trace statistic (0) and maximum eigenvalue statistic (0) exceed their respective critical values at the 5 % significance level. the null hypothesis is rejected at zero cointegrating vectors (r=0) and accept the alternative hypothesis of more than zero cointegrating vectors (r>0). Likewise, the values of trace statistic (1) and maximum eigenvalue statistic (1) are also greater than their respective critical values at the 5 % significance level. the null hypotheses rejected at $\mathrm{r} \leq 1$, $\mathrm{r} \leq 2$ *and* $\mathrm{r} \leq 3$, cointegrating vectors (r=1, r=2 and r=3), however, it is impossible to reject the alternative hypotheses of more than one, two and three cointegrating vectors (r>1, r>2 and r>3). From these tests it is suggested that the Johansen test of trace and maximum eigenvalue reveal number of cointegration vectors is four within the series of lnNIPC, TFP, HCR and PCR. Hence, the undertaken variables are integrated of the same order in the variable in each four series data and they move together towards the long run equilibrium or they have long run relationship.

4.3. Cross-sectional Dependence and Endogeneity Tests

Before estimating parameters, data must be cross-sectionally independent by applying the demeaned method (i.e., the difference between actual observation and common mean) of the panel. Since estimation in the presences of cross–sectional dependence causes bias and inconsistency as Andrew (2005) pointed out. It is considered that the standard augmented Dickey–Fuller ADF regression with the cross–section averages of lagged levels and first-differences of the individual series for cross–sectional dependence test (Pesaran, 2007). The limiting distribution of this test is different from the Dickey–Fuller distribution due to the presence of cross–sectional lagged level in which (Pesaran, 2003) uses a truncated version of (Im-Pesaran and Shin,1997) test to avoid the problem of moment calculation (Baltagi,2005). Based on an AR (ρ) error specification, the relevant individual cross sectional augmented Dickey–Fuller (CADF) statistics are computed from the ρ^{th} order cross- section.

With the transformed data by the demeaned method in (Walter, 2003), regression is made to consider the differenced variable as dependent and its one period lagged as independent variables. Eventually after transformation of the original data, a test is carried out for the cross-sectional dependence of the individual explanatory variables (for detailed information, see Pesaran, 2007). Consequently, it is confirmed that there is no cross-section dependence among four explanatory variables. The output generated for the test will be accessed from the author based on the request. Finally, before arriving at the process of estimation of the parameters, it is necessary to check endogeneity problem that arises from simultaneous equations model with the help of two stages least squares 2SLS, (see, Wooldridge, 2002, 1997a for detailed). In the presence of endogeneity problem, estimation becomes bias and inconsistent. Consider the following simultaneous equations of $\mathrm{lnGNI} - \mathrm{HCR}$ model where lnGNI and HCR are endogenous variables whereas others are predetermined.

$$\mathrm{lnGNI} = \beta_0 + \beta_1 \mathrm{HCR} + \beta_2 \mathrm{PC}S + \mathbf{u} \qquad (\boldsymbol{9a})$$

$$\mathrm{HCR} = \beta_{10} + \beta_{11} \mathrm{lnGNI} + \beta_{12} \mathrm{TFP} + \mathrm{v} \qquad (\boldsymbol{9b})$$

Equation $(9a)$ and $(9b)$ is exact–identified. Here, the two stages least squares 2SLS is applied for solving the problem of endogeneity as a result of simultaneous equations model. The reduced form equations estimated by OLS. That is, a regression of HCR on PCS and TFP is made by OLS method. The estimated human capital resource HCR–OLS is obtained. Then it is estimated that lnGNI as a function of HCR–OLS and PCS using (9). A regression of lnGNI on PCS and TFP is made by OLS method and the estimated lnGNI is obtain. Finally, HCR is estimated as a function of the estimated lnGNI and TFP by the OLS. These procedures are known as the two stages least square method 2SLS.

4.4 Dynamic Panel VAR Estimation of Long-run Coefficients

Based on the three-optimum lag–lengths (found in section 3.4.1), now it is possible to estimate the long–run parameters using panel VAR model and make use of other analyses. Unlike the analyses of long–run estimation parameters in various forms such as the Hayakawa and Kurozumi (2008) dynamic OLS, Phillips and Moon (1999, 2000) panel fully modified OLS estimators, Kao and Chiang (2000) panel fully modified OLS estimators and Anderson, Qian and Rasch (2006), the estimated coefficients result of panel vector autoregressive (VAR) model are asymptotically unbiased and normally distributed. Thus, the obtained results are revealed as follows.

Table 4.4.1: Dynamic panel VAR estimation of long-run Coefficients for HCR model

Variable	Coefficient	t-Statistic	P. Value
$\mathbf{lnGNI2SSLS_{it-1}}$	1.1082	12.900	0.0000**
$\mathbf{lnGNI2SLS_{it-2}}$	-0.0769	-0.6141	0.5397
$\mathbf{lnGNI2SLS_{it-3}}$	-0.0668	-0.7934	0.4283
$\mathbf{HCR2SLS_{it-1}}$	-0.3518	-1.4555	0.1468
$\mathbf{HCR2SLS_{it-2}}$	0.8384	2.7136	0.0071**
$\mathbf{HCR2SLS_{it-3}}$	-0.5019	-2.1969	0.0289*
$\mathbf{TFP_{it-1}}$	-0.0003	-0.1512	0.8799
$\mathbf{TFP_{it-2}}$	0.0021	1.4118	0.1592
$\mathbf{TFP_{it-3}}$	-0.0029	-2.0019	0.0463*
$\mathbf{PCS_{it-1}}$	0.0575	6.1274	0.0000**
$\mathbf{PCS_{it-2}}$	-0.0011	-0.0926	0.9263
$\mathbf{PCS_{it-3}}$	-0.0183	-1.9972	0.0469*
Constant	-0.0028	-0.2865	0.7747
R-squared	0.9653		
F-statistic	596.56		
Prob F-statistic)	0.0000		

** and * denote the level of significance at 1% and 5% with the optimal lag length of three. In order to make free from endogeneity problem, it is estimated that data on GNI and HCR by 2SLS and denoted as GNI2SLS and HCR2SLS. Model Diagnostics: The residual error terms are normally distributed, free from the problem of Autocorrelation and heteroskedasticity. The test results have been accessed from the author.

