AN EMPIRICAL ANALYSIS OF PRODUCTIVITY SPILLOVERS TO THE LOW INCOME COUNTRIES
A CASE STUDY OF ETHIOPIA AND USA AS THE WORLD TECHNOLOGY FRONTIER

Masters of Science in Economics

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1. INTRODUCTION

Sub-Saharan African (SSA) aggregate economic performance remains weak compared to other developing regions, for example Asia and Latin America. Per capita incomes have declined by around 1 percent per annum\(^1\), growth rates are well below the average\(^2\), and there is slow growth in the manufacturing industry that is considered to be the most dynamic industry and so on. A number of studies in the development discipline on Africa, and SSA in particular provide empirical evidence on how both domestic and external factors have negatively favored the productivity growth in this region\(^3\). Some members in the region have even gone as far as putting responsibility for their miserable economic performance on the colonial masters. However, history has it that there are some countries that were never colonized, but are still dwelling in a pool of poverty and poor economic performance in the 21st century. Ethiopia is one of these countries that resisted colonialism and is still struggling to make the daily bread affordable to all Ethiopians, despite reports that it has the fast growing annual GDP\(^4\) and was the fastest growing non-oil dependent African country in 2007 at 8.4% growth rate, International Monetary Fund data mappers (2008).

We, therefore, have decided to focus on Ethiopia in this study and see how it has fared in productivity growth, and whether it has managed to leap from international productivity spillovers championed by the World Technology Frontier. Before we start with the definitions and measurement issues and of course processes through which these spillovers are assimilated, we decide to briefly introduce the country that we are going to spend most of our time on in this work.

Various factors can be considered in explaining Ethiopia’s state of economic and productivity growth today: Poor institutions, self isolation from FDI\(^5\), conflict with Eritrea, the climate effect or geographical disadvantage ranging from the distance to the world technology frontier to drought problems, not forgetting ethnicity diversity among others, are factors that in one way or another have and still affect Ethiopian productivity growth and its eventual economic growth. Harald Badinger (2007) in Trade policy and productivity discusses the effects of trade and institutions on productivity. His results are positive and convincing that these two variables do affect productivity growth across countries. This is of course in line with Frankel and Romer (1999)’s discussion on the endogeneity of the trade variable and ruling out the direct effect of geography on productivity other than through trade.

1:1 Background (Ethiopia)

From 1975-1991 Ethiopia was under a military government. The private sector in this period was stifled by the confiscation of industrial establishments of nationals and foreigners in what was termed as nationalization of manufacturing enterprises. These left most of the

\(^1\) More details on this in Collier and Gunning’s work (1999a, 1999b)
\(^2\) See Ndulu and O’Connell(1999) for details
\(^3\) Frankel and Romer, Easterly and Levine in addition to footnote 1 and 2
\(^4\) Gross Domestic Product
\(^5\) Foreign Direct investment
manufacturing firms state-owned, and protected from competition. Many restrictions and regulations were imposed on potential investors regardless of origin. A capital ceiling of 0.5 million Ethiopian Birr ($54,703.83) was imposed on the private sector, foreign exchange supply was restricted, price controls and so on. The combination of all these factors led to productivity dampening in the country. In 1991, the new government came into power with lots of reforms and the will to transform the economy to a market oriented one. Reforms like privatization, trade opening, and liberal foreign exchange market were introduced.

As if this is not enough, the agricultural products dominate Ethiopian manufacturing. As in many other SSA countries, agriculture sector contributes almost (40%) to GDP and employs more than (80%) of Ethiopian labor force. Increased labor productivity in this sector would mean more labor\textsuperscript{6} to the manufacturing sector and therefore increased production of manufactured goods, other factors remaining constant. Manufacturing productivity started falling in early 1980s due to a turn-down in agriculture production and foreign exchange shortage to the import of raw materials. However, in around 1985, Ethiopia was noted among the best SSA countries with capacity utilization between 70-100%. This didn’t, however, last for long. In 1990s for example due to wear outs and spare part shortages, the Country experienced a further decline.

