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The Determinants of Agricultural Output Growth in Ethiopia

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ABSTRACT

The purpose of this paper is to look into the determinants of agricultural output growth in Ethiopia. Along with this general objective, this study intends to look at the trend of total factor productivity growth in the agricultural sector and its contribution to agricultural output growth. Using autoregressive distributed lag model bounds testing, this research estimates the long-run and short-run cointegration between agricultural output growth and the total factor productivity. In this study, Augmented Dickey-Fuller and Phillip-Perron unit root tests were used to find out the order of integration of the variables. The selected econometric model goes through all the diagnostic tests and confirms the absence of heteroscedasticity, serial correlation, and normality. The finding of this study indicates that total factor productivity, agricultural land, agricultural machinery, and fertilizer all have a significant and positive effect on the growth of agricultural output. According to the findings of this study, total factor productivity is the primary driver of agricultural output growth. Therefore, as it has played a strong role in developed countries' agriculture, total factor productivity has the potential to be a game-changer in terms of sustainable agricultural growth. Taking into account the findings of this study, we strongly recommend that the government of Ethiopia should devise policies in the agricultural sector that could enhance the level of total factor productivity.

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Introduction

The agricultural sector has played a remarkable role in the economic development process. Simply put, it has already contributed significantly to the economic prosperity of advanced countries, and its role in the economic development of less developed countries is critical (Praburaj, 2018). In Africa, agriculture is one of the most important economic sectors, with significant growth potential. In Sub-Saharan Africa (SSA), approximately 60 percent of the population lives in rural areas, and almost all of them rely on agriculture for their livelihoods. Currently, agriculture represents about 15 percent of value-added gross domestic product (GDP) and more than half of employment, which indicates the pivotal role of agriculture in SSA (WDI, 2020).

Similarly, agriculture has been known in past decades for its significant role in the Ethiopian economy. The sector employs 85 percent of the population, contributes 44 percent of the country's GDP, and accounts for 85 percent of export earnings. The country's goal of achieving overall economic growth is heavily reliant on the performance of the agriculture sector (UNDP, 2016). However, agriculture has recently been found to contribute less to the Ethiopian economy than it has in previous decades. It accounted for approximately 34 percent of GDP. An estimated 79 percent of the population lives in rural areas, and nearly all of them rely on agricultural production for a living (WDI, 2020). Furthermore, the agricultural sector employs approximately 65 percent of the country's total working population (ILO, 2020).

Even though the sector's share has been declining over time, its contribution to economic growth is not minor. Agriculture is the main source of inputs for industry and the service sector. Almost all major industries and services sectors are getting their raw materials mainly from agriculture. It is impossible to achieve accelerated growth and sustainable development unless industry and services grow in tandem with agriculture. In less developed economies such as Ethiopia, inputs for industrial development must be generated through a strong link between agriculture and industry (Ministry of Finance and Economic Development, 2010).

Agricultural output is influenced by a variety of factors, including agricultural inputs, the use of new technology, and the efficiency with which inputs are utilized (total factor productivity). As a result, it is critical to address these variables to improve agricultural output, which has a significant impact on the performance of other sectors of the economy. Among other things, total factor productivity is a major focus of this research. It measures the efficiency with which agricultural land, labor, capital, and other agricultural inputs are used to produce a country's crop and livestock output. When more output is produced with the same amount of resources (resources are used more efficiently), total factor productivity rises. Thus, increasing agricultural production efficiency to get more output from the same amount of resources is critical for improving agricultural output.

Although there have been some attempts to investigate the determinants of agricultural output growth in Ethiopia, they have been few and far between. Fantu's (2015) research was the first in this field. He found that the contribution of TFP growth to agricultural output growth is critical. However, we argue that this study had suffered from certain weaknesses to the extent that the researcher excluded the livestock sub-sector from the agricultural output, despite its significant contribution in Ethiopia. The current study includes the contribution of livestock to agricultural output growth to examine the effect of TFP on the sector's growth. Furthermore, the time used in the preceding study was too short to draw sound policy implications because short time series data cannot explain the sector's dynamic nature. However, the current study used the Autoregressive distributed lag model over a relatively long period, from 1981 to 2019.