The results in (Table 4.4.2) can be interpreted as follows. One year lagged in the gross national income; two years lagged in human capital resources and one year lagged in physical capital stock have positively significant impact on the current gross national income (lnGNI) in the short run for a panel of nine East African countries over the period 1980–2018. Again, by looking at the coefficient of determination, R–squared value in (Table 4.4.1), the regression results show that about 96.5 percent variation in ln (GNI) is due to the joint effect of TFP, HCR and PCS. The F-statistic value is statistically significant which indicates our model specification is adequate and fit to the data.

Table 4.4.2 Short–run cumulative causal effects in the panel VAR transmission by Wald test

Hypothesized causal effect of the first variable on third variable through the second variable	χ^2	P. Value
1. H_0: HCR causes lnGNI and lnGNI causes PCS		
$\mathrm{lnGNI} = F(\mathrm{HCR})$ and $\mathrm{PCS} = F(\mathrm{lnGNI})$		
$\mathrm{HCR2SLS}_{it-1} = \mathrm{HCR2SLS}_{it-2} = \mathrm{HCR2SLS}_{it-3} = 0$	8.1177	0.0333*
&		
$\mathrm{lnGNI2SLS}_{it-1} = \mathrm{lnGNI2SLS}_{it-2} = \mathrm{lnNGNI2SLS}_{it-3} = 0$	7.9466	0.0471*
2. H_0: lnGNI causes HCR and HCR causes PCS		
$\mathrm{HCR} = F(\mathrm{lnGNI})$ and $\mathrm{PCS} = F(\mathrm{HCR})$		
$\mathrm{lnGNI2SLLS}_{it-1} = \mathrm{lnGNI2SLLS}_{it-2} = \mathrm{lnGNI2SLLS}_{it-3} = 0$,	20.695	0.0001**
&		
$\mathrm{HCR2SLS}_{it-1} = \mathrm{HCR2SLS}_{it-2} = \mathrm{HCR2SLS}_{it-3} = 0$	7.1959	0.0659
3: PCS causes lnGNI and lnGNI causes HCR		
$\mathrm{lnGNI} = F(\mathrm{PCS})$ and $\mathrm{HCR} = F(\mathrm{lnGNI})$		
$\mathrm{PCS}_{it-1} = \mathrm{PCS}_{it-2} = \mathrm{PCS}_{it-3} = 0$,	51.971	0.0000**
&		
$\mathrm{lnGNI2SLS}_{it-1} = \mathrm{lnGNI2SLS}_{it-2} = \mathrm{lnGNI2SLS}_{it-3} = 0$	20.695	0.0000**

** and * denotes rejection of the hypothesis at the 1%, and 5% level of significance using the optimal lag-length of three.

After excluding the insignificant TFP from the panel VAR system in (Table 4.4.1), it can be conducted that the short-term VAR transmission mechanism channels using the Wald test and all the results are significant, except

HCR as you can see in (Table 4.4.2). This implies that there is a significantly important contribution of human capital resource (HCR) to the development of physical capital stock (PCS) through gross national income in log form (lnGNI). The growth of lnGNI has also a positive implication towards the accumulation of PCS via HCR. Explicitly it can be demonstrated that the inter-temporal relationship between the estimated lnGNI and HCR using the wavelet time scale analyses.

Table 4.4.3: Impulse–response Granger causality test of wavelet time scales for HCR model

Accumulated Responses from	Short-term	Medium-term	Long-term
lnGNI to HCR	0.0044	0.0099	0.0697
Calculated χ^2–value	(12.10)	(20.27*)	(57.85*)
HCR to lnGNI	-0.0007	-0.0001	0.0117
Calculated χ^2–value	(28.06*)	(35.16*)	(52.66*)

* Denote rejection of the null hypothesis of the explanatory doesn't Granger cause of the dependent variable. The lnGDP–2SLS and the FSD–2SLS denote the estimation of GDP in log form and FSD by 2SLS method to overcome the problem of endogeneity. It is calculated that the combined probability in the short, medium and long–run values in the time scale horizons using the formula, $\chi^2 = -2\sum_{i=1}^{L} \ln(P_i^2)$ where $-2\ln P_i$ which has a chi-square χ^2distribution and i stands for country 1, 2, 3..., L (see detailed information in Dmitri et.al., 2002 and Fisher, 1932).

The combined calculated χ^2 in the parentheses were compared with the conventional χ^2 which have been available in (Brooks, 2008). These conventional χ^2 of 15.98 at the 5% level of significance for 9 degrees of freedom which represents number of countries for HCR. Using the optimal lag–length of three in a VAR system, it is calculated that the chi-square and probability values for each country. a simple mean calculation is used for the combined mean coefficient of the time scale, denoted by time scale of β_1, β_2 and β_3 which represent the short, medium and long-term effects of HCR on GNL and vice versa. Finally, it is conducted that the Granger causality tests and estimation coefficients of a panel wavelet analysis in the time scale horizon decompositions with the help of VAR methods.

As it can be seen from (Table 4.4.3) unlike the usual causal effects, the wavelet analysis breaks down the entire series of data from the 1980 to 2018 one layer after another into the immediate Short, Medium and Long term. The results in (Table 4.4.3) show that the accumulated responses of GNI to HCR are positive significant in the medium and long terms while that of HCR to GNI are significantly negative in the short and medium terms and significantly positive in the long run for a panel of nine East African countries. These effects slightly increase over time which indicates that there are bi-directional inter-temporal causal relationships between HCR and GNI in the long-run. These mean, more educated and skilled human capital can produce sufficient amount of real gross national income for the countries and the reverse also holds true. thus, calculations are based on the Chlesky variance-response function with the help of the standard error of the Monte Carlo simulation.

The possible explanation for the unexpected negative accumulated response from HCR to GNI in the short and medium term may be the low-level capacities of the economy that are unable to accommodate more educated and skilled people. The empirical results of this study somehow are related to some previous studies such as the link between human capital and labor market of the Pakistan economy study by (Qadri and Waheed ,2014) and the critical unemployment high level in economic growth of the Spain and the Cyprus though the level of human capital. It is expressed as a percentage of tertiary educated in the study of (Cadil, Petkovováa and Blatnáb,2014). This idea may be also related to the studies by (Sahbi and Jaleleddine,2015, Mohsen and Maysam,2013, Ndambiri et al., ,2012, Anderson, Qian and Rasch,2006 and Freddy et al.,2003).