\textit{The figure below gives the location of Ethiopia in the horn of Africa. The shaded area is Ethiopia and we can as well see the bordering countries. Ethiopia is not only one of the SSA countries, but also a landlocked country and not least, surrounded by countries in conflict. We well know what is happening in Somalia which Ethiopia is party to, Sudan to the west and the Darfur conflict, Eritrea in the north and its strained relationship with Ethiopia, and of course the recent conflict in Kenya.}

\textsuperscript{6} See Basu Et Al., (2006), for the detailed estimations and discussions on how improved technology (technological shocks) will lead to reductions in the factor inputs without reducing output. We therefore believe this will apply on Ethiopian agricultural sector as well.
Figure 1: A map that locates Ethiopia in the horn of Africa.
1:2 MOTIVATION

Motivated by among others: Paul Bennell (1998)’s paper on industrial restructuring in Africa in 1990’s. The results were alarming for most of these countries. In most countries, industrial growth rate fell instead of rising and Ethiopia is no exception. It experienced zero growth for the period 1990-1995. The picture of African performance given by Bennell’s paper is in line with Easterly and Levine (1997)’s conclusions about Africa’s economic history since 1960s as a ”tragedy”. In their paper, they examine direct and indirect effects of ethnic diversity on economic growth and public policy choices. They highlight some of the factors that lead to slow growth. Among others: poor policies, poor education, poor and/or inadequate infrastructure and above all political instability.

SSA is one of the regions in the whole world that has and still is marred with political instabilities something that has resulted in loss of millions of people, both skilled and unskilled. Take an example of what happened in Rwanda in 1994, a conflict that claimed the lives of nearly a million Rwandans both skilled and unskilled, total destruction of the minimal infrastructures that the country had and so on. Sudan and the Darfur conflict, in addition to the SPLA’s^{7} need for recognition and belonging. Somalia and ethnicity problems, Chad and of recent, Kenyan wrangles upon election results that left thousands of its manpower dead. Of course not forgetting the Zimbabwe crisis where inflation as I write this thesis is over 230 millions percent. In all these conflicts, there has been an ethnic issue in the background and it has in one way or another retarded productivity and economic growth in the countries in point and their neighbors as well. Ethiopia is no exception in these studies, and the factors discussed in Easterly and Levine’s paper are of great significance for productivity growth in Ethiopia. The conflict between Ethiopia and Eritrea and of course her present involvement in Somalia has had an enormous impact on policy choices which has in turn affected her economic and productivity growth at home in general. The ethnic diversity in Ethiopia is also of great concern most especially in political circles, but also in communities in general.

Disappointing levels of factor productivity in most low income countries and SSA in particular, greatly affects the industrial labor productivity in these countries, Bennell(1998). He further argues that low technological capabilities of entrepreneurs, managers and workers have been identified as the root cause of poor productivity of manufacturing enterprises in Africa. In addition, Benno J, Ndulu and Stephen A. O’Connell (2005) discuss different five features of African growth performance from 1960-2000 and how these features have greatly affected growth in the region. These include: divergence in incomes and population from incomes and population of other developing regions like Asia, slow accumulation of capital and productivity growth, limited structural transformation whereby the agricultural sector remains the key determinant of overall living standards and essential source of foreign exchange for imported capital goods, in addition to the rural-urban ratio problem, not to mention limited structural transformation in export diversification, Lingering volatility and lastly but not least diversity. It is quite important to note that there are many people in the

^{7} Sudanese Peoples Liberation Army
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agricultural sector who use a lot of time to produce less in almost all under-developing countries and most especially in SSA.

In their article, Explaining African Economic performance, Collier and Gunning (1999) discuss six factors for slow growth. Their work focuses on among others, the rural households and manufacturing firms. Despite different attempts, they found out that neither households nor manufacturing firms have yet sufficiently created the social institutions that promote growth. This is a further confirmation of Easterly and Levine (1997)’s factors for slow growth in Africa. All the factors discussed in these works look at endogenous factors affecting productivity growth. Our main interest here, therefore, is to look beyond borders for some factor that is exogenous and which can positively drive productivity to a better level. In bid to extend the research made above, we decide to examine the effect of the exogenous driving force that we believe has a significant effect on productivity growth in Ethiopia, The World Technology Frontier’s labor productivity.