The general objective of this study is to look into the determinants of agricultural output growth in Ethiopia. Along with this general objective, the study intends to examine the trend of TFP growth in the agricultural sector and its contribution towards agricultural output growth. The remaining sections of this paper are organized as follows: Section two is devoted to a theoretical and empirical review. Section three describes the methodological framework used in the current study. This section also covered data description and specification of the model. The study's findings were presented in section four. Conclusions and policy recommendations were provided in this section five.

Literature Review

Theoretical Literature

This section discusses various theories that can explain the source of agricultural output growth. Among all frontier models, the conservation model, diffusion model, and high-payoff input model are a few examples.

Frontier Model

The frontier model, also known as the resource exploitation model, entails expanding cultivated or grazed land to achieve agricultural growth. For example, European settlement in new areas such as Australia, North and South America during the 18th and 19th centuries demonstrates the role of increased cultivated area in agricultural output growth. Similar events occurred in Ethiopia throughout the Derge and Ethiopian People's Revolutionary Democratic Front (EPRDF) settlement programs, demonstrating the importance of the frontier model in Ethiopia. In nutshell, the model proposes that agricultural output growth occurs as a result of increased cultivated area (Udemezue and Osegbue, 2018).

Conservation Model

The conservation model of agricultural growth assumes that land for agricultural production is becoming scarce, and that soil exhaustion will occur over time as land is intensively used. As a result, the model proposes that better use of agricultural resources through integrated conservation of available soil and integrated crop-livestock husbandry (because livestock provides manure) combined with limited external inputs contribute to sustainable agricultural production by preserving organic soil. In summary, the model suggests that agricultural inputs such as plant nutrients and animal manures that maintain soil fertility should be used to increase agricultural output (Ruttan, 1977).

Diffusion Model

The diffusion model of agricultural output growth entails the process by which a new agricultural production practice spreads from farmer to farmer via domestic or international technology transfer. According to this model, the most effective way to increase agricultural output is to effectively disseminate better husbandry practices among farmers or regions. It is the fact that there is a difference in production between different regions due to differences in production methods or technical knowledge. This is dependent on the establishment of a functioning agricultural research station and extension services. Farmers would quickly adopt new production techniques if the sector was capable of organizing the extension program (Udemezue and Osegbue, 2018).

High-payoff Input Model

According to this model, farmers in traditional agriculture remained poor because there were insufficient technical and economic opportunities in the majority of less developed countries. As a result, the high-payoff input model of agricultural growth contends that an investment designed to make modern high-payoff inputs available to farmers in less developed countries is critical to transforming traditional sector agriculture into a productive source of economic growth. This model necessitates investment in the following areas: (i) public and private investment in research to generate new technical knowledge, (ii) investment in the industrial sector to develop, produce, and market new technical inputs, and (iii) investment in farmers to acquire new knowledge and effectively use new inputs. Less developed countries can achieve high rates of agricultural output growth if they invest effectively in these categories. The enthusiasm with which this model has been received is due to the high rates of return on public investment in agricultural research and the success in developing new high- productivity grain varieties suitable for the tropics. In the case of Ethiopia, an attempt was made to introduce this model in the Chilalo district, but it was unsuccessful due to a lack of investment in the aforementioned requirements. In short, the model emphasized increased investment in technology as well as farmer training to help them adopt these technologies (Ruttan, 1977).

Empirical Studies

Villoria (2019) outlined that there is a debate about how to increase agricultural production between input intensification and land extensification. But, over the last three decades, the majority of growth in agricultural output is not explained by either of these processes, rather by increases in the efficiency with which both land and non-land inputs are used. Such efficiency, also known as TFP, differs from input intensification in that input intensification increases yields by using more non-land inputs such as fertilizers, labor, machinery, energy, or water, but it is not linked to gains in resource efficiency. TFP is also distinct from extensification (bringing new lands into production), which agricultural producers have been doing for a long time. Although both intensification and extensification increased agricultural output, they also resulted in biodiversity loss, greenhouse gas emissions, and soil and water quality degradation. This indicates that TFP growth is important for the economy as a whole, and agricultural growth in particular. Fuglie (2015) confirmed that the majority of growth in global agricultural output since the 1990s has come from more efficient use of labor, land, capital, and inputs, which boosts agricultural TFP. More specifically, since the 1990s, TFP growth has outpaced input to use as the primary source of agricultural growth, accounting for roughly three-quarters of global agricultural growth and nearly all agricultural growth in developed countries.