5. Conclusion

Human capital resource is the basic foundation for economic growth. Human capital endowments allocated to the productive sectors can be an important determinant of economic growth. The skills, knowledge, and innovation that people accumulate in due course are the greatest assets in such countries. Thus, it is possible to say that human capital brings sustainable economic growth.

Moreover, the East Africa region has the lowest level of human capital development, nevertheless, it displays a rapid growth in the expansion of education. The expansion of education system for the development of human capital stock itself has not been matched with a proportionate rise in physical capital due to the low level of income growth and the low returns to educational investments (Simon and Francis, 1998) that caused by the low levels of accommodation of the economy. This highlights the issue of employment challenges that women are going through more than men are. Instead of attending schools, they are being forced to marry at an early age. Due to financial constraints and traditional cultures their education opportunities are denied. In fact, labor theories and policies do not usually include a gender approach to labor challenges in modern economic theory.

Thus, physical policy is an important element in addressing the development of human capital issue in East Africa. This physical policy is all about the effective system of taxation on revenue generation for the governments and mobilizing other resources for inequality and equity concerns. However, in East Africa, this policy would be ineffective when it comes to narrowing the gap in societies in terms of income and wealth inequalities in addition to the lack of inclusiveness of economic growth for all beneficiaries.

In this study, the tests for non-stationery and others, before ultimately estimate the coefficients are conducted. The observed estimation indicates that the growth rates of human capital resources (HCR) and the physical capital stock (PCS) have long-run effects on the growth rate of gross national income (GNI) in a panel of nine East African countries over the period of 1980 to 2018. The short–term transmission mechanism of the VAR system applied in accordance with the Wald test which indicates that HCR growth contributes hugely to the development of PCS through GNI. The GNI growth has also a positive role in accumulating PCS via HCR.

It is explicitly demonstrated that the dynamic inter–temporal relationship between gross national income and human capital growth using a panel wavelet analysis in time scaling decomposition. Thus, the accumulated responses of GNI to HCR are positively significant in the medium–and long–term, while that of HCR to GNI are significantly negative in the short- and medium–run but positive in the long-run. These effects are slightly increased over time which indicates, there are bi–directional inter–temporal causal relationships between HCR and GNI and their robust estimation parameters are made. This leads to say that more educated and skilled human capital can produce sufficient amount of real gross national income for the countries and the vice versa. The possible explanation for the unexpected negative accumulated response from HCR to GNI in the short– and medium–terms may be the low-level capacity of the panel economy in East African countries to accommodate more educated and skilled people. It is also possible to argue that more due attention should be given to HCR than any other in attempt to achieve sustainable development in the process of successful economic progress.

The main policy recommendation of the study is that East Africa countries' governments should give more attention to human capital resources than any other. This is true because in order to achieve sustainable development in the process of successful economic progress, well-developed human capital plays a central role in the performance of the economy.

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The Impact of Improved Beehive on Income of Rural Households: Evidence from Bugina District of Northern Ethiopia

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Abstract

Needless to say, increased adoption of modern beehives can improve the livelihood of smallholder farmers whose income largely depends on mixed crop-livestock farming. Owing to this, improved beehives have been disseminated to farmers in many parts of Ethiopia including Bugina district. However, its impact on the farmers income is less investigated. Thus, this study attempts to estimate the impact of adopting improved beehives on rural households' income and asset holding. Survey data was collected from 350 randomly selected households and analysed using an ESRM. The result has revealed that the adoption of improved beehives has enabled beekeepers to enjoy a higher annual income, and asset formation. On average, improved beehive adopters had earned about 6,077 (ETB[5]) more money than their counterparts. However, the impact of the adoption would have been larger for actual non-adopters, as reflected in the negative transitional heterogeneity effect of 1792(ETB). The result also has indicated that the decision to adopt or not to adopt improved beehives was subjected to individual self-selection. Improved beehives adoption also caused an increase in households' fixed assets, and can be used as an alternative poverty reduction strategy.

Keywords: impact, adoption, endogenous switching regression, income, and improved beehives.
JEL Classification: E13

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[5] ETB is the official currency of Ethiopia. In 2019, purchasing power parity for Ethiopia was 10.4 LCU per international dollars.

I. Introduction

Despite the growing prominence of innovation, limited studies examine the adoption of applications that support innovation processes. Regardless of the growing importance of innovation, however, limited studies have examined the adoption and impacts of applications of those technologies such as improved beehives.

Beekeeping is an especially important source of livelihood to resource-poor Ethiopian farmers and youths as it doesn't require large amounts of land, water, and fertilizer to thrive (Adimassu et al., 2017; Alemberhe & Gebremeskel, 2016; Anand & Sisay, 2011; Gebremedhin, 2015). It also provides essential ecosystem service of crop pollination that increases productivity and helps to maintain a balance between wild forest conservation and diversified agriculture (Alemberhe & Gebremeskel, 2016; Guesh et al., 2018). According to Alebachewu (2018) and Bareke et al. (2018), bees' pollination benefits crop production in Ethiopia with an estimated economic return of around $815.2 million which is 6.24% of the country's agricultural GDP.

Beekeeping can also be used as a climate adaptation mechanism at times of bad weather as bees can produce honey even with the little available rain (Thomas & Tounkara, 2020). Moreover, bee products can improve farm family nutrition and provide medicinal values.

Ethiopia is the leading honey and honey products producer in Africa. Being the first in terms of production and productivity (FAOSTAT, 2018), Ethiopia is the 10th largest honey producer globally (Sautier et al., 2018). The country has the potential to produce 500,000 tons of organic honey and 50,000 tons of beeswax whereas the country currently produces only 43, 000 and 3000 tons of honey and beeswax respectively per annum and its contribution to the national economy (GNP) is only around $1.6 m (Sautier et al., 2018). Although it is below its potential, honey production in Ethiopia has increased from 28,000 tonnes to 50,000 tonnes over the last 15 years period (Sautier et al., 2018). This wide gap between potential and the current capacity is mainly attributed to a lack of skill and awareness and use of modern technologies (Fenet & Alemayehu, 2016).

Among other things, the profitability of beekeeping is determined by the availability of improved bee technologies and improved management skill of beekeepers (Berhe et al., 2016; Kumsa & Takele, 2014). To this end, in the last fifteen years improved hives such as Kenya Top Bar (transitional) and frame hive have been introduced and in each year the government has disseminated a considerable number of improved (box) hives to farmers (Asmiro Abeje, *et al*. 2017; Kumsa et al., 2020). Hive type has been a significant effect on honey yield per hive (Haftom Gebremedhn, 2016). Improved beehive in this paper considers both Kenyan Topbar (Transitional) and modern beehives.