Despite the above evidence and factors for Africa’s slow growth, SSA countries continue to lag behind developed world as far as productivity growth is concerned and that is why, therefore, we decide in this work to look beyond the above mentioned endogenous factors for an exogenous driving force that would add some piece of contribution to the existing literature on the topic. We are, therefore, going to focus on the exogenous driving force and see whether it can help move forward the Ethiopian industrial labor productivity and SSA in general. We restrict ourselves to the situation whereby, productivity in Ethiopia is a function of value-added and labor only. This means that the frontier’s labor productivity can to some extent explain the productivity levels in Ethiopia. And the frontier’s labor productivity is therefore the exogenous driving force here. It is widely believed in catching-up models that due to international spillovers, international productivity growth rate differentials tend to vanish over time and that the bigger the gap between the leader and the follower, the more there is for the follower to learn. However, we observe from our results that Ethiopia has not, if at all, managed to exploit her position to increase her industrial labor productivity as expected and close the gap between her and the world leader something that excludes the automaticity of productivity spillovers as a main mechanism of economic growth for low income countries.

1:3 SUMMARY

Through this work, we investigate the effect of the world technology frontier on Ethiopian industrial labor productivity. We have seen that industrial labor productivity in Ethiopia, despite her limited capacity to exploit the frontier, cannot be understood in absence of world leader’s effect. The period after 1990, as we can see from figure c in the appendix, with the exception of petroleum refineries, shows a divergent tendency and therefore an increasing gap between the leader and the follower. We’ve assumed here that the reasons for this increasing gap is due to other factors affecting productivity growth such as lack of social institutions that promote growth resulting in poor education, poor policies, poor infrastructure, political instability, geographical location and so on as mentioned in the above section that are not included in our estimations since our main interest is finding out the frontier’s effect through productivity spillovers on Ethiopian productivity. In all estimations carried out the minimum requirement for significance at 10%, 5% and 1% significance levels are met, therefore
confirming our hypothesis that the world technology frontier’s labor productivity positively affects Ethiopian labor productivity. In addition to testing the level relationship between labor productivity in the two countries, we did check for the long-run relationship and the possibility of closing the gap between them through the error correction model. We got positive results but far from the expected/desired ones. No equilibrium in the long run that brings Ethiopia and USA closer to each other, instead, Ethiopian productivity is in general diverging from the desired equilibrium. Figures c and d in the appendix show sectors that have been diverging more than others. We therefore conclude that the international productivity spillover hypothesis is not automatic for a country like Ethiopia. It requires that the recipient country is well prepared with a well functioning economic system to adopt the advanced technology from abroad.

1:4 PRESENTATION

In chapter 2 we introduce productivity growth and how it is measured. We decide to concentrate on one way of measuring productivity growth and that is labor productivity. Labor productivity is defined in this chapter as value-added per worker. We further assume a standard production function to show that labor productivity increases with increased value-added and decreases with increased labor input per production unit. In addition, we mention shortcomings for using this measure of productivity growth. In the classical approach section, we give the theory approach in as far as productivity growth and technology transfer is concerned. Terms like catching-up, world technology frontier, technology gap and the poverty trap are introduced. We discuss Nelson and Phelps and Benhabib and Spiegel’s contribution on technology diffusion through innovation and adoption. As we shall see throughout our work, the innovation part of this theory has been minimally discussed due to data problems and generally less spending on R&D in most developing countries, despite its clear and emphasized contributions to technology transfers and productivity growth and lastly, we bring in the previous empirical works on the topic in point so as to keep track on the discussed literature.

In chapter 3 we discuss the econometric specifications. It introduces our strategy and method. Making assumptions has helped us deal with different econometric problems that would otherwise have been a problem in the process of testing our regressions. We have indicated problems we encountered in the original dataset that prompted us to make some adjustments so as to be able to use it and get not only reasonable, but also consistent and unbiased estimates. This chapter discusses the method and ways we are going to use to solve the problems mentioned above. Chapter 4 gives a summarized data overview of the original dataset, definition of variables in our dataset and unbalanced panel dataset and its challenges. In chapter 5 we present and discuss the results from our tests. We present two tables here, one that presents productivity level relationship between Ethiopia and USA and the second one for the error correction model to check for the long-run relationship. Not least a simple

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8 Research and Development
9 Rachel Griffith, Stephen Redding and John Van Reenen discuss the “two faces” of R&D. To catch-up fast, there is need to invest in R&D, and they in addition, point out the distance from the frontier as a potential for technology transfer.
2. PRODUCTIVITY GROWTH

2:1 MEASURING THE RATE OF PRODUCTIVITY GROWTH

There are two alternative measures of the rate of productivity growth that are explicitly related to each other: Labor productivity measure and total factor productivity, Zvi Griliches (1988). Growth accounting techniques that follow Solow (1957) are used to break down the rate of growth of value-added into the contribution of physical capital accumulation, increased labor inputs and “residual” growth/ total factor productivity. This same decomposition can be used to evaluate the contribution of capital accumulation and total factor productivity growth to labor productivity growth. This work is, contrary to many other works before it, focusing solely on labor productivity to measure the rate of productivity growth in low income countries and taking Ethiopia as a case study. We are in other words going to analyze productivity spillovers from the World Technology Frontier to the low income countries. Productivity spillovers can be transferred direct through FDI and trade between countries or indirectly through relations with other countries that have direct access to the new technology. We are, however, not going to distinguish between these channels in this work for simplicity’s sake and data problems we are likely to face in case we decided to do so.