Kwadwo and Samson (2012) opined that agricultural output in African countries has increased over the last decade. This expansion was primarily driven by area expansion rather than productivity gains. The amount of suitable land available for cultivation is decreasing in most countries, particularly as concerns about deforestation and climate change grow. As a result, limited future agricultural expansion in most countries will need to place a greater emphasis on productivity growth.

Ali *et al.* (2008) investigated total factor productivity growth in agriculture in Pakistan: trends over different time horizons from 1971 to 2006. Their research estimated TFP growth rates over several decades. Their findings revealed that the rate of TFP growth was lowest in the 1970s (0.96 percent) and highest in the last six years of the study period (2.86 percent). TFP growth rates were 2.24 percent in the 1980s and 2.46 percent in the 1990s. TFP growth contributed approximately 33 percent of total agricultural output growth during the 1970s, and this contribution increased to 83 percent during the final six years of the study period. TFP growth contributed 53 and 81 percent of total agricultural output in the 1980s and 1990s, respectively. Due to limitations in cultivated area expansion, intensification of input use, population growth, and meeting the challenges of food security, they recommended an increase in productivity growth rather than an increase in input use.

Upali (2017) has researched boosting rural and agricultural productivity for inclusive growth in Asia and the Pacific. He stated that in India from 2001 to 2014, TFP became the dominant factor in agricultural output growth, despite the fact that area expansion and input intensification continued to play important roles. In China, the role of agricultural intensification in output expansion had essentially ended by the late 1980s. In subsequent periods, the use of inputs per area has been dominant, and TFP growth has recently begun to play a dominant role in agricultural development. In short, the significance of agricultural total factor productivity has grown in recent years.

Fantu (2015) provided a thorough analysis of Ethiopia's great run: the growth acceleration and how to pace it. According to his findings, crop output grew at an average annual rate of 8.8 percent between 2004 and 2014. Increases in the amount of labor involved in crop production accounted for approximately 31 percent of this growth on average. Likewise, cultivated land expansion accounted for roughly 13 percent of crop production growth. Another 11 percent of the growth was due to better seed use, and 8 percent was due to the use of artificial fertilizers. Rural roads, after all, contribute 3.3 percent to overall crop production growth. Changes in TFP, which were around 22.4 between 2004 and 2014, are another important factor in crop output growth. This was related to farmers' improved management skills as a result of better education or access to better information. Based on his discussions, we can conclude that intensification (increase in non-land input) contributed approximately 66 percent, extensification (agricultural land expansion) contributed approximately 13 percent, and TFP contributed approximately 22 percent to crop output growth. His research also shows that the contribution of area expansion is decreasing over time.

Data and Methodology

The study used secondary data from National Bank of Ethiopia (NBE) that covers the period 1981 - 2019. The econometric techniques were used to analyze the data. As a theoretical framework, we used the Cobb-Douglas production function in this study.

$$Y=AK^{\alpha}L^{\beta}AL^{\mu}F^{\gamma} \quad (1)$$

Where α, β, μ, and γ are the share of inputs. The above equation can be transformed into a natural logarithm form as below.

$$LnAOG= \theta lnTFP+\alpha lnK+ \beta lnL+ \mu lnAL+ \gamma lnF+ei \quad (2)$$

Definition and Measurement of Variables Used in the Model

Agricultural output growth (AOG) is the total value of crop and livestock commodities produced, measured in thousands of dollars. Total agricultural land (AL) is measured in hectares of rain-fed cropland equivalents. This includes both rain-fed cropland and irrigated cropland, as well as permanent pasture. Capital (K) is the stock of agricultural machinery. Because capital is a combination of various factors, it is difficult to find comprehensive and accurate data for it. For this study, we were forced to proxy it by the total stock of farm machinery. Labor (L) refers to the number of economically active adults working in agriculture. Fertilizer (F) is a chemical substance that is applied to crops to increase their productivity. The fertilizers contain essential nutrients for plants such as nitrogen, potassium, and phosphorus. It was measured in Metric tons.

Total Factor Productivity (TFP) is an economic efficiency indicator that accounts for some of the differences in output per capita. It is the proportion of agricultural output growth that cannot be explained by increases in traditionally measured inputs such as labor, capital, and land used in production. TFP is measured as the ratio of total agricultural output to total inputs such as labor, capital, and land. Production can be increased without increasing productivity by utilizing more resources. On the other hand, by using less input, productivity can be increased while maintaining the same level of output. However, it is widely assumed that productivity refers to a production system's ability to produce more economically and efficiently.