According to CSA (2008), there are about 4,601,806 beehives in the country out of which about 95.5% were traditional, 4.5% improved (4.3 % transitional and 0.20% frame hives). under Ethiopian farmers' management condition, the average amount of crude honey produced from the traditional hive is estimated to be 5-10 kg/hive/year which is much lower than the amount that could be produced by using improved beehives According to(Fikadu et al. 2017). The estimate is to reach 20-30 kg per colony per year.

The semi-arid of the Eastern Amhara area is delineated as the potential beekeeping site of the government (Alemu et al., 2013). Despite the potentials and prospects of beekeeping in the area, little is known on technology adoption impact on annual incomes of rural beekeepers.

The population of the Bugina district is growing quickly. It is doubling almost every quarter of a century (CSA, 2011). This has a negative effect on landholding and other natural resources because man to land ratio has increased significantly. However, according to Bugina District Livestock and Fishery Resource development department (2018), the diffusion and spread of affordable improved beehives such as 215 Kenya Top Bar (Transitional) and 3254 framed (boxed) beehives are expected to boost harvests and family incomes. But there is conflicting information between the actual performance of improved hives and their claim of success by its promoters. Some researchers such as Asmiro Abeje, and his colleagues (2017) have dealt with this district to assess the adoption & intensity use of modern beehive with its determinant factors, and to analyse factors affecting adoption of modern beehive & to identify the constraints of modern beehive adoption. However, they have not been able to address the adoption impact on beekeeper`s annual income. Therefore, this study ought to analyse the impact of adopting improved beehives on the income of beekeepers in the said study area.

2. Materials and Methods

2.1 Study Area

The Bugina district is one of the fourteenth (eleven Rural and three Urban) districts in the North Wollo Zone of Amhara regional state, According to FSCDPO (2011). The altitude of the district ranges from 1336 and 2827 m.a.s.l. The Annual temperature and rainfall vary between 7.5 ºc to 26 ºc; and750 mm to 1162 mm respectively.

In the semi-arid part of the Amhara region, including Bugina district, large areas of inaccessible lands for crop cultivation and livestock grazing (along escarpments, hills, and rising and falling mountains) are covered with various types of bushes, which are potential for beekeeping (Aynalem & Mekuriaw, 2017). The district is among the potential beekeeping districts in Wag-Himra administrative zone as it is identified by the regional government (Alemu et al., 2013).

Data Source and Collection Tools

The study has employed household-level cross-sectional data collected using face-to-face interviews. We have used a multi-stage sampling method for selecting representative sample households from the population. In the first stage, eight sample *Kebeles*[6] from thirteen available have been randomly selected.

The estimated total population (households who practice beekeeping Bugina) were 1817 of whom 999 (55%) were non-adopters and 818 (45%) were adopters. For sampling in the second stage, 350 total households from the two groups were selected using a sample size determination formula. Since the target population is less than 10,000, we used (Cochran, 1963) sample size determination formula.

$$n_0 = \frac{z^2 pq}{e^2} \qquad \textbf{(1)}$$

Where n_0 is the sample size, $z^2$is the abscissa of the normal curve that cuts off an area α at the tails (Suppose the researcher wishes to have a 95% confidence level (Z), e is the desired level of precision (0.05), p is the estimated proportion of expected adopters (0.45), and q is 1-p (0.55). Therefore, n_0 =380. Then,

[6] Lower administrative unit

n =314; where n is the desired sample size, but additional 36 observations were included to compensate potential observations to be discarded for any reason during data clearance. Hence, the actual sample size of the study conducted was 350 (156 users and 194 non-users) respondents. The number of the adopter and non-adopter samples was determined by using their proportion from the total population.

2.2 Methods of Data Analysis

Descriptive statistics, inferential statistics, and econometric models have been used to address the study objectives. The endogenous switching regression (ESR) model has been used for evaluating the impact of modern beehive adoption on the outcome variable, which is income in this case.

The decision to adopt or not to adopt an improved beehive is left to be on volunteer bases and may also be based on individual self-selection and preference (Di Falco *et al*., 2011) beekeepers that adopted may have systematically different characteristics from the beekeepers that did not adopt. Unobservable characteristics of beekeepers may affect both the adoption decision and the income earned from beehives, resulting in inconsistent estimates of the impact of adoption on beekeepers. To this end, endogenous switching regression by full information maximum likelihood (FIML) was used to account for potential Endogeneity problems.

The ESR model is estimated using two-stage regression. In the first stage, a value of 1 or 0 is assigned to represent the choice of whether a household decides to use an improved beehive. We specified the mode for the selection equation for improved beehive adoption as:

$$S_i^* = Z_i\alpha + u_i \text{ with } S_i = \begin{cases} 1 \text{ if } S_i^* > 0 \\ 0 \text{ other wise} \end{cases} \qquad (\mathbf{2})$$

Following Di Falco et al., (2011), the second stage of an endogenous switching regression (ESR) model can be specified in two regimes: (1) to adopt and (2) not to adopt as follows.

Regime 1: $y_{1i} = X_{1i}\beta_1 + \varepsilon_{1i} (3a)$
Regime 2: $y_{2i} = X_{2i}\beta_2 + \varepsilon_{2i} (3b)$

Where S_i is a dichotomous variable representing a participation of rural beekeepers in improved beehive adoption; z_i refers to vectors that affect rural beekeeper`s decision to adopt improved beehive, X_i represents a vector of explanatory variables which determines the amount of income gained annually. Even though Z and X may overlap, but there must be at least one variable (instrumental variables) in Z is required not to be included in X to properly identify the outcome equations, latent variable (S_i^*) represents the expected benefits of adopting as compared to not adopting; parameter α represents coefficients for the row vectors to be estimated, and α and β are a vector of unknown parameters to be estimated. y_{1i} and y_{2i} are outcome variables (i.e. total amount of money generated in the year) in regimes 1 and 2 respectively, and the error terms (ε_1 & ε_2) in the continuous outcome equation and u_i in the selection equation. Finally, the error terms are assumed to have a trivariate normal distribution, with zero mean and covariance matrixΩ; i.e., (ε_1,ε_2 $\cup_2$) $N \sim (\mathbf{0}, \Omega)$. This model is defined as a "switching regression model with endogenous switching" (Maddala & Nelson, 1975).