2:2 LABOR PRODUCTIVITY GROWTH

Labor productivity growth is measured by the rate of growth of value-added per hour worked. Labor productivity \( = \frac{\text{value\_added}}{\text{man\_labor}} \).

Let us assume a production function:

\[ Y = A K^\alpha L^{1-\alpha} \]

\(^{10}\) For further discussion on productivity growth measured by Solow residuals, see Donna M. Costello, (1993). She studies 5 major industries in 6 major countries in what she called the Cross-country, Cross-industry comparison of productivity growth.
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\[ Y = AF(K, L) \]  

Whereby \( Y \) is output, \( A \) is total factor productivity, \( K \) is capital and \( L \) is labor. By dividing the above equation with \( L \) we get;

\[ \frac{Y}{L} = AF\left(\frac{K}{L}, \frac{L}{L}\right) \]  

\[ \frac{Y}{L} = A \cdot F\left(\frac{K}{L}\right) \]

\[ \left(\frac{Y}{L}\right) = \hat{A} + F\left(\frac{R}{L}\right) \]  

This means that labor productivity, ceteris paribus, increases with increased growth in value-added and decreases with increased hours worked. The disadvantage with this measure that we have chosen to use in this thesis is that, it measures only one factor of production, and hence a problem to distinguish between labor productivity being high in a sector as a result of high degree of technical efficiency or because of a large stock of physical capital, Cameron, Proudman and Redding (1998). This measure of productivity growth imposes less restriction on the data than total factor productivity. This is one of the important reasons why we have decided to use it in this work, since we are dealing with a less developed country with data collecting and reporting problems as we shall see in chapter 4. One of the alternative measures could have been gross value of output, but this measure is abandoned since it involves a considerable amount of double counting due to the fact that part of output is used as intermediate inputs in other industries. In chapter 4, we define briefly value-added used in this thesis.

Labor productivity measure, however, suffers from the difficulties of computing correctly an index that is based on value-added “real” output in the world of changing commodities and services and secondly, measuring quality (skilled or unskilled) and quantity of labor service, Zvi Griliches (1988).

2:3 CLASSICAL APPROACH TO THIS PROBLEM

The classical approach of “catching-up” to the world technology frontier hypothesis was proposed by Gerschenkron in 1962. The idea behind the catching-up theory is that there exists a technology frontier to which all developing technologies should look on to. This is demonstrated in figure 2 below:
The gap between the technology leader and other economies can be closed, but at a different rate and degree. The further away from the leader, the more advantageous it is for the less developed. The technology gap theory is what inspired Gerschenkron (1962) to introduce the term “advantage of backwardness” which we shall later see that it is actually a cost to those countries lagging behind. Though he believes in his work that this productivity spillover issue is possible, he at the same time points out that for this process to work there must be lots of investments, infrastructure and strong institutions. From figure (2) above, countries lie at different levels between the frontier and the follower. Countries close to the frontier have less to learn from it and therefore will experience less productivity growth. We can take examples from European countries here. Most of these countries lie close to the frontier if not on the same line. These countries’ productivity can only increase as a result of innovation but not imitation from the frontier.

On the other hand, a country like Ethiopia and others at the same level of development, low income countries, will enjoy their being far from the world technology leader by imitating or copying the already existing technology. Most of the work, for example research and

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11 See also Robert. J. Barro and Xavier on the relationship between per capita income growth and starting levels of output per capita
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invention, is therefore done by the world technology leader and it’s up to the follower to put it into use. There is, in other words, more to learn from the world leader if the technology gap is big and less to learn if the technology gap is small, Nelson and Phelps (1966). Closing this gap between technology frontier and the current level of labor productivity depends partly on the level of human capital development or level of education, Benhabib and Spiegel (1994).