Autoregressive Distributed Lag Approach of Cointegration Test

To see the long-run relationship between AOG and its determinants, we have to dwell sometimes on the cointegration test. There are numerous cointegration tests, including the Engle and Granger tests, maximum likelihood-based Johansen, and Johansen-Juselius tests. These methods require that all variables in the model be stationary at the first difference, i.e. (1). Poor performance in the case of a small sample is another limitation of these methods. Compared with the previously developed Engle and Granger (1987) and Johansen and Juselius (1990) cointegration method, the ARDL approach to cointegration has many advantages. The first advantage is that it can be applied to variables integrated into order zero, order one, or fractionally integrated. Second, it is relatively more effective when the sample size is small and limited. Another advantage is the possibility of obtaining unbiased estimates from the long-run model (Belloumi, 2014). Considering the above advantages and having a small sample size, the following ARDL model is applied to identify the long-run relationship and short-run dynamics of AOG and its determinants in Ethiopia.

$$Ln(AOG_t) = \beta + \sum_{i=1}^{p} \beta_{1i} Ln(AOG_{t-i}) + \sum_{i=0}^{q} \beta_{2i} Ln(TFP_{t-i}) + \sum_{i=0}^{q} \beta_{3i} Ln(L_{t-i}) + \sum_{i=0}^{q} \beta_{4i} Ln(K_{t-i}) + \sum_{i=0}^{q} \beta_{5i} Ln(AL_{t-i}) + \sum_{i=0}^{q} \beta_{6i} Ln(F_{t-i}) + \beta_7 Ln(AOG_{t-i}) + \beta_8 Ln(TFP_{t-i}) + \beta_9 Ln(L_{t-i}) + \beta_{10} Ln(K_{t-i}) + \beta_{11} Ln(AL_{t-i}) + \beta_{12} Ln(F_{t-i}) + ei \quad (3)$$

Where p and q are optimal lag length, β1, β2, β3, β4, β5, and β6 represent short-run dynamics of the model, and β7, β8, β9, β10, β11, and β12 are long-run elasticities. Before running the ARDL model we have tested the level of integration of all variables because if any variable is I (2) or above, the ARDL approach is not applicable. For this, we used the Augmented Dickey-Fuller test (ADF) and Phillip-Perron test (PP). To find the long-run relationship, we have conducted a bounds test of equation (3) using F-statistic with two bounds, i.e. lower bound and upper bound. If there is no cointegration in equation (3) we analyze only short-run relationships but if there is cointegration we must analyze both short-run and long-run relationships. So, if the variables are found to be co-integrated, that is there exists a linear, stable, and long-run relationship among variables, such that the disequilibrium errors would tend to fluctuate around zero mean, equation (3) can be rewritten in the following form**:**

$$Ln(AOG_t) = \beta + \sum_{i=1}^{p} \beta_{1i} Ln(AOG_{t-i}) + \sum_{i=0}^{q} \beta_{2i} Ln(TFP_{t-i}) + \sum_{i=0}^{q} \beta_{3i} Ln(L_{t-i}) + \sum_{i=0}^{q} \beta_{4i} Ln(K_{t-i}) + \sum_{i=0}^{q} \beta_{5i} Ln(AL_{t-i}) + \sum_{i=0}^{q} \beta_{6i} Ln(F_{t-i}) + \lambda EC_{t-i} + et \quad (4)$$

Where P and q represent the optimal lag length, λ is the speed of adjustment parameter and EC represents the error correction term derived from the long-run relationship as given in equation (4).

Results and Discussions

This section summarizes the study's findings and discussions. Before analyzing the econometric output, it is necessary to examine the trend of variables over time, which provides us with a general overview of the direction of the relationship.

Trend of Agricultural Output Growth and Agricultural Total Factor Productivity growth

The graph below depicts the trends in agricultural TFP growth and AOG from 1981 to 2019. As shown in the graph, the trend of agricultural TFP growth in Ethiopia has been fluctuating. Annual agricultural TFP growth in Ethiopia was high in 1996, 2002, and 2010, but low in 1992, 1998, and 2001This trend indicates that agricultural TFP growth and AOG mirrored each other over the study periods. This suggests that changes in AOG are determined by agricultural TFP growth.