The specification was chosen for the income-generating equations (3a) and (3b), which follows the common practice in the agricultural economics literature (Coelli and Battese, 1996), allows us to use as exclusion restrictions the variables related to the beekeeper household`s level of perception, and characteristics.

The ESR model can be used to compare the expected income of the beekeepers under four scenarios: (a) observed income of actual adopters (b) observed income of non-adopters (c) the expected income that adopters would get if they don't adopt, counterfactual (d) the expected income that non-adopters would get if they adopt, counterfactual. The conditional expectations for income-earning in the four cases are presented and defined as follows;

$\mathrm{E}(y_{1i}|s_i = 1) = X_{1i}\beta_1 + \sigma_{1u}\lambda_{1i}$ (4a) (predicted outcome of adopters should they have adopted)

$\mathrm{E}(y_{2i}|s_i = 0) = X_{2i}\beta_2 + \sigma_{2u}\lambda_{2i}$ (4b) (predicted outcome of non-adopters if they had not adopted)

$\mathrm{E}(y_{2i}|s_i = 1) = X_{1i}\beta_2 + \sigma_{2u}\lambda_{1i}$ (4c) (predicted outcome of adopters had they not adopted)

$\mathrm{E}(y_{1i}|s_i = 0) = X_{2i}\beta_1 + \sigma_{1u}\lambda_{2i}$ (4d) (predicted outcome of non-adopters had they adopted)

Table 9: Conditional Expectations, Treatment, and Heterogeneity Effects

Sub-sample	Decision stage		Treatment Effect
	To adopt	**not to adopt**	
Farm households who adopted	(a) $E(y_{1i}\|s_i=1)$	(c) $E(y_{2i}\|si=1)$	ATT
Farm households who did not adopt	(d) $E(y_{1i}\|si=0)$	(b) $E(y_{2i}\|si=0)$	ATU
Heterogeneity effect			ATH

Source: Adopted from Di Falco et al. (2011)

Cases (4a) and (4b) in Table 1 represent the actual expectations observed in the sample. Cases (c) and (d) represent the counterfactual expected outcomes observed in the sample.

S_i=1 if the beekeeper adopt; S_i= 0 if the beekeeper does not adopt, y_{1i} = income of the beekeeper, if the beekeeper adopt. y_{2i} = income of the beekeeper if the beekeeper does no adopt.

Where y1i stands for adopters' annual income, si =1, is the decision to adopt improved beehive y2i stands for non-adopters' annual income, si =0, is the decision not to adopt

y2i stands for adopters' annual income, si=1 if adopters decided to not adopt

y1i stands for non-adopters' income, si=0, if non-adopters decided to adopt

Following Heckman et. al (2001), the average treatment effect of adopting improved beehives on the treated (ATT) can be estimated as a difference between (a) and (c) – i.e. $\mathrm{ATT} = \mathrm{a} - \mathrm{c}$. The ATT represents the impact of improved beehive adoption on the income of households that adopted improved beehives. Similarly, we calculate the impact of the average treatment effect on untreated (ATU) as a difference between (d) and (b) – i.e. $A\mathrm{TU} = \mathrm{d} - \mathrm{b}$.

As a final point, we investigate the average "transitional heterogeneity" (ATH) that examines whether the impact of adopting improved beehive is larger or smaller for the beekeeper households that actually adopted or for the beekeeper household that actually did not adopt in the counterfactual case – i.e. $\mathrm{ATH} = \mathrm{ATT} - \mathrm{ATU}$.

2.3 Variables and their Definitions

Below are the variables used in the participation equation, outcome equation and dependent variables are defined.

Dependent variables

Participation Decision: is the dummy variable that represents the participation of the households in improved beehives.

Outcomes variable

Annual income (AI): is the amount of money in Ethiopian Birr (ETB) generated within a year from several income sources.

Fixed Asset Value (AV): beekeepers' physical assets (such as build houses, livestock breed, electronics, bee colony, and farm materials like motor pumps,) are among the asset that evaluated by the local market price during the survey period measured in ETB.

Independent variables

The selection of the variables used in this study is mainly based on an empirical literature review. Table 2, below, presents the variable used in the adoption decision.

Table 2: The definition of variables used in adoption of improved beehives

Variable code	Type	Definition of variables	Measurement	Hypothesis
AgeBK	Continuous	Age of household Head	year	±
AgeBK2	Continuous	Age Square of household head	year	-
SexBK	Dummy	Sex of household Head	1 if Male 0 otherwise	+
AdualtEqu	Continuous	family size	Number	+
EduLevl	Dummy	Education status	1 Literate 0 Iliterate	+
LandSz	Continuous	Land size in hectare	Ha	
AcsCrdS	Dummy	Access to Credit	1 if yes 0 otherwise	+
ExtCont	Dummy	Access to Extension contact	1 if yes 0 otherwise	+
Gofincom	Dummy	Off-farm income	1 if yes 0 otherwise	+
TLU	Continuous	Livestock owned	Number	+
MBClimcr	Dummy	Households' perception of Modern beehive adaptive capacity to climate change	1 if yes 0 otherwise	+
ResdYr	Continuous	Beekeeper's stayed in their prior residence in year	Year	+

3. Result and Discussion

3.1 Socio-demographic Characteristics

From the total sample, 156 (44.5 %) were adopters of improved beehive while 194 (55.5%) were non-adopters. It is also found that 95.7% of them are men-headed while 4.3% are women-headed households. Only 2 % of the adopter households were headed by women and the remaining 98% by men. Likewise, there is a significant association between improved beehive adoption and literacy as 24 % of non-adopters and 56 % of the adopters can at least read and write with basic arithmetic skills.

Similarly, the survey result showed 55% of the adopters and 45% of the non-adopters have got extension service. Extension service here refers to advice, training, demonstration related to improved beehive construction and utilization. There is a significant association between the adoption of improved beehives and access to extension service. More adopters (53%) as opposed to only 47% of the non-adopters perceived that improved beehives are better in reducing the effect of drought on beekeeping as compared to the traditional ones Table 3.

