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Modeling the Dynamics of Sectoral TFP Growth in Ethiopia: Explaining Persistent Economic Debacles

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Abstract

This paper provides a rigorous analysis for modeling the dynamics of sectoral total factor productivity growth in Ethiopia over the period 1970 - 2010. It also attempts to estimate total factor productivity growth rate for agriculture, industry and service sector using sectoral growth accounting approach, and then examines determinants that affect sectoral productivity by employing a vector autoregressive model that incorporates exogenous variables. The study then finds that sectoral economic growth largely depends on factor accumulation instead of factor productivity. As a result of this, labour becomes the dominant source of agricultural growth while capital deepening explains the immense source of growth in industry and services over the reference period, regardless of the various political economy regimes. Total factor productivity growth, however, is negative on average across economic sectors and heavily reflects the lack of efficiency and technological change that bottlenecked economic growth. The study also finds that economy openness, imported capital goods, and service liberalization are statistically significant variable and positively influence the sectoral total factor productivity growth in agriculture, industry and service sector respectively. The study therefore recommends that the government focuses on widening economy openness in order to driving up agricultural total factor productivity, and pays more attention to importation of strategic technologies and reduces trade and service barriers associated with in order to foster industrial and service total factor productivity respectively.

Keywords: Structural Change Process, Sectoral TFP, Sectoral Growth Accounting Approach, VARX Model, Zivot and Andrews Test, Stationarity Test with Structural Break, Clemete, Montanes and Reyes Test

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1. Introduction

The performance of the world economy has astonishingly been changed in terms of growth rate, economic structure, investment, trade, product diversification, and the like. The world also becomes a village due to a multifaceted globalization effect in general and information technology in particular. As a result, the per capita growth rate that was around 0.05 percent in the 18th century tended to be around 2 percent on average in the 20th century (Lin, 2012). However, there is always permanent difference in income level across countries. For instance, the Sub-Saharan Africa (SSA) region that had 612 million populations produced a GDP of only US$315 billion, as measured in constant 2000 US$, in 1997. This is lower that of Netherland that had around 15 million populations. However, the level of GDP in SSA region exceeded that of Netherland, and the economy grew by 4.8 percent in SSA while it was only 1.7 percent in Netherland in 2010. There is still an incomparable wide variation in real per capita income, SSA and Netherland accounted for $641 and $26,557 respectively (WB, 2011).

One of the argumentative questions raised here is that why such type variations are occurred among countries and what matter in this regard till economic convergence catches up the world production frontier in long run. This is heavily attributed to difference in total factor productivity and technological gap that developing country not able to catch the world technology frontier through international spill-over effect. This entails a special attention of catching-up productivity growth depending on initial condition and accessing the stock of knowledge of abroad (Kumar and Russell, 2002 and Nelson and Phelps, 1966).

Ethiopia is one of strategic countries in this regard because of economic debacles which existed inherently and persistently associated with productivity growth, widening the gap between domestic technology and world technology frontiers. The level of technological innovation in the domestic economy is poor and uncompetitive and that

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of technology transfer from abroad is very limited with various trade and service barriers in the last decades. As a result of this, the Ethiopian economy has poorly performed and became the world agenda in case of abysmal poverty, recurrent food deficiency, instability, erratic growth and sluggish economic transformation (Rahmato, 2004 and Chole, 1992). The economy exhibits a mixed performance of positive and negative real GDP growth rate. It shows negative growth rate performances seven times over the period 1981-2010 (WB, 2011).

In addition, the structure of the GDP is characterized by lowest and stagnant share of the manufacturing sector (4.8 percent on average) that was expected to drive productivity and sustainable growth. The highest share of service sector in GDP in turn leads to a structural change burden as explained by Baumol's disease, causing economic growth rate to decline in the long run (Baumol, 1967). The study, therefore, examines the determinants and driving forces of the dynamics of TFP (total factor productivity) growth for agriculture, industry and service sector in search of perpetual growth and rapid structural change. The main research questions that the paper addresses are the following: What do explain the Ethiopian economic growth at sectoral level: factor accumulation or productivity growth? What does the sectoral TFP performance look like? What are the factors that influence the sectoral TFP growth in order to drive a perpetual growth rate and structural change? The study employs sectoral growth accounting approach and VARX (autoregressive model that incorporates exogenous variables) model in order to estimate sectoral TFP growth and examine the determinants of sectoral TFP growth over the period 1972-2010.

2. Macroeconomic Performance and Political Regimes

The Ethiopian economy has experienced various growth options in different fashions in the past three main political regime changes with different economic policy shifts. Mixture of feudo-capitalism and state-owned economic policy are the fundamental economic policy of the government in the imperial regime (1940-1974) and the socialist regime (1974-1991) respectively. The current reformist government (1991 to date) has subsequently undertaken a series economic reform program of WB and IMF with various phases of Neo liberalization and State-led development (MOFED, 2010).

The macroeconomic performance over the decades has been showing a mixed performance as measured by inflation rate. Historically, it was low relative to other sub-Saharan African countries. The first historic level of inflation was 21% in 1991/92, mainly owing to the forceful political power transition from the socialist government to the current regime. However, the recent inflationary spiral unprecedentedly increased despite good harvest of agricultural produce. The general inflation reached 37.2% as of September 2008 while food inflation was 51.8% (CSA, 2008; NBE 2007 and NBE, 2011). The summary of macroeconomic performance over the decades is presented as follows (Table 1).

Table 1: Major Macroeconomic Performance Indicators

Major Macroeconomic Indicators	Part of Socialist Regime (1980-1990)	Neo-Liberalization Regime (1991-2000)	Pro-Poor growth Regime (2001-2010)
Total investment(% of GDP)	16.2	15.0	23.3
Gross national savings (% of GDP)	6.8	10.1	19.7
Government revenue(% of GDP)	14.4	13.7	18.4
Government expenditure(% of GDP)	18.5	18.7	21.9
Grant, excluding technical support (USD)	0.30	0.54	1.96
Broad Money (% of GDP)	20.0	29.7	38.6*
Total Reserve (in months of Import)	2.3	4.3	3.05*
Inflation rate	5.2	7.5	11.1
Total Export (percent of GDP)	6.5	8.7	12.7
Total Import (percent of GDP)	11.6	16.4	30.4

Source: WB Report 2011, and IMF Report 2012, online database

N.B: *data for both broad money and total reserve presented here up to 2008 and 2009 respectively. The classification of the regimes is presented according to the Ministry of Finance and Economic Development.

With respect to foreign currency reserve, the country's gross official reserve when the socialist government was toppled in 1991/92 was almost nil, equivalent to 1.3 weeks of imports. It recovers up to 6 months of import coverage in the first phase of liberalization, due to the balance of payment support by donors augmented by the increase in export dwindled to cover only 3.6, 2.3 and 2.2 months of imports as of June 2005, 2006, and 2007, respectively. The reserve position was 5 weeks of import coverage in December 2008 and created a deadlock situation especially for investment activities (Kagnew and Zerayehu, 2009). The recent macroeconomic instability that mainly was caused by historically unprecedented inflation and acute shortage of foreign currency reserve that continues to hamper the ongoing investment and growth. The monetary authority attempted to curb this macroeconomic instability. However, the monetary policy's speed of adjustment towards the long run equilibrium is about 2 percent per quarter and about 8 percent annually when there is a macroeconomic shock to the system. In order to have full adjustment, it could take many years. This exacerbated a daunting challenge for the sustained economic growth. For these reasons, it is not easy to tackle the macroeconomic instability within a short time (Zerayehu, 2006).

3. Literature Review

The concept of structural change represents a dynamic process of change in sectoral relative contributions to GDP in which the share of manufacturing in GDP rapidly increases. Such increase in the share of industry causes the agricultural share in GDP to decline concomitantly in a non-linear pattern. Amidst, the contribution of services in GDP begins to grow. This dynamic process continues until the share of manufacturing takes the leading position and contributes to GDP (Kuznets, 1966; Chenery and Taylor., 1968; Kongsamut et al., 1997; and ECA 2011). Comparing with agriculture and service, industrializing the economy means moving towards higher productivity, higher earnings and profit, integrated industrial products, product sophistication and output diversification, relatively low risk (volatility and vulnerability), widen employment creation and so one. Enhancing total factor productivity in this regard is the central process of structural change and perpetual growth. Both theories and empirics indicate that factor accumulation of saving and investment should be considered as a necessary but not sufficient condition for sustaining economic growth and transformation (Todaro and Smith, 2011).

An alternative framework of factor productivity is then considered to complement the role of factor accumulation (William and Ross, 2001). It was Solow (1956) who first questioned the accumulationist view and then kicked off the debate that growth involves technical change. He found that seven-eighth of output growth attributed to TFP growth in his study. Following the exogenous growth model, the endogenous growth model pioneered by Romer's (1986) and Lucas' (1988) provides due emphasis on new knowledge (Grossman and Helpman, 1991), innovation (Aghion and Howitt, 1992) public infrastructure (Barro, 1990; Stephen, 2001) and the like. In general, the recent theories suggest that TFP in the sense of change in technology, knowledge, human capital and spillover effect drives the long-run growth while accumulation of factors does not explain long run growth. Some believed that technology-led productivity growth is the source of sustaining growth and transformation (Kuznets 1973; Schumpeter 1947 and Schultz 1964). Studies conducted by Hirschman (1958) and Johnston and Mellor (1961) give more emphasis on the role of linkages of the economy. Many also pay attention to the roles of the market, and institutions (Matthews, 1986 and Rodrik, 2003), and low resource cost and enabling environment in economic transformation (Thaddee et al, 2009). Most developed countries experience in this regard shows a considerable portion of GDP growth can be explained by growth in TFP (Dollar and Sokoloff, 1990). However, some studies carried out by Easterly, Geda, and others reach at different conclusions. Easterly

W. (2002) decomposes growth into TFP and capital deepening by employing the methodology of Klenow-Rodriguez-Clare. He finds that the permanent component growth over the period 1951-2001 is estimated around 0.48 percent, explained by TFP growth (0.59 percent) instead of capital deepening (0.08 percent). His study also posits most of the growth is due to non- agricultural sources despite the government's commitment to agricultural development led industrialization strategy. Geda and Degefe (2005) also investigate the same issue by considering education per worker as one the explanatory variable over the period 1960-2000 and employ Collins and Bosworth methodology. Unlike Easterly, they find that growth is explained by capital deepening, not by the growth rate of TFP. The growth in real GDP per worker is 0.73 percent on average over the reference period. Physical capital per worker in this regard accounts for 1.18 percent while TFP shows negative performance (0.63 percent). Education has better contributed to the growth of GDP per worker than the TFP does, reflecting the considerable role of human capital in terms of education in the Ethiopian economy.