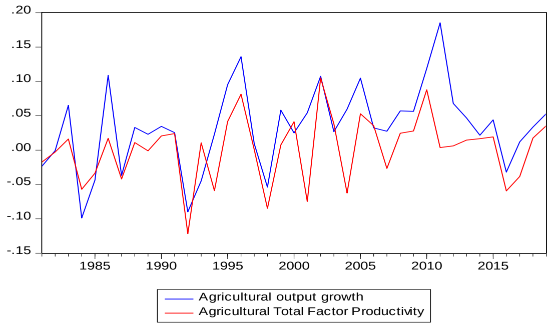

Figure 1. Trend of agricultural output growth and agricultural total factor productivity

Time Series Analysis

Unit Root test

The unit root is a property of some random processes (such as random walk), and it can cause problems with statistical inference in the time series model. We're looking for the unit root in our data because it's a time series. Before we can use the data for observation, it must not have a unit root or be stationary. If the collected data is not stationary, we must make it stationary before proceeding with regression and inference. Regressing non-stationary time series yields erroneous results that can lead to incorrect policy recommendations. According to Gujarati (2008), stationary time series is important for at least two reasons. First, if the time series is not stationary, we can only study its behavior during the period in question. As a result, each time-series data set corresponds to a specific episode that cannot be expanded to other periods. Second, if we have two or more non-stationary time series, regression analysis involving these time series may result in spurious or nonsense regression. The ADF and PP unit root tests were used by the researcher to determine whether the data had a unit root or not. Table 1 shows that, except labor, all variables are stationary at the 1% level. However, labor is at a stationary at 5%. In general, at the 5% level, all variables are stationary.

Lag Length Selection Criteria

In economics, the dependence of a variable (regressand) on other variables (regressors) is rarely instantaneous. Very often, a regressand responds to regressors with a lapse of time which is called a lag. As a result, in time series analysis, some caution must be exercised when including lags in a model. The question is how many lags should be included in a model. In reality, there is no hard and fast rule for determining lag length. Too much lag increases the likelihood of multicollinearity problems in the model, in addition to decreasing degrees of freedom, which makes statistical inference unstable. Similarly, including too few lags will result in specification errors. As a result, before estimating a time series equation, the maximum lag length must be determined. The simplest way to determine the optimal lag length is to use a criterion such as the Akaike Information Criterion (AIC) / Schwarz Criterion (SC) / Hannan-Quinn (HQ) and select the model with the lowest values of these criteria. The selected lag order is indicated by an asterisk sign (*) in table 2, which is distributed between lags zero and one, but mostly on lag order one. As a general rule, choose the criterion with the lowest value, which is the AIC at -14.305 and HQ at -13.66. This is because the lower the value, the better the model. We can conclude that the optimal lag length for the model is one and the best criterion to use is AIC and HQ.

Bound Test

Pesanran et al. (2001) devised the ARDL bounds testing approach to cointegration to test the presence of a long-run relationship between the variables. As a result, the presence of cointegration among the series was tested in this study using the bounds testing approach. As a result, the table 3 shows that the computed value of F-statistic (27.12) is greater than the upper bound critical value of F-statistic at 1%, 5%, and 10%, allowing us to reject the null hypothesis of no long-run equilibrating relationship. As a result, we conclude that the variables have a long-term relationship.

The long-run coefficients are estimated after checking for long-run cointegration between the dependent and explanatory variables.

Estimated Long-Run Coefficients from ARDL Approach

Table 4 shows the long-run results of the ARDL model. The findings confirmed that agricultural TFP growth is the most significant variable of AOG in Ethiopia. There is a positive and significant relationship between AOG and agricultural TFP growth at 1 percent of the significance level. It implies that if agricultural TFP increases by 1 percent, in response there will be an increase of agricultural output by 1.04 percent. We can also say that a 100 percent increase in TFP brings about 104 percent (more than double) addition to AOG. This is because over time farmers became relatively efficient in using their resources and managing their production practice that helps to boost agricultural output. This finding goes in line with Alhassan, H. (2021), Poapongsakorn, N. (2006), Suphannachart, W and P. Warr. (2010).