Table 3: Summary of descriptive statistics for discrete variables by adoption

Variables	Values	Non-Adopters		Adopters		Total Sample		χ^2-Value
		N(194)	%	N(156)	%	N(350)	%	
SexHHH	Men	182.00	93.8	153.00	98.0	335.00	95.7	3.83**
	female	12.00	6.19	3.00	1.92	15.00	4.29	
ExtCont	Don't access	78	40.21	12	7.69	90	25.3	47.85***
	Access	116	59.79	144	92.3	260	74.3	
ClimPerc	Not perceive	152	78.35	74	47.4	226	64.6	36.12***
	Perceived	42	21.65	82	52.6	124	35.4	
EduLevl	Illiterate	147	75.77	69	44.2	216	61.7	36.4***
	Literate	47	24.23	87	55.8	134	38.3	
Off-inco	No	117	60.31	70	44.9	187	53.4	0.1041*
	Yes	77	39.69	86	55.1	163	46.6	
AcsCrdet	Don't access	189	59.62	128	40.4	317	90.6	23.93***
	Accessed	5	15.15	28	84.9	33	9.43	

Source: Computed from own survey data, (2018) Moreover, the livelihood of households within the farming community has been found to depend on a diverse set of income sources. Farmers in the study area are reported to earn income both from the farm and off-farm activities. The mean annual income of sample households is found to be ETB 13544.26 where there is a significant difference in mean annual income between adopters (ETB 19189.28) and non-adopters (9004.96). The chi-square (χ^2) analysis also revealed a significant mean annual off-farm income among the adoption groups in favour of the adopters. The chi-square test result also showed an association between access to credit and adoption were significantly associated.

On one hand, the age of the sample household heads ranged from 20 to 78 years with a mean of 48.8 years. On the other, the average number of economically active family members for adopters and non-adopters was 3.9 and 3.5 respectively with a significant mean difference Table 4. Similarly, the mean livestock holding of sample households was 4.48 TLU.

The average total land holding of the surveyed households has estimated to be 1.53 hectares with 1.37 hectares for adopters and 1.66 hectares for non-adopters with a significant t-value (Table 4). This result has shown that beekeeping does not require a huge land holding. To thrive as beekeepers, sufficient and fertile land would tend to consider beekeeping as a side-line practice rather than hugely investing labour and capital in modern beekeeping. However, a few Empirical studies stated that farm size does not affect the adoption of an improved hive (Wodajo, 2012).

Table 4: Summary of descriptive statistics for continuous variables by adoption

Variables	Non-Adopters (N=194)		Adopters (N=156)		Total sample (N=350)		T-value
	Mean	st.dev	Mean	st.dev	Mean	st.dev	
AgeBK	49.44	11.86	48.10	10.67	48.84	11.35	1.095
AdualtEqu	3.54	1.24	3.89	1.40	3.69	1.32	-2.535***
TLU	4.45	3.05	4.50	2.66	4.48	2.88	-0.166
ResdYr	13.16	7.47	39.04	16.18	24.7	17.70	-19.82***
LandSz	1.66	1.18	1.37	0.74	1.53	1.02	2.71***

Source: Computed from own survey data, (2018)

Note: *** represent statistically significant at 1% significance level.

Beekeepers' income source

In the study area, respondents depend on agriculture for their livelihood, employment, income earnings, food, and non-food production and consumption. Crop income (irrigated and rain-fed crops), off-farm, non-farm income, and income from livestock were the source of income in the study area. As stated in (Table 5), In the study area, as it is observed from the survey results the relative share of income from bee product to the total annual household income is the largest. Hence, beekeeping is the most important source of income in the study area. It is followed by livestock production, non-farm, and off-farm respectively. However, income from crop production is the lowest which indicates the absence of surplus cereal production.

Table 5: Beekeeper income comparison level by ETB

Income gained from	User (N=156)	Non –user (N=194)	Combined	Difference	T-test
	Mean	Mean	Mean	Mean	
Crop income	573	304	424	269	-1.86*
Off-farm income	880	344	583	535	-2.12**
Non-farm income	1929	591	1187	1338	-3.86***
Livestock income	5318.8	5242.9	5276.7	76	-0.2
Bee product income	10488.38	2522.59	6073	7966	-14.9***
Total income	19189.28	9004.96	13544.26	10184.32	-11.4***

*** p<0.01, ** p<0.05, * p<0.1 represents levels of significance.

Improved beehive adopters have significantly (1% levels) higher farming income & total income than non-user beekeepers. The survey result has revealed that the mean annual bee product income of the users was ETB 10488 (315%) higher than non-users (Table 5).

Beekeepers' Physical Asset Value

Household assets are vital resources for livelihood improvements. Similar to natural capital, access and owing physical assets were found to be an essential variable towards the enhancement of households' livelihoods (Abdelhak et al., 2012). It is difficult to determine the resale values of assets accurately. Respondents were asked to list their assets and evaluate the current local market value during the survey period. As shown in (Table 6) the mean asset value of beekeeper assets owned by the user is ETB 143750.3 (357%) higher than the non-user. The t-test result has revealed that the asset holding between the user and non-user has been found to be significant at 1% level confidence relative to the comparison group whose asset ownership is concentrated in the basic household items. This result shows that the adoption of improved beehive allows beekeepers to promote and expand their assets and activities which in turn improve their livelihood.

Table 6: Asset possession mean comparison

Variable	**User (N=156)**	**Non –user (N=194)**	**Combined**	**Difference**	**T-test**
	Mean	Mean	Mean	Mean	
Asset Value (AV)	143750.3	31397.52	81474.74	112352.7	-14.86***

* p<0.1 represents levels of significance.

3.2 Results of the Econometric Model

Factors influencing adoption of improved beehives

The study results (Table 7) have indicated that the level of education, the active labour force in terms of adult equivalent, access to credit and extension service, and beekeepers stayed in their prior permanent residence are determined by the probability of households' participation in improved beehive adoption. C*eteris paribus*, educated household heads have a 23% more chance of adopting modern beehives than illiterate ones. This result has expected that education must play a role in raising the ability to access and use information thereby improving people's awareness for informed decision making. The result is in line with previous results done by (Affognon et al., 2015), (Adgaba et al., 2014), and Tadele Adisu Haile Selassie, 2016).

Availability of family labour force has affected the adoption of improved beehive positively and significantly. This implies that labour is one of the most extensively used inputs of agricultural production including beekeeping in the study area. Farmers with large family size in terms of adult equivalent might significantly adopt the technology to satisfy the immediate need of their family.