As discussed earlier, TFP is the driving force of long run growth and has a permanent effect on structural change. It also generates an increasing return to scale and sources of efficiency as well as enhances the welfare of the society (Andres, 2007). Therefore, what are the chief determinants of change in TFP in order to articulate a sound economic policy? Both neoclassical and modern growth theories propose differently about the determinants of technological change. The neoclassical models consider technological progress as an exogenous variable like manna coming from heaven (Solow, 1956). However, the modern growth models explain the sources of technological change as an endogenous variable (Romer, 1990). This model takes endogenous knowledge creation as the principal determinant. The existence of new ideas and stock of ideas creates the dynamic process of economic transformation (Romer, 1990). From the theoretical perspective and empirical evidences, the best disaggregated determinants of

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TFP are: creation of knowledge and innovation; transfer of innovation; adoption and adaption of innovation; and absorptive capacity (Anders, 2007).

Creation of knowledge and innovation about how to produce is the principal driving machine for perpetual economic growth and improvement in the wellbeing of the society by lowering unit cost of production, advances quality and efficiency. In effect, knowledge creation positively influences the TFP growth (Abdih and Joutz, 2005). Romer (1990) in this regard argues that the stock and the creation of new knowledge through R&D are plenty as compared to any other resources with the assumption of increasing return to scale. However, R&D by itself is costly so that most developing countries could not afford it. As a result of this, the effect of R&D on the long run growth might be inconclusive in case of poor countries (Jones, 1995). Therefore, most countries acquire the state-of-the-art technology from countries which are leading in discoveries and idea creations through importation of knowledge intensive goods and service, and foreign direct investment (Mayer, 2001; Keller and Yeaple, 2003 and Torfinn and Jorn, 2005). However, the effects of both importation of knowledge intensive goods and FDI on TFP depends on the absorptive capacity and system of patent rights (Aitken and Harrison (1999). On top of these factors, the transfer and diffusion of technology heavily depend on the openness of the foreign trade and level of liberalization of the domestic trade, positively influence sectoral TFP growth (Khan, 2006; Nicoletti and Scarpetta, 2003 and Arnold, Javorcik, and Mattoo (2007).

Once the innovation is created domestically or imported from abroad, the next issue is how the recipients use the innovation. There are two possible ways taken by countries: adoption and adaption. Some use the innovation as it is (adoption) and some use it by customizing with their own existing environment (adaption). This also depends on the absorptive capacity of the recipients in order to scale up TFP growth (Nelson and Phelps, 1966). The impact of absorptive capacity on TFP also depends on stock of human capital in terms of education and health and infrastructural development (Benhabib and Spiegel, 1994; Isaksson, 2002; Nachega and Fontaine, 2006; Aschauer, 1989; Fan and Zhang; 2004 and Hulten, 1996). Apart from the aforementioned factors, macroeconomic stability has its own implication on the growth of TFP. Providing distinctive attention to developing countries, macroeconomic stability in general and inflation in particular are key factors in TFP growth. If it is stable, it has a positive influence on TFP growth. Otherwise, the inflationary condition could cause investment to be discouraged due to economic uncertainly, adversely affecting the TFP growth (Akinlo, 2005).

4. Methodology

In understanding the different components and definitions of TFP, there are different types of estimation technique for sectoral TFP. The growth accounting approach; regression approach, parametric and semi parametric approach are mentioned in literature. The study, however, uses the growth accounting approach in order to reap the benefits derived from taking into account all compositions of TFP and for keeping uniform assumption with the dynamic CGE model. Abramovitz (1956) and Solow (1956) introduced TFP for the first time, which refined by Denison (1967). TFP in this approach includes technological progress, technical and allocation efficiencies, scale effects and the like. The residual factor in GDP growth rate captures the TFP, not explained by growth in capital, land and labour. According to this approach, there are two distinct sources of growth: input-driven (increasing factor accumulation) and TFP-driven (increasing factor productivity). The first one invokes the assumption of diminishing return to scale while the latter one invokes increasing return to scale.

Consider a Cobb-Douglas production function for each sector – agriculture, industry and service as presented by equation 1. Note that the model excludes agricultural land, N, through all equations for non-agricultural sectors.

$$Y = f(A, L, K, N) \qquad (1)$$

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Where Y denotes sectoral GDP, L stands for sectoral labour, K stands for sectoral capital stock, and N stands for agricultural land. 'A' also designates the sectoral TFP. The model assumes constant return to scale at sectoral level, which directly fits with the CGE model assumption. By differentiating both sides, equation 1 can be written as follows.

$$dY = \frac{\partial Y}{\partial A}.dA + \frac{\partial Y}{\partial L}.dL + \frac{\partial Y}{\partial K}.dK + \frac{\partial Y}{\partial N}.dN \quad \text{.....................................} (2)$$

Dividing the entire equation by Y yields the growth rate of sectoral GDP, i.e.

$$\frac{dY}{Y} = \frac{\partial Y}{\partial A}.\frac{dA}{Y} + \frac{\partial Y}{\partial L}.\frac{dL}{Y} + \frac{\partial Y}{\partial K}.\frac{dK}{Y} + \frac{\partial Y}{\partial N}.\frac{dN}{Y} \quad \text{..} (3)$$

Manipulating equation 3 mathematically by multiplying the independent variables with A/A, L/L, and K/K as presented in equation 4. This helps to get factor income share in the coefficients.

$$\frac{dY}{Y} = \frac{\partial Y}{\partial A}.\frac{dA}{Y}.\frac{A}{A} + \frac{\partial Y}{\partial L}.\frac{dL}{Y}.\frac{L}{L} + \frac{\partial Y}{\partial K}.\frac{dK}{Y}.\frac{K}{K} + \frac{\partial Y}{\partial N}.\frac{dN}{Y}.\frac{N}{N} \quad \text{...............................} (4)$$

Rearrange equation 4 and get equation 5

$$\frac{dY}{Y} = \frac{\partial Y}{\partial A}.\frac{A}{Y}.\frac{dA}{A} + \frac{\partial Y}{\partial L}.\frac{L}{Y}.\frac{dL}{L} + \frac{\partial Y}{\partial K}.\frac{K}{Y}.\frac{dK}{K} + \frac{\partial Y}{\partial N}.\frac{dN}{N}.\frac{N}{Y} \quad \text{...............................} (5)$$

Letting $g_y = \frac{dY}{y}, g_A = \frac{dA}{A}, g_L = \frac{dL}{L}, g_K = \frac{dk}{K}, g_N = \frac{dN}{N}$ permits construction of equation 6 as follows.

$$g_y = \frac{\partial Y}{\partial A}.\frac{A}{Y}.g_A + \frac{\partial Y}{\partial L}.\frac{L}{Y}.g_L + \frac{\partial Y}{\partial K}.\frac{K}{Y}.g_K + \frac{\partial Y}{\partial N}.\frac{N}{Y}.g_N \quad \text{...............................} (6)$$

The term $\frac{\partial Y}{\partial A}.\frac{A}{Y} = g_{TFP}$ is not directly observable and refers to as Solow residual or total factor productivity growth. This means that

$$g_y = g_{TFP} + \frac{\partial Y}{\partial L}.\frac{L}{Y}.g_L + \frac{\partial Y}{\partial K}.\frac{K}{Y}.g_K + \frac{\partial Y}{\partial N}.\frac{N}{Y}.g_N \quad \text{......................................} (7)$$

The sectoral growth accounting approach imposes the assumptions of competitive markets and constant returns to scale in the context of neoclassical economics. This assumption implies that the coefficients that are the output elasticities are equal to the

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factor income share. As factors earn their marginal product in neoclassical economics, the marginal products of labour, capital and land are wage (w), capital rent (r) and land rent (z), respectively. Therefore, we can substitute $w = \frac{\partial Y}{\partial L}, r = \frac{\partial Y}{\partial k}, z = \frac{\partial Y}{\partial N}$ in the equation 7 and get the following equation that explains output growth in terms of factor income share.

$$g_y = g_{TFP} + w.\frac{L}{Y}.g_L + r.\frac{K}{Y}.g_K + z.\frac{N}{Y}.g_N \quad \text{(8)}$$

Looking at equation 8, the multiplication of marginal product and input ratio per output gives the factor income share out of total income. Mathematically, the parameter $\alpha = w\frac{L}{Y}, \beta = r\frac{K}{Y}, \gamma = z\frac{N}{Y}$ measure the factor income share of labour, capital and land respectively. Therefore, equation 8 can be rewritten as follows.

$$g_Y = g_{TFP} + \alpha.g_L + \beta.g_K + \gamma.g_N \quad \text{(9)}$$

Rearrange equation 9 to get the growth rate of TFP equation, lead to:

$$g_{TFP} = g_Y - (\alpha.g_L + \beta.g_K + \gamma.g_N) \quad \text{(10)}$$

In the sectoral growth accounting approach, the factor income shares are exogenous variables so that they can be calculated using national accounts. If the data is not available in the national account, it is also possible to find a proxy using labour composition. Alternatively, it is feasible to borrow the factor income shares from past studies in similar countries. Given this background, the study picks up the national income account of year 2006 in order to calculate the factor income share. This helps to have a consistent base with the SAM 2006 for CGE model.

On the basis of such factor income shares out of the total national income, the final measure of sectoral TFP for the agriculture, industry and services presented below gives complete specifications for each sector. Note that such factor shares for each sector are almost similar with some countries experience.