Table 1. Result of unit root test for the variables

Variables	Unit Root Test						Order of integration
	ADF test at level			PP test at level			
	t-Statistic	TCV	Prob	t-Statistic	TCV	Prob	
LnAOG	-4.67928	-3.61558	0.0005	-4.67928	-3.61558	0.0005	I(0)
LnTFP	-6.85680	-3.61558	0.0000	-6.86993	-3.61558	0.0000	I(0)
LnL*	-3.26313	-2.94114	0.0239	-3.36705	-2.94114	0.0186	I(0)
LnAL	-4.78968	-3.62678	0.0004	-8.57852	-3.61558	0.0000	I(0)
LnF	-7.24339	-3.62102	0.0000	-11.5451	-3.61558	0.0000	I(0)
LnK	-6.16199	-3.61558	0.0000	-6.16199	-3.61558	0.0000	I(0)

TCV: Test critical values, *show significance level at 5 percent levels.

Table 2. Optimal lag length for the model

VAR Lag Order Selection Criteria						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	259.5258	NA	4.50e-14	-13.70410	-13.4428*	-13.61200
1	306.6494	76.41663*	2.54e-14*	-14.3053*	-12.47677	-13.6607*
2	339.1613	42.17758	3.60e-14	-14.11683	-10.72084	-12.91958

* indicates lag order selected by the criterion

Table 3. ARDL bound Test results

F-Bounds Test Null Hypothesis: No levels relationship				
Test Statistic	Value	Significance	I(0)	I(1)
F-statistic	27.12	10%	2.08	3
K	5	5%	2.39	3.38
		2.5%	2.7	3.73
		1%	3.06	4.15

Table 4. Estimated long-run coefficients from the ARDL approach

Dependent variable: AOG				
Regressor	Coefficient	Std. Error	t-Statistic	Prob
LnK	0.029601**	0.010791	2.743123	0.0100
LnL	-0.406063	0.609266	-0.666480	0.5100
LnF	0.058368*	0.013982	4.174552	0.0002
LnTFP	1.043628*	0.137003	7.617555	0.0000
LnAL	0.268672*	0.093910	2.860944	0.0075
C	0.033619	0.018966	1.772611	0.0861

Note: ** and * are significance levels at 5% and 1% respectively.

Table 5. Estimated short-run coefficients using the ARDL approach

Dependent variable: AOG				
Variable	Coefficient	Std. Error	t-Statistic	Prob
C	0.030704	0.017615	1.743057	0.0912
LnAOG (-1)	-0.913278*	0.091148	-10.01977	0.0000
LnK	0.027034**	0.010520	2.569704	0.0152
LnL	-0.370849	0.554840	-0.668389	0.5088
LnF	0.053306*	0.011189	4.764201	0.0000
LnTFP	0.953123*	0.112711	8.456333	0.0000
LnAG	0.245372*	0.077570	3.163255	0.0035
CointEq(-1)	-0.913278*	0.060676	-15.05161	0.0000

Note: ** and * are significance levels at 5% and 1% respectively.

Over the study period, the last three decades, total factor productivity has driven the majority of the growth in agricultural production in Ethiopia. As a result, maintaining agricultural growth is vital since the majority of impoverished people who reside in rural areas rely on agriculture for a living, either directly or indirectly. Environmental degradation and concern about climate change, diminishing returns on factor inputs, decreasing arable land, decreasing water supplies and other natural resources, and rising fuel and fertilizer prices are all posing difficulties to agriculture. To sustain agriculture, we must focus on the elements that most influence agriculture. According to the findings of this study, total factor productivity is one of the primary determinants of agricultural growth in Ethiopia, which can be determined by factors such as technical change (agricultural research and extension services), efficiency gains, economies of scale, and case-specific factors. The successful use of these components can boost total factor productivity, implying greater agricultural production.

Fertilizer is another significant factor of AOG. The effect of fertilizer on AOG is significant at a 1 percent level of significance. The coefficient 0.058 of fertilizer shows that a one percent increase in fertilizer leads to a 0.058 percent increase in AOG in the long run. The fertilizer import and its use become increasing in the past two decades and this has a direct implication on agricultural production. Because Ethiopia has depleted soils (International Fertilizer Development Centre, 2012), the application of fertilizer activates soil fertility which helps farmers to raise their production. The need to increase agricultural production at the national level to meet our needs requires the usage of improved inputs that cannot be productive without being supported by fertilizer. In this regard, fertilizers are becoming increasingly important and our findings show that agricultural production and fertilizers have a strong relationship in Ethiopia over the study period. Though fertilizer application promotes agricultural output, its contribution is non-sustainable. This is because it has potential costs for the environment. This is associated with increased use of fertilizer and other chemical inputs that negatively affect water, air, soil, biodiversity, and other parts of the ecosystem in which our country is not in a position to control the fertilizer side effects. So, optimization of fertilizer usage in agricultural production is of critical importance. This finding goes in line with Tilmanet et al (2002).