Their, Nelson and Phelps’, main argument is that countries should focus more on what is happening across the borders rather than internal factors for productivity growth. What is happening outside, in this case, industrial labor productivity growth in USA, has more effect on domestic, here Ethiopian, industrial labor productivity growth than internal factors.

Theoretical level of technology is the best practice level of knowledge that would prevail if technological diffusion were completely instantaneous. It’s the measure of stock of knowledge available to innovators. Their productivity model which states that the rate at which the latest theoretical technology is realized in improved technological practice depends upon educational attainment and upon the gap between the theoretical level of technology and the level of technology in practice, Nelson and Phelps(1966), is as follows, and we choose to use the same variable format that we are going to use in the rest of our work instead of the total factor productivity given in the reference for simplicity’s sake.

\[
yl(t) = \Phi(H) \times (yl(t) - yl(t))
\]  
(4)

\[
\frac{yl(t)}{yl(t)} = \Phi(H) \times \left(\frac{yl(t)^* - yl(t)}{yl(t)}\right), \Phi(0) = 0 \text{ and } \Phi(1) > 0
\]  
(5)

\[
\frac{\partial (yl(t))}{\partial yl(t)} = \Phi(H) \times \frac{1}{yl(t)} > 0
\]  
(6)

This implies that increased frontier’s labor productivity will lead to increased domestic labor productivity growth rate.

\[
\frac{\partial (yl(t))}{\partial (yl(t)^*-yl(t))} = \Phi(H) > 0
\]  
(7)

This implies that the labor productivity growth rate increases with increased relative productivity gap.

yl(t)^*: The frontier’s level of labor productivity

yl(t): The domestic level of labor productivity

\[
\frac{yl(t)^*-yl(t)}{yl(t)} : \text{The relative labor productivity gap.}
\]
Left hand side in (5) gives the labor productivity growth which is equal to the product of human capital and the relative productivity gap. The hypothesis here is that high \( H, \Phi \), \( y_l(t)^* - y_l(t) \) leads to higher labor productivity growth. A high education level makes it easy for followers to innovate, imitate and adopt new technologies, something that leads to increased labor productivity. However, it should be noted that higher productivity growth due to high \( H \) can only be achieved if \( y_l(t)^* - y_l(t) > 0 \). Since we are dealing with industrial labor productivity in this work, we follow Rattsø and Harding (2007)’s assumption, letting \( H \) stand for science education suited for industrial production. The rate of increase in the productivity in practice is an increasing function of education attainment and proportional to the relative productivity “gap”, \( \frac{y_l(t)^* - y_l(t)}{y_l(t)} \). Our work will however concentrate most on this last factor, the relative productivity gap between countries, and less on education. To do this, we shall need a model that distinguishes between technology transfer that requires a certain level of education attainment and that one that is dependent on the technology gap between countries. This is discussed in the logistic diffusion model below. Productivity spillovers in this model will depend on the follower’s capability to imitate inventions at the frontier or what Abramovitz termed as the “absorptive capacity”, Fagerberg, J. and Verspagen, B. (1998).

2:3.1 THE EQUILIBRIUM GAP AND LONG-RUN EQUILIBRIUM

This is the long-run solution. In the long-run equilibrium, we assume that all countries will have the same rate of growth but different productivity or income levels depending on their level of human capital.
Equilibrium gap is therefore a decreasing function of educational attainment. From the figure above, we see that we have a stable long-run equilibrium in point E. Before this point, productivity growth rate at the frontier is greater than the follower’s productivity growth rate. This means that the relative gap between the two is increasing and therefore moving towards right hand side in the figure 3 above. On the other hand, to the right of point E, the follower’s productivity growth rate is above the frontiers productivity growth rate. In this situation, the relative gap between the two must be falling, hence movements to the left in our figure. At point E we have that:

\[
\frac{y_{l(t)}^*}{y_{l(t)}} = \frac{y_{l(t)}^*}{y_{l(t)}} = \frac{\lambda}{\Phi(h)} = \frac{y_{l(t)}^* - y_{l(t)}}{y_{l(t)}}
\]  

(8)
Equilibrium gap $\frac{y^*_t - y_{t(t)}}{y_{t(t)}} = \frac{\lambda}{\Phi(h)}$

In technologically progressive economies $\lambda > 0$

Assuming the technologically progressive economy, increased education attainment will move

$\frac{\lambda}{\Phi(h)}$ to the left and hence reduced productivity gap.

Curve rotates to the left.