Hence, it was hypothesized that households with a large family would adopt the technology more those that are not. The result is consistent with the findings of (Adgaba et al., 2014), (Ajao & Oladimeji, 2013), (Bekuma, 2018), and (Tadele Adisu Haile Selassie, 2016). On the other hand, access to extension service and credit has influenced the farm households' participation in improved beehive adoption positively. These results are confirmed with the findings of previous studies (Ajao & Oladimeji, 2013), (Affognon et al., 2015).

Table 7: ESR factors affecting adoption of improve beehive

Variables	Coefficient.	Robust Std. Err.	P>z
SexBK	.576	.541	0.286
AgeBK	-.082	.081	0.311
$AgeBK^2$	.0006	.0008	0.470
EduLevl	.592	.223	0.008
AdualtEqu	.214	.104	0.040
LandSz	-.007	.031	0.811
Gofincom	-.116	.274	0.672
TLU	-.008	.050	0.875
ExtCont	1.31	.315	0.000
AcsCrdS	1.162	.432	0.007
ResdYr	.091	.011	0.000
MBClimcr	.159	.236	0.497
_cons	-2.888	1.941	0.137
chi2(1)	8.62***		
Observation	350		

***, **, and * refers to statistical significance at 1%, 5%, and 10%.

Source: Computed from own survey data, (2019)

ESR model estimates the impact of improved beehive adoption on income & asset

According to Table 8, out of the total eleven explanatory variables, output for the income /outcome equation of the model, five variables are found to be significantly determinants of household income. These are the education level of beekeepers, cultivated land size, income-generating other than beekeeping, livestock holding, access to extension contact, and access to credit service. In general, the sign of coefficients of all variables have taken the researchers' prior expectation. Sex of beekeeper, beekeeper's education level, and extension contact on users, cultivated land size and off-farm income on non-users, and livestock holding on both (user & non-user) beekeepers' asset-building had significant effect with this concise background, the effect of the significant explanatory variables on beekeeper rural farm households' income level is discussed below.

Education is found to have a positive and significant influence on the income of households and livelihood improvement, and it is statistically significant at 1% level of significance. As hypothesized, its coefficient had a positive sign. Indeed, if the education of beekeeper household head raised by one level, beekeepers' income would rise approximately by 16.2% more than non-literate beekeepers while other variables keeping constant. The result of this finding is that education leads to proficient household management and, significantly improves economic performance as a whole. Similarly (Jehovaness A., 2010) suggests that the productivity of individuals with a higher level of education who are engaged in any agricultural activity is likely to be higher than that of less-educated farmers.

Cultivated land size: it was positively and significantly affected for both the non-user and user income at a 10% significance level. Households have cultivated land who can produce a relatively sufficient amount of crop on their own or through different contractual agreements such as sharecropping.

Income-generating other than beekeeping: it is found to have a positive and significant influence on the income of households, and it is statistically significant at 1% and 10 % level of significance respectively for non-users and users. This shows that non-farm income has a significant effect on the income of non-users' beekeepers more than the users one. Similarly (Abraham Gebrehiwot, *et al.*, 2015) households' engagement in other income-generating activities might not have a higher probability of participation in agricultural technology adoption in a sense that the households with larger other income might not necessarily participate in beekeeping practice.

Livestock holding measured in Tropical Livestock Unit (TLU) is found to have a positive and significant influence on income and asset formation of households, and it is statistically significant at a 1% level of significance. It contributes to total household income directly through the sale of livestock and their products, and indirectly through use as a source of draught power for crop production activities. Moreover, Livestock has a direct role in raising agricultural productivity that can help households stabilize consumption by absorbing income shocks that might arise from crop failures triggered by natural disasters. Oxen are the sole draught power sources and hence lack of oxen besides its negative effect on land productivity, it also signifies a lower economic status of farm households. A similar result was reported by other studies (Abraham Gebrehiwot, *et al*., 2015), (Bekele Shiferaw, *et al*., 2014), and (Menale Kassie, *et al*., 2014)

Access to credit affected user household income-generation positively and significantly at a 1% significance level. The positive sign indicates that household who uses credit does initiate investment in farm and non-farm practice for their income-generating activities (IGA) and it enables the beekeeper households to purchase farm inputs such as bee colony, improved beehive and other necessary accessory timely which all makes the production and productivity of an apiary or bee yard increases on a given farm plot. This is consistent with other studies such as (Ajao & Oladimeji, 2013), (Aikaeli, 2010).

The result of σ_{1u} (0.36) and σ_{2u}(0.41) represent the covariance of the selection and the outcome equation of adopters and non-adopters respectively, which is non zero and positive indicates the presence of endogeneity. That is to say, we can conclude to reject the null hypothesis of the absence of sample selectivity biased.

In addition to the endogeneity test, ρ_j (correlation coefficient between the error term in selection equation with outcome Equation (1) i.e., adopter (-0.42), and with outcome Equation (2) i.e., nonadopter (0.58) provide economic interpretation depending on their signs. The opposite signs indicate that users enjoy above-average income and fixed asset holding once having improved beehive. The coefficient **ρ**1 and **ρ**2 can give evidence for model consistency under a condition **ρ**1 (-0.42) < **ρ**2 (0.58) or σ_{1u} (0.36) is < σ_{2u} (0.41). This implies that the user enjoys income and fixed asset level than they would if they did not have to adopt (Trost, 1981).

The parameter has a negative sign in the equation for adopters, implying that beekeepers that adopt improved beehives have a significantly higher income more than a beekeeper who is randomly selected from the sample.

Table 8: Endogenous switching regression model estimates for the outcome equation

Variable	Income (AI)		Asset Value (AV)	
	Non-User	User	User	Non-User
SexBK	-0.117	0.0946	0.929**	0.113
	(0.131)	(0.211)	(0.436)	(0.098)
AgeBK	0.0103	0.00677	0.0103	0.00292
	(0.0194)	(0.0125)	(0.0257)	(0.0144)
AgeBK2	-0.000136	-3.57e-05	-8.94E-05	-4.99E-05
	(0.000190)	(0.000116)	(0.000238)	(0.000141)
EduLevl	0.0187	0.181***	0.208*	0.0477
	(0.0726)	(0.0658)	(0.133)	(0.0543)
AdualtEqu	0.0387	0.0154	0.0555	0.00556
	(0.0297)	(0.0252)	(0.0516)	(0.0222)
LandSz	0.0133*	0.00356*	0.0159	0.00986*
	(0.00744)	(0.0115)	(0.0233)	(0.00553)
Gofincom	0.348***	0.151*	0.0235	0.0994*
	(0.0752)	(0.0828)	(0.17)	(0.0562)
TLU	0.0906***	0.0355***	0.0524*	0.0301***
	(0.0120)	(0.0131)	(0.0272)	(0.0089)
ExtCont	0.00532*	0.0613*	0.238*	0.049
	(0.0654)	(0.112)	(0.0229)	(0.0478)
AcsCrdS	0.228	0.215***	0.259*	0.0515
	(0.192)	(0.0806)	(0.0164)	(0.148)
Constant	7.798***	8.634***	9.069***	9.603***
	(0.457)	(0.420)	(0.87)	(0.34)
σ_i	0.41**(0.024)	0.36**(0.020)	.75***(.042)	.304***(.015)
ρ_i	0.59**(0.18)	-0.43**(0.20)	-.414**(.179)	-.0135*(.173)
Observations	194	156	156	194