At one percent level of significance, the effect of agricultural land on agricultural output is positive and statistically significant. The coefficient 0.27 of agricultural land indicates that a one percent increase in agricultural land improves the agricultural output by 0.27 percent in the long run. It is a fact that the area under cultivation became increasing (new lands have been brought to cultivation) over time in Ethiopia. This implies that as the area under cultivation expands the output increases. It is a fact that in Ethiopia, for a long period of time, agricultural output increased from the increase in area under cultivation. This is finding is in line with Cheru et al., (2019). But, to what extent the expansion of area under cultivation continues to increase agricultural output with little suitable agricultural land remains a question. This indicates that the expansion of area under cultivation is not the sustainable source of agricultural output growth as we have a limited supply of agricultural land.

At a five percent level of significance, the effect of machinery on agricultural output is positive. The coefficient 0.03 of machinery indicates that a one percent increase in agricultural machinery improves the agricultural output by 0.03 percent in the long run. Among many reasons why agricultural production in Ethiopia is below its demand to achieve food security is that the production was undertaken by traditional tools with lower productivity. To modernize the production practices, agricultural machinery such as tractors and harvesting tools imports have been increasing over time in Ethiopia which allows for better production practices. By its nature, agricultural machinery reduces the quantity of labor and raises the speed of work because timing is crucial. Hence, with farming machinery, farmers can confirm they are as productive as possible. The results presented in this paper signify the importance of agricultural TFP growth in the sector. This finding is supported by Takeshima, H. et al (2013), and Zhang et al (2017).

Estimated Short-Run Error Correction Model Using ARDL Approach

According to the estimated result given in the table 5, the effect of agricultural TFP on AOG is once again the essential variable with the largest coefficient which had a positive and significant effect in the short-run. Its partial elasticity is about 0.95 percent at a 1 percent significance level in the short-run. This indicates that a 1 percent improvement in agricultural TFP increases the agricultural output by about 0.95 percent in the short-run. We can also say that the 0.95 value of the coefficient of agricultural TFP tells that a ten percent increase in TFP brings about a 9.5 percent addition in AOG in the short run, which needs more emphasis from policymakers.

Another result presented in table 5 is agricultural land. The partial elasticity of AOG to the change in the agricultural land is positive and significant at a 1 percent significance level. The short-run coefficient value of 0.25 for the agricultural land shows that a 10 percent increase in the agricultural land increases the agricultural output by 2.5 percent. In the short-run, the responsiveness of agricultural output to a 1 percent increase in agricultural machinery is 0.027 percent. The partial elasticity of fertilizer is 0.053 in the short-run. A 1 percent increase in fertilizer will increase agricultural output by 0.053 percent. The result also suggests that the explanatory power of agricultural output growth on itself is negative.

As the variables were co-integrated, we run the error correction term as reported in table 5 above. The coefficient of error correction term measures how strongly the dependent variable reacts to a deviation from the equilibrium relationship in one period or how quickly such an equilibrium distortion is corrected. The error correction term is statistically significant and does have the theoretically expected sign that is negative, meaning that it validates that there exists a long-run equilibrium relationship among variables. The coefficient of -0.91 indicates that from the previous disequilibrium, the long-run equilibrium relationship of AOG is quickly re-established at the rate of about 91 percent per annum. The value indicates a stronger adjustment rate. Based on this result we can say that the adjustment takes place very quickly.

Diagnostic Tests

Before applying the model estimates for economic analysis, the results would be subjected to several econometric tests. These include tests for heteroscedasticity, serial correlation, normality, functional form, and stability. The econometric tools employed included Breusch-Pagan-Godfrey, Breusch-Godfrey Serial Correlation Lagrange multiplier (LM) Test, Jarque-Bera, Ramsey Regression Equation Specification Error Test (RESET), and Cumulative Sum (CUSUM) respectively. These diagnostic are discussed as follows:

Table 6. Diagnostic check of model assumptions

Test statistic	F-statistic	P-value
Serial correlation [a]	0.000250	0.9875
Normality [b]	340.1648	0.0000
Heteroscedasticity [c]	0.676141	0.6698
Functional form [d]	0.347420	0.5600