For the agricultural sector:

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$$g_{TFP} = g_Y - (0.0754 g_L + 0.102 g_K + 0.144 g_N) \qquad (11)$$

For the industry:

$$g_{TFP} = g_Y - (0.3405 g_L + 0.6595 g_K) \qquad (12)$$

For the services: -

$$g_{TFP} = g_Y - (0.23 g_L + 0.77 g_K) \qquad (13)$$

5. Specification of the VARX Model

Using the estimates of the sectoral TFP growth from the growth accounting approach, the study specifies the determinants of sectoral TFP. The broad source of the TFP growth is innovation (knowledge creation) in a domestic economy and technology transfer (absorption and transmission of knowledge) from abroad. We present this in equation 14 presents as follows.

$$g_{TFP} = f(\mathit{innovation}, \text{technology } \mathit{transfer}) \qquad (14)$$

Many studies show that research and development (R&D) serve as a proxy for knowledge creation and point out its long relationship with the TFP growth rate (Chen and Dahlman, 2004). Research conducted by Alston, Norton and Pardey (1998) also indicates the long-lasting impact of R&D on TFP in the long run. Therefore, equation 14 can be rewritten as:

$$g_{TFP} = f(R\&D, \text{technology } \mathit{transfer}) \qquad (15)$$

The world technology frontier, moreover, provides positive externalities and spillover effects to the individual country in order to fill the technology gap. Most countries prefer to acquire technology from abroad instead of creating the state-of- the art technology due to the cost of innovation. Hence, the technology created abroad crosses the national border and is principally transferred to the domestic economy through importation of technology (Keller and Yeaple, 2003; Mayer, 2001). Such channels, in turn, depend on the nature of imported technology and barriers during technology transfer. Importation of

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capital goods is mostly relevant for enhancing TFP growth and thereby structural change. Thus, equation 15 can be extended to the following equation by taking into account importation of capital goods and transfer barriers.

$$g_{TFP} = f(R\&D, imported\ capital\ goods, technology\ transfer\ barriers) \ldots\ldots\ldots\ldots\ldots\ (16)$$

A barrier to technology transfer reduces the absorption of technology from the world frontier and shrinks the TFP growth rate. This repercussion ranges from slowing down the pace of transfer to blocking technology adoption. In effect, it widens the gap between the world technology frontier and the domestic technology innovation (Ngai, 2004). Trade barriers and capacity barriers are worth mentioning in this regard so that equation 16 can be written as follow.

$$g_{TFP} = f(R\&D, imported\ capital\ goods, trade\ barriers, capacity barriers) \ldots\ldots\ldots\ (17)$$

In most developing countries, capacity and trade barrier is broadly explained in terms of openness of the economy and service trade liberalization in order to addressing the limitations associated with both external economy and domestic economy, respectively. The existence of limited openness of the economy is the main challenge in encouraging the inflow of technology and thereby productivity growth. The size of openness of the economy matters the access to capital goods, advanced technologies and competitive market. On top of this foreign trade, domestic service trade restriction causes poor productivity and slows down economic growth overtime (Asghar, 2007). Note that limited openness can be caused by low TOT, high tariff, poor quality and the like. These are the factors behind the limited openness that restrict technology transfer. Equation 18 gives the extended one by decomposing trade barriers into openness and service trade liberalization index as presented in the following way.

$$g_{TFP} = f(R\&D, imported\ capital\ goods, opennes, service\ trade\ liberalization, capacity\ barriers) \ldots\ (18)$$

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Capacity barrier, as mentioned in equation 18, includes both innovative capacity and absorptive capacity barriers. The level of human capital development can address the constraints associated with the innovative and absorptive capacity (Nelson and Phelps, 1966; Benhabib and Spiegel, 1994). In addition to human capital, Easterly and Rebelo (1993) proposes infrastructural development as one of the key factors responsible for capacity constraints. Both primary school enrollment and road network human capital are proxy variables for human capital and infrastructural development, respectively. The endogenous growth model also explicitly takes in to account both accumulation of human capital and physical capital in terms of infrastructure in order to explain the international variation in growth rates across countries (Romer, 1990).

Therefore, equation 18 can be extended as follow.

$$g_{TFP} = f(R\,\&\,D, imported\ capital\ goods, opennes, service\ trade\ liberalization, human\ capital, infrastructure) \quad \ldots. (19)$$

On top of the specified determinants, the stability of macroeconomic performance has its own implication on the TFP growth. If instability exists, this negatively affects the TFP growth. Therefore, the study incorporates inflation rate as a proxy variable for measuring the stability of macroeconomic performance. Therefore, equation 20 presented below gives the final model of TFP at the aggregate level.

$$g_{TFP} = f(R\,\&\,D, imported\ capital\ goods, opennes, service\ trade\ liberalization, human\ capital, infrastructure, inflation) \quad \ldots\ldots.(20)$$

On the basis of the aggregate TFP growth model, the study then drives sectoral TFP growth models for the agriculture, industry and services. Following the flow of inputs and outputs among sectors in terms of investment and consumption, the study adds the lag of sectoral TFP growths in order to capture the interactions of sectoral TFP among the three sectors. This makes the model to have two broad components such as dependent interactive variables and exogenous variables. Such incorporation of sectoral interaction in the model claims the VARX model. The VARX model refers to a VAR that contains dependent variables that interact with each other and the exogenous variables. This allows the lag values of the sectoral TFP growths in order to build the model of sectoral productivity dynamics.

Considering the lack of data on R&D for the entire economy, the study takes into account only agricultural R&D. On the same note, the study takes the number of enrolled pupils in primary education and road network as proxy variables for human capital and infrastructure, respectively. The ratio of private credit to GDP is also considered as a continuous proxy variable for service trade liberalization index. A high ratio means that the economy is more liberalized, which is a lower ratio indicates the existence of more trade restriction in the economy.

Following the growth accounting approach that gives TFP in terms of growth rate, the study, therefore, considers all explanatory variables in terms of growth rates so as to be uniform with TFP. However, the explanatory variables of openness and service trade liberalization index considered in terms of ratios. Such presentation helps in generating stationary time series, robust modelling and good diagnostic tests. Taking TFP in terms of growth rate also helps in keeping consistence with the dynamic CGE model as CGE model takes sectoral TFP in terms of growth rate. Note that sectoral TFP is expressed in terms of growth rates for two reasons. As an outcome, the sectoral growth accounting approach produces a growth rate of sectoral TFP. On the other hand, the dynamic CGE model requires TFP in terms of growth rate as an input. These two facts require that the most explanatory variables be expressed in terms of growth rate for securing uniformity, stationarity and robust diagnostic test. Therefore, the final VARX model for each sector is presented as below.

For the agriculture:

$$g_{TFPA} = f(g_{LTFPA}, g_{LTFPI}, g_{LTFPS}, g_{ard}, g_{imc}, g_{pep}, g_{nwr}, opp, lr, inf) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots... (21)$$

For the industry:

$$g_{TFPI} = f(g_{LTFPA}, g_{LTFPI}, g_{LTFPS}, g_{ard}, g_{imc}, g_{pep}, g_{nwr}, opp, lr, inf) \ldots\ldots\ldots (22)$$

For the service:

$$g_{TFPS} = f(g_{LTFPA}, g_{LTFPI}, g_{LTFPS}, g_{ard}, g_{imc}, g_{pep}, g_{nwr}, opp, lr, inf) \ldots\ldots\ldots (23)$$

Where g_{TFPA} = TFP growth rate for agriculture; g_{TFPI} = TFP growth rate for industry; g_{TFPS} = TFP growth rate for service; g_{LTFPA} = lag values of TFP growth rate for agriculture; g_{LTFPI} = lag value of growth rate for industry; g_{LTFPS} = lag value of growth rate for service; g_{imc} = growth rate of imported capital goods g_{ard} = growth rate of government expenditure for agricultural R&D ; g_{pep} = growth rate of pupils in primary school; g_{nwr} = growth rate of road net works in kilometers ; opp = openness of the economy; lr = service trade liberalization index; $\inf$ = inflation

Note that the VARX model has a comparative advantage over the VAR model. The VAR model consists of all dependent variables and is used for forecasting purpose whereas the VARX model contains both dependent (endogenous) variables and exogenous variables included in the model allowing articulation of policy prescription.

6. Unit Root Test with Structural Breaks

The ADF test is often applicable in detecting the existence of stationarity in a time series with the assumption of no structural break. However, neglecting the issues of structural breaks leads to biased results and lessens the possibility of rejecting a bogus unit root (Perron, 1989). The study, thus, considers endogenous structural breaks in the time series data. This helps to detect the exact nature of stationarity of time series, and to know the year when the structural break is in time series. Zivot and Andrews (1992) test and Clemete, Montanes, and Reyes (1998) test are widely applicable in cases of single break and two-breaks, respectively.

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The Zivot and Andrews (ZA) model considers one structural break and uses many dummy variables for each structural break year. As the exact endogenous break is unknown, the ZA model then assumes every point as a potential break. It, therefore, sequentially conducts a regression for every structural break point, in which the minimum t-statistic indicates where the endogenous structural break date is found.

The following equation gives the ZA model.

$$y_t = \alpha + \beta t + \gamma DU1_t + \omega DT1_t + \mu y_{t-1} + \sum_{i=1}^{k} \lambda \Delta y_{t-i} + \varepsilon_t \quad \text{.................................... (24)}$$

$$DU1_t = \begin{cases} 1\,if\ t > T_B \\ 0, otherwise \end{cases} and, DT1_t = \begin{cases} 1, if\ t > T_B \\ 0, otherwise \end{cases}$$

Whereas y_t is a time series variable, t is the time trend, $DU1_t$ is the intercept dummy variable indicating mean shift (change in the level), $DT1_t$ stands for the slope dummy representing change in the slope of the trend function. Besides, T_B represents a potential break point, k denotes lag length.

The null hypothesis states that the time series that excludes any structural break is non-stationary whereas the alternative hypothesis indicates that the series that includes one structural break is stationary. The Clemete, Montanes and Reyes (1998) model, on the other hand, test stationarity in the presence of two breaks in the time series. They propose two models: - Additive outlier (AO) model and Innovative outlier (IO) model in order to address instantaneous structural break and gradual change, respectively.