LR test of indep. eqns. :	ESR
chi2 (1) 8.6**	Wald chi2 (11) 110.7***
Log likelihood 239.35	Number of obs = 350

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Source: own survey result, (2018)

Table 9 presents the average treatment effect of adopting improved beehives on smallholder's income and asset formation. The average expected income earned per household per year for households that adopted improved beehives is estimated to be16, 566 ETB, while it is about 6848 ETB for those households that did not adopt the entitative. T, and the average asset values for the adopters is 119158.3 ETB while 28213.45 ETB for non-adopters. This simple comparison, however, may mislead to conclude that on average the adopter households earned about 9718 ETB (that is 141.91 %) more income than the households that did not adopt, and 90944.85 ETB (322%) more average asset value than non-users. Hence, the counterfactual case (c), and (g) in income and asset equation referring to the income and asset of beekeepers who actually adopted would have earned if they don't adopt was used as a comparison group. Accordingly, compared to the counterfactual (10489.47 and 44995.07 ETB) actual adopters have earned an additional 6076.97 ETB and 74163.25 ETB income and asset value, implying that adoption of improved beehives leads to 57.93 % and 164.8% income and asset value increment respectively.

Table 9: Impact of adopting improved beehive: treatment effect, and heterogeneity effect.

Outcome Var.	Sub-sample	Decision stage		Treatment effect
		To adopt	Not to adopt	
Annual income	Beekeeper's who adopted	(a) = 16566.44	(c) = 10489.47	ATT= 6076.972
	Beekeeper's who did not adopt	(d) =14717.39	(b) =6848.072	ATU=7869.316
	Heterogeneity effect			TH=-1792.34
Asset Value	Beekeeper's who adopted	(e) = 119158.3	(g) = 44995.07	ATT= 74163.25
	Beekeeper's who did not adopt	(h) =92442.4	(f) =28213.45	ATU=84228.99
	Heterogeneity effect			TH=-10065.7

Source: computed from survey data (2018)

Likewise, the ATU value can be interpreted as actual non-adopters would have earned 7869 & 84228.99 ETB more income and fixed asset value if they decide to adopt. Here it is important to note that the impact from adopting a beehive is even higher for actual non-adopters in the counterfactual case. This is clearly shown in the average transitional heterogeneity effect i.e., the impact of adopting improved beehives on income and asset value is smaller by 1792.34 and 10065.7 ETB for households that did adopt as opposed to those who did not respectively. These results imply that there are systematic socioeconomic different characteristics between the two groups, and self-selection is biased on technology adoption. It also indicates that resolving barriers to adopting beehives would help to improve the overall income and livelihood of the community at large.

4. Conclusion and Recommendation

This study has analysed the determinants of households' decision to adopt improved beehive and its impact on their annual income and asset value. The study was done in Bugina district, northern Ethiopia in eight honey-producing randomly sampled *Kebeles*. Of the total 350 sample households, 44.57% of them were adopters.

Based on the results of this study, three main conclusions are drawn. First, the group of households that did adopt beehives has systematically different characteristics as opposes to the group of beekeeper households that did not adopt. Second, the adoption of improved beehives increased beekeepers' income and fixed asset formation; however, beekeepers who have decided to adopt are likely to have higher income and fixed asset value compared to actual non-adopters. Third, the transitional heterogeneity impact of adopting improved beehives on beekeeper's income and the fixed asset value is smaller for households that adopt than for the rural beekeeper households that did not adopt in the counterfactual case (i.e. if non-adopters were adopted), on the other hand, the negative sign of transitional heterogeneity indicates the presence of improved beehive adoption biased (self-selection or non-randomized) problems. These results are particularly important to design effective adoption strategies to fully realize the potential impacts of improved beehive adoption on the income and overall livelihood of rural beekeeper households. However, sustainable returns to beehive adoption are influenced by the education level, beekeepers' stability on their prior residence, credit service, extension contact, and beekeepers' perception towards improved beehive comparative advantage. Therefore, effective access to education, credit service, extension service, and awareness creation will facilitate adoption participation and thereby income and fixed asset formation of rural beekeepers.

However, the authors point out that the modernization of production, the education of beekeeper improvements are essential parts of the increased competitiveness of the sector. The authors stress the necessity of improving all the factors of competitiveness in the apiculture sector, with their economic strength and the level of the commercial attitude.

Although the study has revealed that adoption of improved beehive could increase rural beekeeper‘s income, and fixed asset formation, there is no sufficient, protective, and sustainable shade. Due to this with climate variability bees absconding faced, even for those who take part in adoption. Therefore, the district or regional level government has to encourage adult education, awareness creation via frequent extension package, and material support to beekeepers to undergo expanded improved beekeeping practice. It is recommended that the responsible body to work hard on the rural beekeepers to aware of the comparative advantage of the improved beehive. The government should support and encourage rural farmers to be stable within their prior residence. Furthermore, returns to adoption are influenced by the credit access, in part because of the lack of initial capital for input and accessory purchase the beekeepers faraway to adopt in turn to pick up their income. Therefore, effective access to education level, active labor force, credit, and extension service will facilitate adoption participation.

Since the study has directed its resources exclusively among the members of the society of beekeepers in the specific district of “Northern Ethiopia”, it is questionable if the conclusions could be generalized to be taken as representative. The researchers suggest that similar research be carried out in different locations of the country and in different beekeeping societies, to establish other possible influences. Then, the findings of the study could be compared to the sociocultural factors in different regions and the beekeepers’ willingness to adopt new beekeeping technologies or professional advice from specialized bodies.

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