Note: a: LM test of residual serial correlation; b: Jarque-Bera test; c: LM test for heteroscedasticity; d: Ramsey's RESET test

To check the efficiency and consistency of the model, various diagnostic tests were conducted as reported in table 6. If we consider the functional form/model specification by using Ramsey reset test as reported in table 6, we can confirm that testing the hypothesis that the coefficients on the powers of fitted values from the regression are jointly zero, that is, the model is correctly specified. The null cannot be rejected since the p-value is more than 0.05. The result for autocorrelation was also presented in table 6. The null hypothesis of the test is that there is no serial correlation in the residuals up to the specified lag order. The result shows that our model is free from autocorrelation as a p-value of 0.98 is higher than 0.05. The model also passed the Heteroscadasticity test indicating the variances are constant over time. But we could reject the null hypothesis for the Jaque-Berra normality test which says that the residuals are normally distributed, for the reason that the p-value associated is smaller than the standard significance level 0.0000. According to Enders (1995), the existence of normality problems does not affect and distort the estimators' unbiasedness and consistency property, because the main purpose of normality tests is for inference (testing hypothesis about the population parameter) (as cited in Helen, 2012). Therefore the in-existence of normality in this model doesn't affect our estimates.

Stability Test

Stability tests were conducted to show whether the parameter estimates are stable over time. To this end, Cumulative Sum (CUSUM) was employed. This test identifies systematic changes in the regression coefficients. It was plotted at the critical bounds of 5% levels of significance. If this plot stays inside the critical bounds, the null hypothesis that all the coefficients are stable will not be rejected. Figure 2 plot the results for CUSUM tests. The results of CUSUM indicate the absence of any instability of the coefficients because the plot of the CUSUM statistics falls inside the critical bands of the 5 percent confidence intervals of parameter stability (Pesaran et al., 2001).

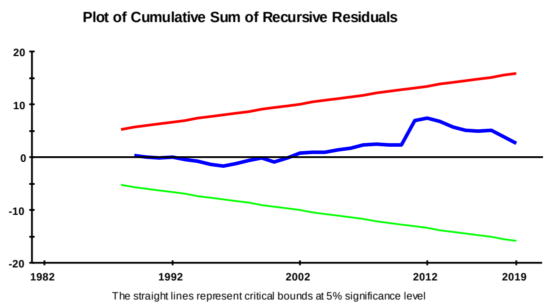

Figure 2. Plot of Cumulative Sum of Recursive Residuals

Conclusions and recommendations

This study empirically examines the effect of TFP, farm machinery, labor, the area under cultivation, and fertilizer on AOG in Ethiopia from the period 1981 to 2019. The ADF and PP unit root tests were used to find out the order of integration of the variables. ARDL approach to cointegration was used due to certain advantages to finding out the long-run relationship between variables and an error correction representation of the ARDL model was also presented. The selected econometric model goes through all the diagnostic tests and confirms the absence of heteroscedasticity, serial correlation, and normality. CUSUM test confirms the stability of the model that validates the applicability in policymaking. According to the results of this study, TFP is the most significant determinant of AOG in Ethiopia both in the short-run and long-run. A rise in total factor productivity in agriculture has the potential to raise income and eventually lead to a green economy. In this regard, higher income leads to higher spending on modern farm input and agricultural total factor productivity both of which contribute to sustainable growth in the sector.

Farm machinery is also found to be a significant variable that can determine the level of agricultural output. According to this study, the use of agricultural machinery led to a marked increase in labor productivity in agricultural output. As labor productivity improved, more labor forces become released to engage in non-farming activities, and in this way, it contributes to the entire economy. Although agricultural land expansion and fertilizer application are significantly improving agricultural output, future agricultural output growth should come from total factor productivity improvement as the area under cultivation and fertilizer are not sustainable for environmental issues. This is because TFP has the potential to be a game-changer in sustaining agricultural growth.

Taking into account the findings of the present study, we strongly recommend that the government of Ethiopia should devise such policies in the agricultural sector which could enhance the level of TFP. This action would help the agricultural sector of Ethiopia to exhibit sustainable growth. To achieve sustainable agricultural output government should invest in land improvement. Lastly, extensive environment-friendly farming that can promote biodiversity/reduce the pressure of agriculture on the ecosystem can also be suggested.

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