The following equation gives the IO model as below.

$$y_t = \alpha + \beta y_{t-1} + \delta_1 DT_{1t} + \delta_2 DT_{2t} + \omega_{1t} DU_{1t} + \omega_{2t} DU_{2t} + \sum_{i=1}^{k} \gamma_i \Delta y_{t-i} + \varepsilon_t \quad \text{.................. (25)}$$

$DU_{1t} = \begin{cases} 1, if\ t > T_B \\ 0, otherwise \end{cases}$, $DU_{2t} = \begin{cases} 1, if\ t > T_B \\ 0, otherwise \end{cases}$ for representing intercept dummy

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$DT_{2t} = \begin{Bmatrix} 1, if\ t > T_B \\ 0, otherwise \end{Bmatrix}$, $DT_{2t} = \begin{Bmatrix} 1, if\ t > T_B \\ 0, otherwise \end{Bmatrix}$ for representing the slop dummy

The AO model, moreover, has two stages in order to test for stationarity. The first step removes the deterministic part of the variable by modeling:

$$y_t = \alpha + \omega_{1t} DU_{1t} + \omega_{2t} DU_{2t} + \overline{y_t} \quad \text{.. (26)}$$

In the second step, the study uses the following model in order to test.

$$\overline{y_t} = \rho \overline{y_{t-1}} + +\omega_{1i} DT_{1t-i} + \omega_{2i} DT_{2t-i} + \sum_{i=1}^{k} \varphi \Delta \overline{y_{t-i}} + \varepsilon_t \quad \text{.. (27)}$$

Where

$DU_{1t} = \begin{Bmatrix} 1, if\ t > T_B \\ 0, otherwise \end{Bmatrix}$, $DU_{2t} = \begin{Bmatrix} 1, if\ t > T_B \\ 0, otherwise \end{Bmatrix}$ for representing intercept dummy

$DT_{1t} = \begin{Bmatrix} 1, if\ t > T_B \\ 0, otherwise \end{Bmatrix}$, $DT_{2t} = \begin{Bmatrix} 1, if\ t > T_B \\ 0, otherwise \end{Bmatrix}$ for representing the slop dummy

Note that the endogenous structural break test has a comparative advantage on ADF test and exogenous structural break test. It considers structural break which the ADF test does not take into account. Besides, the endogenous structural break test considers the response of policy changes and lags structure whereas the exogenous structural break test does not consider them. In addition to these, non-stationary time series data allows us to have spurious regression results that adversely affect the statistical significance level of coefficients in the VARX model, misleading policy prescription. This in turn negatively affects simulation results from the dynamic CGE model through inappropriate calibrated induced TFP growth rates. Therefore, we need to have stationary time series data and a model of VARX that satisfies stability condition.

7. Data Source

Data for sectoral real GDP, spending on the agricultural R&D, inflation rate, openness, imported capital goods, private credit per GDP, road network, and cultivated land and

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data for a number of pupils enrolled at primary school are collected from the World Bank, Ministry of Finance and Economic Development, National Bank of Ethiopia, United Nation Conference on Trade and Development, and Ethiopian Economic Association. As there is not disaggregated data for sectoral gross capital formation and labour force, we decompose the number of labors in non-agricultural sector into industrial labour and service labour based on the share of employment rates of 33 percent in the industry and 67 percent in service. The Labour survey in 2005 referred for confirmation. We also decompose the aggregated gross capital formation into sectoral level using the sectoral share of public expenditure. This is because of the fact that the government expenditure has the same fashion with gross capital formation. Besides, it is the key contributor of gross capital formation.

8. Empirical Results and Analysis

As described earlier, sectoral growth accounting approach produces the estimates of TFP growth rates for agriculture, industry and services. Using the estimates of sectoral TFPs, the VARX model that considers both sectoral interaction and exogenous variables identifies the powerful determinants of sectoral TFP growth.

8.1. Estimates of Sectoral TFP Growths

Both empirical and theoretical evidences show that economic growth can be decomposed into factor accumulation and factor productivity. The Ethiopian economy in this regard manifests a multifaceted performance depending on the political economic policy regimes such as the feudal-capitalism (up to 1974), socialism (1975-1988), mixed economy (1989-1991), more of liberalization (1992-2000) and the pro-poor growth regime (2000 to date).

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Table 15:-Sectoral TFP growth using Growth Accounting Approach (%)

Sectoral Decomposition of GDP Growth Rate	Political economy regimes*					Average for 1972-2011
	1972-1974	1975-1988	1989-1991	1992-2000	2001-2011**	
Agricultural GDP growth rate	1.5	1.0	3.4	1.6	7.1	3.1
Contribution of labour	1.4	2.3	2.7	2.1	2.1	2.2
Contribution of land	0.1	-0.1	-0.1	1.0	0.5	0.3
Contribution of capital	1.7	1.6	0.9	0.3	1.4	1.2
TFPG-Agriculture	-1.7	-2.7	-0.1	-1.7	3.2	-0.6
Industrial GDP growth rate	5.2	4.1	-6.3	4.1	9.7	4.9
Contribution of labour	1.2	0.8	1.0	0.3	2.2	1.1
Contribution of capital	19.2	25.9	-6.1	-3.8	22.9	15.5
TFPG-Industry	-15.3	-22.6	-1.3	7.7	-15.4	-11.7
Service GDP growth rate	5.5	3.9	2.7	4.2	10.7	5.9
Contribution of labour	0.8	0.5	0.7	0.2	1.5	0.8
Contribution of capital	2.1	8.6	-13.1	14.6	12.3	8.8
TFPG-Service	2.6	-5.2	15.1	-10.6	-3.0	-3.7

Source:-Author's own calculation based on sectoral growth accounting approach.

*Note that Ethiopia passes through different political economy regimes-feudal-capitalism in 1940-1974, socialism in 1975-1988, mixed economy in 1989-1991, more of liberalization in 1992-2000, and pro-poor growth regime in 2001-2011.

**Data for sectoral GDP are collected on the basis of the government report that states 11 percent GDP growth rate, on average, in 2005-2011. This figure is not shared by independent bodies.

The sectoral growth accounting approach decomposes the source of growth into labour, capital and TFP as presented in table 15. The empirical results indicate that the accumulation of labour factor is the dominant source of growth in the agriculture sector over the period 1972-2010. Both capital and land positively contribute to the average growth rate of agriculture while the agricultural TFP growth rate is negative on average in 1972-2010. Following the pro-poor economic policy shift, the agricultural TFP growth takes the lead in influencing the agricultural growth during 2001-2011. This might be because of the pro-poor growth strategy that addresses the rural-poor that are heavily engaged in agriculture.

Regarding industrial TFP growth, accumulation of capital dominates the growth rate of the industry value-added in the same reference period, followed by labour contribution. The TFP growth still remains negative as manifested in the agriculture sector in 1972-2010. During the period 1992-2000, the industrial TFP growth positively contributes and takes the lead in the contribution to growth rate of the industry value-added. This is mainly due to the fact that many industrial firms are encouraged and participated as the economy was free from the bondage of socialism in 1991. In the service sector, the contribution of capital to the service value-added is dominant during the socialist and liberalization regimes while the TFP growth dominantly influenced the service value-added during 1972-1974 and 1989-1991. In short, sources of growth vary with the types of economic sectors and policy regimes.

In a nutshell, labour is the dominant source of the agricultural growth while capital deepening is the big source of growth in industry and services in 1972-2011, regardless of the various political economy regimes. However, the sectoral TFP growths negatively affect the growth rate of each sector in 1972-2010. This negative growth rate possibly reflects the lack of efficiency and the shortage of technological change in the economy. This leads to deterioration of productive efficiency and erratic economic growth. In addition to this negative performance, the sectoral TFP growth rates are highly fluctuating overtime and across sectors in the entire period. Comparing with total productivity, the main finding is that the Ethiopia economy can be explained by factor accumulation, not factor productivity in the reference period. By implication, the

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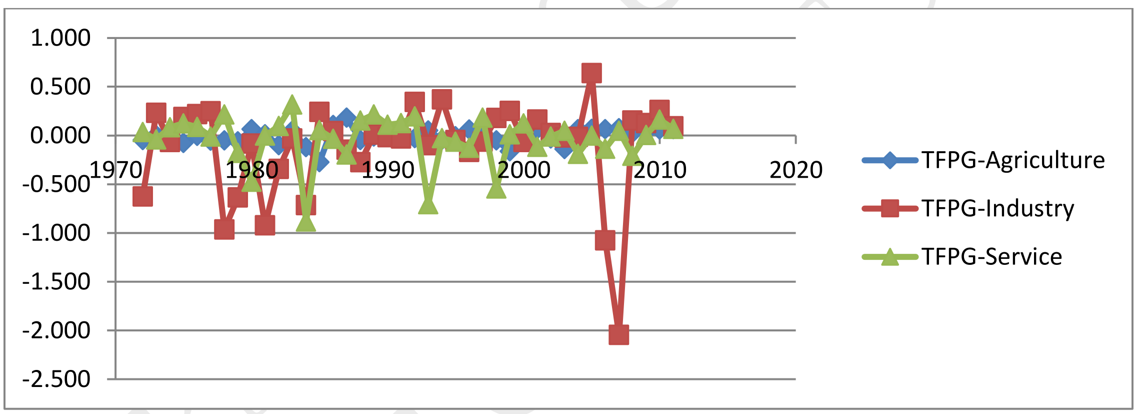
stochastic trend in sectoral TFP and the average negative TFP growth explain the erratic economic growth rate. Therefore, such TFP growth is the bottleneck to the long run growth and structural change, creating severe economic debacles and a deadlock situation. The VARX model examines the determinants of sectoral TFP growth rate on which it is possible to calibrate the induced TFP for the dynamic CGE model.

Pertaining to the dynamics of sectoral TFP growth rate, Figure 12 shows that the growth rate of TFP in the agriculture, industry and service moves stochastically around zero overtime. However, the fluctuation varies across sectors. In the case of agriculture, the dynamics of TFP growth rate seems less swinging as compared to the other two sectors. The growth path of the industrial TFP highly fluctuates across time with some outliers. Such variations indicate that factors that are heavily responsible for variations in the sectoral TFP growth rate are likely to be different per each sector.

Figure 12: The Dynamics of Sectoral TFP growth by growth accounting approach



Source:-Author's own calculation, estimated using sectoral growth accounting approach

The alternative regression-based approach, unlike the growth accounting approach, treats the coefficients of growth equation 9 as the elasticities of output to factors. Note that these coefficients are not equal to factor income share so that it violates the assumptions of constant return to scale and perfectly competitive market. The regression equation of sectoral output on growth rates of factors of production generates the elasticity of sectoral GDP growth rate in response to the growth rate of factors (Table 16).

Table 16:- The Estimated elasticity of sectoral output to factors using regression model

Factors	Estimated Elasticity of output to factors of production		
	Agriculture Sector	Industry Sector	Service Sector
Labour	0.675642	0.478128	0.520051
Capital	0.0474227	0.0293424	0.0354559
Land	0.114464		

Source: - Author's calculation using the regression-based approach

Table 17 gives the estimates of sectoral TFP growth rates based on regression approach. The growth rate of value added in each sector is heavily dominated by the labour contribution in the period 1972-1991. Contrary to the growth accounting approach, the TFP growth in the industry and service takes the lead in dominating the sectoral growth rate in the subsequent period following the policy shifts.

Table 17:-Sectoral TFP growth using the Regression-based Growth Approach

Sectoral Decomposition of GDP Growth Rate	Political economy regimes*					Average for 1972-2011
	1972-1974	1975-1988	1989-1991	1992-2000	2001-2011	
Agricultural GDP growth rate	.51	1.05	3.40	1.62	7.15	3.1
Contribution of labour	1.24	2.06	2.46	1.91	1.86	1.9
Contribution of land	0.09	-0.10	-0.08	0.77	0.37	0.2
Contribution of capital	0.80	0.73	0.40	0.12	0.66	0.6
TFPG-Agriculture	-0.62	-1.64	0.63	-1.17	4.24	0.3
Industrial GDP growth rate	5.16	4.11	-6.34	4.14	9.66	4.9
Contribution of labour	1.73	1.13	1.47	0.38	3.06	1.6
Contribution of capital	0.86	1.15	-0.27	-0.17	1.02	0.7
TFPG-Industry	2.57	1.82	-7.56	3.93	5.58	2.7
Service GDP growth rate	5.50	3.92	2.67	4.20	10.72	5.9
Contribution of labour	1.88	1.23	1.59	0.42	3.33	1.7
Contribution of capital	0.10	0.40	-0.60	0.67	0.56	0.4
TFPG-Service	3.51	2.30	1.68	3.13	6.83	3.8

Source:-Author's own calculation using Regression-based growth approach

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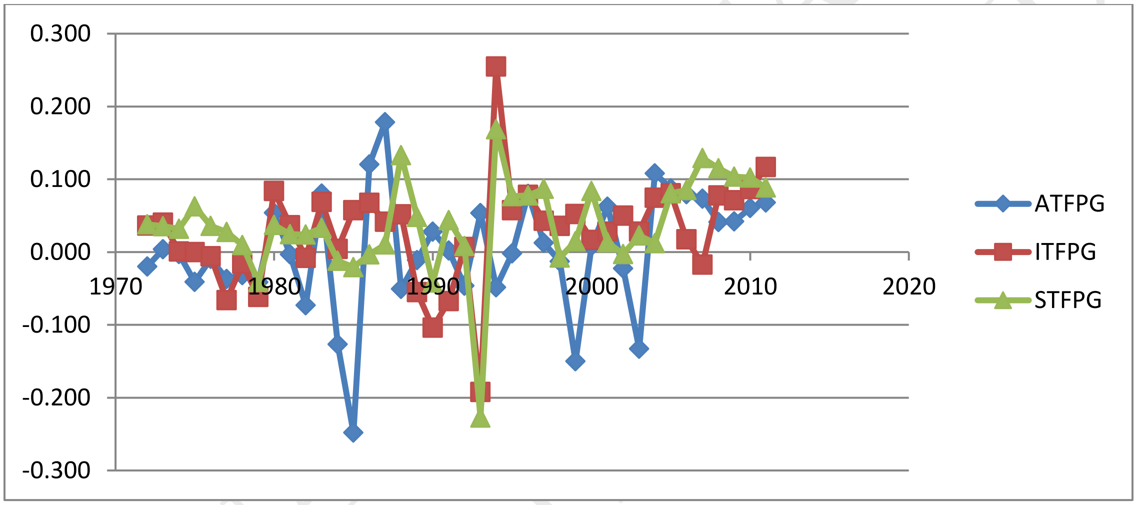
The TFP growth rate dominates the agricultural value-added growth rate in 2001-2011, due to the pro-poor growth strategy designed to address the issues of creating employment and holding a large number of populations. Unlike the growth accounting approach, the average growth rate of TFP becomes positive in 1992-2011. The agricultural GDP is heavily contributed by labour whiles the value-added in the industry and service are heavily and unusually contributed by the sectoral TFP growth during the entire period. In comparison with the previous dynamics of sectoral TFP growth, the TFP growth rates in all sectors show stochastic movement with many outliers in all sectors of agriculture, industry and services.

Figure 13:-The Dynamics of Sectoral TFP growth by regression-based approach



Source:-Author's own calculation, estimated using the regression-based approach

Comparing the estimated sectoral TFP growth rates from both approaches, the study chooses the growth accounting approach in order to calibrate the induced sectoral TFP growth. This is mainly because of 1) maintaining a consistent assumption of constant return to scale across the paper including the CGE model 2) The results from the growth accounting approach show that the agriculture uses labour intensive technology while the industry and service use capital intensive with negative TFP growth rate across sectors, on average. This result relatively reflects the actual economic performance of the Ethiopian economy and other comparators' experience.

8.2 Analyzing the Determinants of Sectoral TFP Growths

Using the estimates of the TFP growths for the agriculture, industry and services, the paper specifies, estimates, and analyzes the determinants of sectoral TFP growth using VARX model. On the basis of the econometric results, the study uses statistically significant explanatory variables in order to generate the induced sectoral TFP growths. Hence, optimal lag length, stationarity test, regression outcomes, diagnostic test, impulse response function, and variance decomposition are presented as follows.

Optimal Order of Lag:

The optimal number of lags is important for appropriateness of the model and determines the statistically significance level of explanatory variables and the forecasts. Table 20 gives alternative techniques of Akaike Information criterion (AIC); Schwarz Bayesian criterion (BIC), Hannan-Quinn criterion (HQC) and the log likelihood ratio (LR).

Table 20:-Selection of the Optimal Lag Length

lags	LR	p(LR)	AIC	BIC	HQC
1	50.64228		-0.813460	0.770059	-0.260769
2	68.99877	0.00003	-1.333265*	0.646134*	-0.642402*
3	73.30875	0.47307	-1.072708	1.302570	-0.243672
4	77.37432	0.52099	-0.798573	1.972585	0.168635

Source:-Author's estimates

The log likelihood ratio suggests the order of lag 2 as the probability of LR is small compared to the 5 percent level of significance. This is also confirmed by the AIC, BIC and HQC. Therefore, the paper uses an optimal lag length of 2 for testing stationarity of the time series and estimating the VARX model.

Unit Root Test:

All time series data must be stationary, meaning constant mean and variance over time, in the regression model. Otherwise, the regression result becomes spurious. The paper in this regard uses three alternative tests to detect whether there is stationarity in the time

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series. The ADF test assumes no structural beak in the time series. However, the Zivot-Andrews unit root test assumes one structural break whereas Clemente-Montanes-Reyes unit-root test accounts for two structural breaks in the time series. The latter two believes that structural break does have a permanent effect, not transitory effect, in the pattern of time series.

The ADF test

Table 21 gives the ADF test with order of lag 2. Optionally, the table presents the explanatory variables in terms of level, and growth rate. All the time series that expressed in terms of their growth rates keep consistency with the sectoral TFP growth rates in either option. However, openness and a proxy for an index of liberalization are naturally ratios so that the study considers them as they are in terms of ratio. Table 21 gives the ADF test for unit root.

Table 21:-Augmented Dickey-Fuller test for unit root

1% critical value -3.668 5% critical value -2.966 10% critical value -2.616			
Option-1		**Option-2**	
Variables	Test Statistic with ADF	Variables	Test Statistic with ADF
TFPGA	-2.860 (0.0501)**	TFPGA	-2.860 (0.0501)**
TFPGI	-3.214 (0.0192)*	TFPGI	-3.214 (0.0192)*
TFPGS	-3.942 (0.0017)*	TFPGS	-3.942 (0.0017)*
ARD	-1.644 (0.4603)	GARD	-3.295 (0.0151)*
IMC	5.250 (1.000)	GIMC	-3.539 (0.0070)*
PEP	0.082 (0.9648)	GPEP	-2.948 (0.0400)**
RNW	2.981 (1.000)	GRNW	-3.781 (0.0031)*
PRICE	-1.891 (0.3365)	INF	-2.079 (0.2532)
OPP	-0.895 (0.7896)	OPP	-0.895 (0.7896)
LR	-1.648 (0.4583)	LR	-1.648 (0.4583)

Source:-Author's estimation

*N.B- Values in the bracket are the MacKinnon approximate p-values * denotes statistically significant at 5% level of significance and ** stands for statistically significance at 10% level of significance.*

The option-1 points out that only sectoral TFP growth rates are stationary while all other time series are not. The option-2, on the other hand, shows that all variables expressed in terms of growth rate (sectoral TFP growths, agricultural R&D, imported capital goods, pupil enrolled in primary school and road network) are stationary while the two ratio variables and inflation rate are still not stationary. However, the most empirical evidences that exhibit stationarity for ratio time series provide a suspect of the existence of structural break that affects the pattern of time series of the two variables. Besides, the unparalleled political economic shifts in Ethiopia in 1970-2011 cause the economy to have a structural break that affects the pattern of time series, calling for Zivot-Andrews and Clemente-Montanes-Reyes unit-root test.

Zivot-Andrews unit root test for allowing for one break

Table 22 provides the Zivot-Andrews unit root test for all variables. Except inflation rate, all the variables explained by the growth rates are stationary at 5% level of significance. Inflation rate is non-stationary even in the case of one structural beak. Both openness and liberalization index remain non-stationary despite one structural break. Note that variables with one structural break do not alter the stationarity decision for the ratio variables.

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Table 22:-Zivot-Andrew unit root test for allowing for a break in intercept

Variables	Break year	Minimum t-statistics	Critical Values	
			1% level of significance	5% level of significance
TFPGA	2004	-7.401*	-5.43	-4.80
TFPGI	1985	-5.555*	-5.43	-4.80
TFPGS	1993	-7.896*	-5.43	-4.80
GARD	1998	-6.543*	-5.43	-4.80
GIMC	1994	-7.290*	-5.43	-4.80
GPEP	1994	5.841*	-5.43	-4.80
GRNW	1994	-7.142*	-5.43	-4.80
INF	2005	-3.357	-5.43	-4.80
OPP	1994	-2.839	-5.43	-4.80
LR	1996	-3.751	-5.43	-4.80

Source:-Author's estimation

One of the interesting points in this test is that the year chosen for structural break for each variable is not uniform. Except the industrial TFP growth, all variables in the VARX model show the existence of endogenous structural break in the post-liberalization period (after 1992). Though the government committed to liberalize the economy in 1992, it does not fully liberalization the market so that some sectors of the economy remain as they were. Moreover, some of the variables do not respond out rightly to the structural adjustment policy and a series of economic policy reforms. For instance, the break year for the private credit per GDP is 1996 where the private banks were allowed to participate in the economy in 1996/97. Inflation rate has a structural break in 2005. This indicates that the trend in inflation rate from 1972-2004 almost similar. However, since 2005, the inflation rate does not behave as the previous period, possibly mainly due to the fact that the government successively runs extensive public expenditure and depletion of the foreign currency resource following election 2005 disputes and a paradigm shift towards state-led development program.

Clemente-Montanes-Reyes unit-root test for two breaks with AO and IO models

The ZA test points out that the inflation rate, openness, and index of liberalization are non-stationary in the existence of one structural break. This claims the CMR unit-root test that enables to examine the stationarity condition in the existence of two structural breaks in the time series for both additive outlier (AO) and innovation outlier (IO). Table 23 gives the details.

Table 23:- Clemente-Montanes-Reyes unit-root test with double mean shifts, AO and IO model

Variable	Additive Outlier (AO)		Innovational Outlier (IO)	
	Min t	Optimal Breakpoints	Min t	Optimal Breakpoints
INF	-8.195*	1979 & 2004	-6.269*	1978 & 2006
OPP	-3.681	1995 & 2001	-5.645*	1986 & 1991
LR	-6.807*	1976 & 1997	-3.372	1991 & 1994

Source: Author's Estimation

N.B:- Min.'t' is the minimum t-statistics calculated. 5% critical value for the two breaks; -5.490

The AO assumes a rapid structural break by which both inflation rate and liberalization index are stationary. However, openness is not stationary in the assumption of a rapid break in slope. Interestingly, it becomes stationary in the case of innovation outlier (IO) that considers a gradual structural break. This indicates that openness of the economy shows the existence of a gradual structural change than a rapid structural change.

Finally, all variables that are expressed in terms of growth rate and ratio are stationary when the study considers structural break using by ZA unit root test and its complement, the CMR unit root test. Note that there are cases where the VARX model with non-stationary data eliminates the stochastic part and produces stationary residuals and cointegration, yields consistent parameter estimates.

Regression Results and Analysis for VARX Model

At the optimal lag order of 2, the OLS estimates for the VARX system using the data 1972-2011 are presented below with three equations. The inclusion of addition information of exogenous variables in the VAR model contributes for a better trend predictability compared with the simple VAR model.

The first equation in the VAR system indicates there is a strong sectoral TFPs interaction of the industry and service with the agriculture at different lags. The lagged values of sectoral TFP growth are statistically significant at different lags for each sector, reflecting different lag structure matters differently for the sectoral impacts of agriculture TFP. Exceptionally, only the agricultural TFP growth and service TFP growth at lag 1 have a positive impact on the current period of agricultural TFP growth, mirroring the service sector as the leading consumer of the agricultural products and thereby creates a massive demand for the sector. Thus, the higher growth of service TFP stimulates agriculture to enhance productivity.

Table 24: Equation for the agricultural TFP with Heteroskedasticity-robust standard errors

Variables	coefficient	std. error	t-ratio	p-value
const	-0.0391166	0.0277652	-1.409	0.1717
tfpga_1	0.226065	0.130303	1.735	0.0956 *
tfpga_2	-0.426641	0.145727	-2.928	0.0074 ***
tfpgi_1	0.0223727	0.0251977	0.8879	0.3834
tfpgi_2	-0.0513581	0.0184041	-2.791	0.0101 **
tfpgs_1	0.133646	0.0505163	2.646	0.0142 **
tfpgs_2	-0.0376304	0.0425246	-0.8849	0.3850
gard	-0.0768301	0.0287418	-2.673	0.0133 **
grnw	-0.174601	0.261843	-0.6668	0.5113
gimc	0.0392750	0.0215664	1.821	0.0811 *
gpep	-0.00730330	0.0909797	-0.08027	0.9367
inf	-0.00114779	0.00101903	-1.126	0.2712
opp	0.00336982	0.00151023	2.231	0.0353 **
lr	-0.00238199	0.00273760	-0.8701	0.3929

Source: Author’s estimates

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Looking at the lags, all sectoral TFP growths have positive impacts at lag-1 and negative impacts at lag-2 on the current period agricultural TFP growth. Such inconsistent relationships reveal the existence of erratic TFP growth rates across sectors and overtimes, leaving the envisaged sustainable economic growth with an inherent challenge. Apart from sectoral TFP growths, the other statistically significant explanatory variables are government expenditure on agricultural R&D, imported capital goods and openness of the economy. As can be seen from Table 24, the growth rate of government expenditure on R&D is statistically significant and has a negative impact on agricultural TFP growth. This does not mean that R&D, which is a proxy for technological innovation, adversely affects the agricultural TFP growth. It rather means that the government might not able to utilize this public resource efficiently and productively for R&D activities due to many factors. Among other factors, the existence of low investment in agricultural R&D along with negative growth rates in above one-third of the study period causes a negative implication for sectoral TFP. Except in the case of industry, the correlation statistics also point at the existence of a negative correlation between the growth rate of agricultural R&D and TFP growth in agricultural and service sectors. Unlike developed economies, the payoffs from the agricultural R&D are negligible are constrained by the lack of sound intellectual property rights, low human capital development, and the inexistence of a strong link between research outputs and practical activities.

Openness to international trade, on the other hand, positively influences the agricultural TFP growth. This implies that it allows the economy to acquire advanced technologies and intermediate capital that scale up the production capacity efficiently. It also exposes the economy to the intensively competitive and sizable market that sharpens the exported agricultural products to fit with international standard. Thus, such wide opportunity for acquisition and exposition causes the agricultural TFP to grow more and positively influence the growth rate of the sector, creating a fertile ground for agricultural

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technology transfer from abroad. Understanding the structure of trade and GDP in the study period, agricultural products account for the lion's share in the export market so that widening the agriculture sector to the international market provides an opportunity of increasing the sector TFP growth. The importation of capital goods including fertilizers, agricultural machineries, chemicals, and other technologies puts on positive influences on the agricultural TFP growth, reflecting technology transfer through importation of capital goods is a decisive factor that is responsible for structural change process via TFP. However, the low human capital development negatively affects the TFP growth and technology diffusion. In a nutshell, the expenditure on agricultural R&D for technology innovation cannot be an alternative way for enhancing the TFP as R&D requires immense and expensive investment so that the country is unable to do so. Rather, technology transfer from abroad in terms of importation of capital goods has a positive implication for TFP growth. This shed some light that technology transfer is preferable as compared to technology innovation. This is mainly attributed to the lower unit cost of technology in the case of technology transfer comparing with innovation.

The second equation in the VAR system explains the determinants of industrial TFP growth (Table 25). Very few of the explanatory variables are non-random ration outcomes. It is only the growth rate of imported capital goods which has a strong relationship with the industrial TFP growth. This means that technology transfer in terms of capital goods is the chief source of industrial TFP growth, instead of technological innovation proxied by R&D. Most of the manufacturing industries in Ethiopia require a surge of advanced imported technologies of machineries, metals and the like.

Unlike the first equation, agricultural and service TFPs are not statistically significant, attributing to the existence of poor performance and scanty share of manufacturing in GDP. Note that the share of manufacturing accounted for only nearly 4.5 percent of GDP in the study period. This also reflects the fact that the industry cannot be the power house

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and driver of innovation, allowing the share of agriculture in GDP to reduce while that of the services increases.

Table 25:- Equation for the industrial TFP with Heteroskedasticity-robust standard errors

Variables	coefficient	std. error	t-ratio	p-value
const	-0.185540	0.233255	-0.7954	0.4342
TFPGA_1	-0.609601	0.728661	-0.8366	0.4111
TFPGA_2	-0.112920	0.950747	-0.1188	0.9064
TFPGI_1	0.141439	0.250223	0.5653	0.5771
TFPGI_2	-0.161042	0.200483	-0.8033	0.4297
TFPGS_1	0.0327591	0.323906	0.1011	0.9203
TFPGS_2	0.301932	0.274486	1.100	0.2822
GARD	-0.0511189	0.172789	-0.2958	0.7699
GRNW	1.42159	3.28087	0.4333	0.6687
GIMC	0.535041	0.258871	2.067	0.0497 **
GPEP	-0.189120	0.803942	-0.2352	0.8160
INF	0.000256301	0.00582208	0.04402	0.9653
OPP	-0.0202679	0.0210487	-0.9629	0.3452
IR	0.0373625	0.0309338	1.208	0.2389

Source: Author's estimation

Most R&D activities and technology creation occur in the developed countries. Only that marginal share of these activities belongs to developing countries. Therefore, most of the poor countries like Ethiopian opt to import and diffuse technology in terms of capital goods towards the industrial sector. This benefit is generated from the R&D activities in the developed countries and then spread to the domestic economy of Ethiopia through imports of capital goods. This improves the existing manufacturing techniques and develops advanced products that enhance economic growth.

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Equation 3 in the VAR system explains about the determinants of service TFP growth (Table 26). In sectoral interactions, there are no lagged values of sectoral TFP growth that are statistically significant in the model. However, the TFP growths for both industry and agriculture have positive impacts at lag 2 and negative impact at lag 1. Besides, the lagged values of service TFP have a negative relationship with the current growth rate of service TFP.

Table 26: -Equation for service TFP with Heteroskedasticity-robust standard errors

Variables	coefficient	std. error	t-ratio	p-value
const	-0.0531573	0.128952	-0.4122	0.6838
TFPGA_1	-0.0928793	0.375716	-0.2472	0.8069
TFPGA_2	0.368335	0.356431	1.033	0.3117
TFPGI_1	-0.0190266	0.0574678	-0.3311	0.7435
TFPGI_2	0.0146389	0.0668758	0.2189	0.8286
TFPGS_1	-0.264068	0.193095	-1.368	0.1841
TFPGS_2	-0.241372	0.167465	-1.441	0.1624
GARD	-0.305120	0.0725031	-4.208	0.0003 ***
GRNW	0.202089	0.492782	0.4101	0.6854
GIMC	0.0761891	0.0911215	0.8361	0.4113
GPEP	-0.351061	0.428494	-0.8193	0.4207
INF	0.000344785	0.00340992	0.1011	0.9203
OPP	-0.0167168	0.00621506	-2.690	0.0128 **
IR	0.0349581	0.0138799	2.519	0.0189 **

Source:-Author's estimation

Apart from such sectoral interactions, the growth rate of expenditure on agricultural R&D, and openness are statistically significant and have a negative implication on the

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service TFP growth rate. An inefficient utilization of public resource that channeled towards R&D causes the negative relationship. The correlation statistics test also confirmed such a relationship. However, the causative factors that are responsible for the negativity of openness on service TFP growth may be attributed to the lack of ability to absorb the technology spillovers and externalities derived from openness due to the country's technological and institutional incapability in the service sectors. The negative impact of openness might also attribute to its transitory impacts, instead of permanent impacts as shown in several developing countries and technological and institutional incapability of the sector to utilize and reap the benefits derived from openness. In addition, the nature of the services sector is dominated by the hotel and restaurant, domestic trade and the like. This means that the service in Ethiopia characterized by the traditional activities, much away from technology and ICT. This service composition does not allow the sector to generate a positive relationship between openness and service TFP growth in the study period.

An index that measures the extent of liberalization in the service trade is statistically significant and has a positive relationship with the service TFP growth. When the service trade was liberalized by increasing the participation of private investors, it surges up the TFP growth in the service sector. Therefore, the service TFP growth requires lesser service trade restriction and regulation for both domestic and foreign investment. In this regard, the financial development in general and private credit per GDP in particular is relevant for increasing the service TFP. The government, therefore, should attempt a series of economic policy reforms and structural adjustment program which allows the economy to be activated and creates a vibrant conducive investment environment. However, there are still many restrictions and regulations that retard the service sector. For instance, the

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government policy does not allow foreigners to invest in the financial sector even though the government launched liberalization and structural adjustment program since 1991. Taking a positive relationship between service TFP growth and index of liberalization in terms of private credit, the service sector has untapped potential of increasing the service TFP by liberalizing the service trade more. To recapitulate, the statistically significant determinants of the sectoral TFP vary from sector to sector. Widening the openness of the economy, increasing imported capital goods, and liberalization are the crucial determinants of the sectoral TFP growth in the agriculture, industry and services, respectively. Besides, the impact of technology transfer is preferable comparing with the technology innovation, mainly due to the fact associated with innovation like inefficiency and expensiveness.

Diagnostic Test

No research can conclude the results of regression analysis without considering a range of diagnostic tests for heteroskedasticity, autocorrelation, normality, goodness-to-fit and the like. The diagnostic tests assist to detect the inadequacy of the model and identify the strengths and weakness of the model. They also reduce the probability of wrongly rejecting or accepting the null hypothesis. In general, the diagnostic tests minimize the drawbacks by indicating problems associated with it. Table 27 gives the summary of the diagnostic tests.

For testing the goodness-of-fit, the Likelihood ratio test indicates that all explanatory variables jointly explain the VARX model as a whole. In other words, all the explanatory variables are jointly statistically significant in explaining the VARX model. The F-tests generated for each agricultural TFP equation and service TFP equation also point out that the dependent variables are jointly explained by the independent variables and the model is a good fit. However, the F-test for the industry TFP equation in the system does not show joint statistical significance. This does not lead to rejection of the VARX model. Rather, it calls for the Granger causality test in order to identify the causality relationship for forecasting.

Table 27 also presents the diagnostic results of Portmanteau test and Durbin-Watson in order to check the existence of autocorrelation. The Portmanteau test on the basis of Ljung–Box test indicates that there is no serial residual correlation in the VARX model as whole at 10% level of significance. The Durbin-Watson test for each question tends to approach 2, indicating the inexistence of serial residual autocorrelation in each equation. Both the Jarque-Bera test and the Doornik-Hansen test confirm that the residuals in the system of VARX are not distributed normally. The Jarque-Bera test for each equation confirms that the error terms in equation of industry and service normally distributed when testing at 5% level of significance. However, it is not normally distributed in the equation of agricultural TFP. This abnormality problem does not affect the property of BLUE and consistency. Nonetheless, it is mainly important to put on hypothesis about population parameters (Enders, 1995). Note that the VARX model considers heteroskedasticity-robust standard errors so that the model is free from the problems associated with heteroskedasticity. In a nutshell, the VARX model and the equations in the system satisfy the OLS assumptions.

VAR system, lag order 2, OLS estimates, observations 1974-2011 (T = 38)

Determinant of the covariance matrix = 7.552551e-006; Log-likelihood = 62.319886

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Table 27:-Summary of Diagnostic Tests

Particular	Assumptions	Tests	Distribution & Values	Remarks
For the VAR as a whole	Normality	Jarque-Bera test	Chi-square=16.834 (0.00991)	Reject Ho
	Normality	Doornik-Hansen test	Chi-square(6) = 27.588 [0.0001]	Reject Ho
	Goodness to fit	Likelihood ratio test	Chi-square(9) = 26.4502 [0.0017]	Reject Ho
	Autocorrelation	Portmanteau test	LB(9) = 80.7407 [0.0654]	Accept Ho
For Agricultural TFPG equation	Goodness to fit	F-test	R-squared 0.693306 ; Adjusted R-squared 0.527181 F(13, 24) .053240 ; P-value(F) 0.001489	Reject Ho
	Normality	Jarque-Bera test	chi2 = 5.085 (0.07866)	Accept Ho
	Autocorrelation	Durbin-Watson test	rho -0.035449 Durbin-Watson 2.055865	Accept Ho
For industry TFPG equation	Goodness to fit	F-test	R-squared 0.320062 Adjusted R-squared -0.048238 F(13, 24) .877320 P-value(F) 0.584948	Accept Ho
	Normality	Jarque-Bera test	chi2 = 10.327 (0.00572)	Reject Ho
	Autocorrelation	Durbin-Watson test	rho -0.044372 Durbin-Watson 1.988101	Accept Ho
For Service TFPG growth	Goodness to fit	F-test	R-squared 0.621293 Adjusted R-squared 0.416160 F(13, 24) .261640 P-value(F) 0.000058	Reject Ho
	Normality	Jarque-Bera test	chi2 = 6.281 (0.04327)	Reject Ho
	Autocorrelation	Durbin-Watson test	rho -0.088418 Durbin-Watson 2.131882	Accept Ho

Source:-Author's Estimation

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N.B:- The null hypothesis (Ho) for testing the autocorrelation is that there is no autocorrelation while the null hypothesis (Ho) for normality test is that the time series is normal. The null hypothesis for F test states that the coefficients of all the explanatory variables are equal to zero. Besides, when the Durbin-Watson test tends to approach 2, it indicates that there is no autocorrelation. Otherwise, error terms are serially correlated negatively or positively.

Granger causality Test

Testing the Granger causality for the sectoral TFP growths using Wald test indicates that the agricultural TFP growth equation shows some causality relationship among sectors. It rejects the null hypothesis that industry TFP growth and/or service TFP growth, jointly and separately, does not cause agricultural TFP growth. In short, both industry and services TFP Granger cause agricultural TFP growth. However, no sectoral TFP growth causes the industrial TFP growth and services TFP growth. This also indicates the poor sectoral economic performance and weak sectoral linkages with industry and service in terms of TFP growth (Table 25).

Table 28:-Granger causality Wald tests Results

Equation	Excluded	chi2	df	Prob > chi2
TFPGA	TFPGI	10.654	2	0.005
TFPGA	TFPGS	21.687	2	0.000
TFPGA	ALL	32.374	4	0.000
TFPGI	TFPGA	0.46914	2	0.791
TFPGI	TFPGS	0.76883	2	0.681
TFPGI	ALL	1.0382	4	0.904
TFPGS	TFPGA	2.4435	2	0.295
TFPGS	TFPGI	0.23377	2	0.890
TFPGS	ALL	2.8896	4	0.574

Source:-Author's estimation

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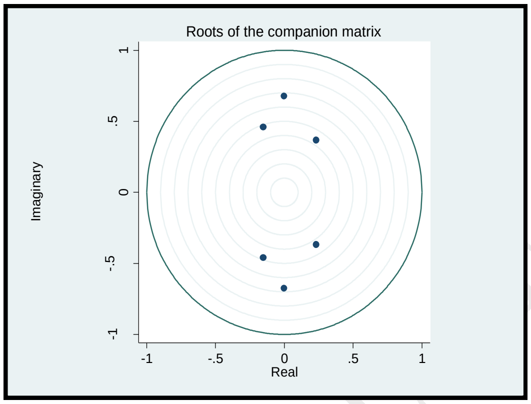
Stability Condition of the VARX Model and Analysis of One-Time Shock

The requirement of satisfying the stability condition of the VARX model points out that the unit roots or the solutions of the VARX system are below one, or all the Eigen values lie inside the unit circle, which is the necessary and sufficient condition for stability. Otherwise, the impact of the impulse (shock) in some variables might not decrease with time. A crucial condition for the VAR model to be valid and consistent requires the covariance to be stationary in order to avoid the formation of explosive roots. This confirms that the VARX model the study uses satisfy the stability condition and can be used for forecasting. Graphically, the result confirms the stationarity of VARX as all characteristic roots lie inside the unit circle.

Figure 14:- Stability Test for VARX



Source: Author's estimation

Table 29:-Eigen value stability

Eigen value	Modulus
-.00205458 + .6758683i	.675871 -
.00205458 - .6758683i	.675871 -
.15411940 + .4591577i	.484333
-.15411940 - .4591577i	.484333
.23281170 + .367998i	.435458
.2328117 - .367998i	.435458

Source: Author's estimation

N.B: - For a characteristic equation of the type, $a\lambda^2 + b\lambda + c = 0$, $\lambda_1, \lambda_2 = \frac{-b}{2a} \pm \frac{\sqrt[i]{b^2 - 4ac}}{2a} = \alpha \pm \beta i$; Real roots: $\lambda_1, \lambda_2 = \alpha \pm \beta$ Imaginary roots: $\lambda_1, \lambda_2 = \alpha \pm \beta i$ where $i = \sqrt{-1}$. In general case, the modulus of a complex number, a + bi is $\sqrt{a^2 + b^2}$. The stability of the VAR model requires the moduli of the Eigen values to lie within the unit circle. Otherwise, the system is not stationary. Rather it is explosive or non-convergent.

As the VARX model is stable, the next issues the paper discuses are the impulse response functions and variance decomposition in response to a one-time shock in the system. The

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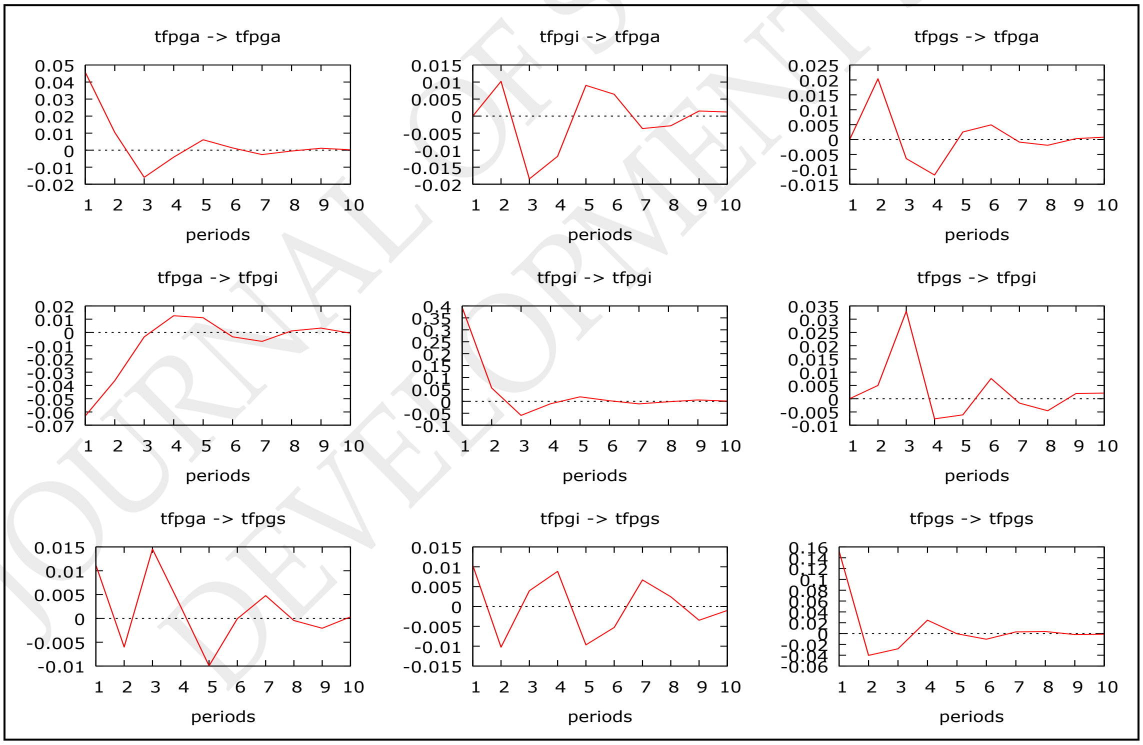
Impulse Response Function refers to the dynamic interactions among endogenous variables of sectoral TFP growths and traces the effect of a one-time shock on current and future values of the endogenous variables. It sheds light for empirical causal analysis and policy effectiveness. Figure 17 shows the impulse response functions in the 10 forecasting periods and indicates how the sectoral TFP growths responded to a change in the other variables. As can be seen from the figure 17, all the responses in each equation are high at the initial period and the shock then dies through time and then tends towards zero at the end of 10 years. Each row of the graph indicates the response of sectoral TFP growths in one sector over time to a positive shock emanated from the TFP growths of the other two sectors.

All shocks create an explosive time path at the initial period and then converge to zero after some time, dying through time. This confirms that the VAR system is stable. Note that an unstable system would produce an explosive and divergent time path.

Figure 15:-Impulse Response Function for Sectoral TFP growths



Source:-Author's estimation

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N.B: - tfpga , tfpgi and tfpgs stands for TFP growth rate in the agriculture, industry and services sectors.

Variance Decomposition refers to the separation of the variation in an endogenous variable into the component shocks during the forecast period. It also provides information about the contribution or the share of each sectoral TFP growths to the variation of the endogenous variables in each equation. Accordingly, 65 percent of the error variance of agricultural TFP growth in the agricultural TFP equation is explained by own shock while the remaining 35 percent is explained by the shocks on industrial TFP growth (26 percent) and the service TFP growth (9 percent). However, the equations of industrial and services TFP growths are heavily explained by own shocks: 94 percent and 89 percent respectively. This reflects both industry and services are relatively weak in sectoral linkage (Table 20).

Table 30:-Variance Decomposition for Sectoral TFP growths

Decomposition of variance for Agricultural TFP growth rate				
period	std. error	TFPGA	TFPGI	TFPGS
1	0.0457416	100.0000	0.0000	0.0000
2	0.0521541	80.9157	3.8276	15.2568
3	0.0579284	73.1779	13.2353	13.5868
4	0.0604446	67.6702	15.9725	16.3574
5	0.0614732	66.4156	17.6001	15.9844
6	0.0620158	65.3027	18.3595	16.3378
7	0.0621838	65.1243	18.6064	16.2692
8	0.0622799	64.9297	18.7561	16.3142
9	0.0623091	64.9018	18.7969	16.3013
10	0.0623262	64.8674	18.8245	16.3081
Decomposition of variance for Industrial TFP growth rate				
period	std. error	TFPGA	TFPGI	TFPGS

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1	0.39917	2.4942	97.5058	0.0000
2	0.404765	3.2360	96.7488	0.0152
3	0.41038	3.1546	96.1842	0.6611
4	0.410772	3.2429	96.0629	0.6942
5	0.411397	3.3057	95.9802	0.7141
6	0.411489	3.3107	95.9414	0.7480
7	0.411686	3.3344	95.9167	0.7489
8	0.411717	3.3346	95.9043	0.7610
9	0.411774	3.3400	95.8969	0.7631
10	0.411781	3.3401	95.8943	0.7657
Decomposition of variance for Service TFP growth rate				
period	std. error	TFPGA	TFPGI	TFPGS
1	0.153188	0.5324	0.4577	99.0099
2	0.158831	0.6379	0.8411	98.5210
3	0.162009	1.4183	0.8681	97.7136
4	0.164136	1.4043	1.1358	97.4599
5	0.164721	1.7589	1.4712	96.7699
6	0.165138	1.7500	1.5660	96.6840
7	0.165372	1.8286	1.7249	96.4465
8	0.165433	1.8279	1.7455	96.4266
9	0.165492	1.8422	1.7881	96.3697
10	0.1655	1.8424	1.7916	96.3660

Source:-Author's estimation

9. Conclusion and Policy Prescriptions

The Ethiopian economy has performed with erratic growth rate and sluggish structural change over the period 1970-2010. It also exhibited a very low and negative growth rate seven times in the reference period, indicating the existence of recurrent drought that occurred every five year. Moreover, the structure of the GDP was characterized by low and stagnant share of the manufacturing sector (4.8 percent on average) that was

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expected to drive productivity and sustain economic performance. In the consequence of the lion's share of service sector in GDP, the economy tended to encounter a structural change burden as explained by Baumol's disease (Baumol, 1967). One of the causative factors, among others, is the persistence of low and erratic TFP growth over the reference period. It is hard and unthinkable to achieve sustaining economic growth without structural change that mainly emanated from growth in TFP. Increasing the growth rate of sectoral TFP is one of the principal sources of perpetual growth as it has a nature of an increasing return to scale. As TFP is capable of curing the problems, the study identifies the key determinant of TFP for agriculture, industry and service sector using VARX model.

The estimates by the sectoral growth accounting approach confirmed that factor accumulation explains the growth trajectory in Ethiopia. Labour is the dominant source of the agricultural growth while capital deepening is the big source of growth in industry and services over the period 1972-2011. However, the study also finds that the sectoral TFP growth rates are erratic with negative performance on average, reflecting the existence of the lack of efficiency and the shortage of technological change in the economy and creating severe economic debacles and a deadlock situation. Therefore, the study is engaged in looking for factors that influence this stochastic and low sectoral TFP growth. The VARX model that accounts for both endogenous and exogenous variables produces remarkable econometric results in this regard. Out of the determinants of agricultural TFP, foreign trade openness, industrial TFP and service TFP at lag, and imported capital goods and service are statistically significant and positively influence the current agricultural TFP. Regarding the industrial TFP growth, it is only the growth rate of imported capital goods that is statistical significant and positively influences the industrial TFP. The service TFP is negatively influenced by openness and positively affected by liberalization index. However, the growth rate of expenditure on R&D

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negatively influences the current growth rate of agricultural and service TFP in the case of Ethiopia.

Based on these findings, the study draws multifaceted policy implications at sectoral level in the face of achieving remarkable economic growth with structural change. For increasing agricultural TFP, there must be a policy that favors both industrial and service TFP as they positively influence the current growth of agricultural TFP. Moreover, the government should attempt to widen the openness of the economy to international trade as it allows the economy to acquire advanced technologies and intermediate capital that scale up the production capacity and agricultural TFP. This also widen opportunity for acquisition and exposition that causes the agricultural TFP to grow more, creating a fertile ground for agricultural technology transfer from abroad. On top of this, enhancing the growth rate of imported capital goods and service is a recommended policy in order to foster industrial TFP growth. For increasing service TFP, the government should liberalize the service trade and allow increasing participation of private investors. It requires lesser service trade restriction and regulation for both domestic and foreign investment in the service sector. In general, the government should focus on technology transfer from abroad instead of engaging in costly technology innovation in area of agriculture and industry. Moreover, it also revisits the level of liberalization in area of foreign trade and domestic service trade in order to scale up the performance of agriculture and service sectors.

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