Conclusion: According to the models above, the rate of return to education is greater the more technologically progressive an economy is. Educated people make good innovators, so that education speeds the process of technological diffusion, Nelson and Phelps (1966). However, since we are dealing with developing countries, in this case a SSA country with Data collecting and reporting problems, we are going to be forced to limit ourselves in as far as discussing education contribution to labor productivity growth is concerned, despite findings by many researchers, Harding and Ratto (2007) among others, that interaction between a country’s level of education and the frontier’s productivity give a statistically significant effect on the domestic productivity.

2.3.2 TECHNOLOGY DIFFUSION AND LOW INCOME/POVERTY TRAP

Nelson and Phelps’ discussion on technological catch-up to the world technology frontier is further discussed by Benhabib and Spiegel (1994, 2002, and 2005) through two models, exponential and logistic models of technology diffusion. They extended this model by distinguishing between technology adoption and innovation diffusion processes as source of growth.

As in the Nelson and Phelps discussion, so does Benhabib and Spiegel discuss the role of the world technology frontier to productivity growth but from a different perspective. In their work, they emphasize the role of income levels through the term, poverty trap; in as far as catch-up is concerned. They argue that rich countries have little productivity gap between them and therefore low catch-up rate. On the other hand, middle and low income countries have bigger productivity gaps from the frontier and should catch-up faster than rich countries. This faster catch-up is experienced through high growth rates. However, it’s only the Asian Tigers so far that have this theory real. According to this theory, we would expect the

12 Singapore, Taiwan, Hong Kong and South Korea
country in point here, Ethiopia, whose productivity gap from the frontier is very big, to catch-up faster than countries closer to the frontier.

In the same spirit, Romer (2006) points out two difficulties faced by poor countries in as far as cross-country differences in real incomes and therefore catch-up difficulties are concerned; The quantitative and conceptual difficulties.

Quantitatively, assuming the Solow model for all economies, but not all have access to the same technology, lags in the diffusion of knowledge needed to account for observed differences in incomes are extremely long. It may be centuries or more. It’s therefore hard to believe that the reason some countries are so poor is that they do not have access to the improvements in technology that have occurred over the past century.

Conceptually, Technology is non-rival. Same technology can be used by different firms. That is, Knowledge is publicly available. But, if knowledge is publicly owned, how come then poor countries do not have access to the same knowledge as developed countries? Why is it that poor countries’ workers and managers can’t read the appropriate literature as regards sources and policies for development and economic growth? This has been objected. If technology is public, then it cannot be used as an explanatory variable to explain differences in productivity growth. The difficulties faced by poor countries in such a situation are not lack of access to the advanced knowledge/technology, but lack of ability to use it. Romer(2006) concludes that the differences across countries in the standard of living is not due to differences in the level of technology/knowledge, but differences in whatever factors that allow richer countries to take advantage of advanced technology.

Whereas exponential diffusion leads to the closing of the gap between the leader and the current level of productivity, logistic diffusion on the other hand leads to divergence in productivity growth rates and therefore not catch-up, Jess Benhabib and Mark M. Spiegel(2002). They further argue that logistic model allows for the dampening of the diffusion process and therefore slower productivity growth than the world frontier. This means that the gap between the leader and follower can continue to grow, and these two specifications have, therefore, different implications on the nation's growth path.

In this model, as mentioned before, we assume two countries; Ethiopia, and the United States of America. The United States of America, the technology frontier, is represented by superscript *. Ethiopia is the follower and is represented by $y_{lt}$ while USA is the leader. The exponential diffusion model can be studied in the equation (9) below:

\[
\begin{align*}
\left( \frac{y_{lt}}{y_{lt}} \right) &= g(H) + c(H) \left[ \frac{y_{lt}^*}{y_{lt}} - 1 \right] \\
\end{align*}
\]

Domestic industrial labor productivity = $y_{lt}$
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\( g(H) \): The technology diffusion that depends on the level of innovation in Ethiopia.

\( c(H) \left[ \frac{y^{l(t)\ast}}{y^{l(t)}} - 1 \right] \) This gives the rate of technology diffusion from USA to Ethiopia through adoption.

The above figure shows the effect of low human capital and big technology gap. It summarizes Benhabib and Spiegel’s theory on adoption and innovation and the poverty trap issue. While Nelson and Phelps did not attempt to explain how some countries fail to experience productivity growth, Benhabib and Spiegel’s work has managed to bring this problem to attention through what they call the poverty trap. This is a situation whereby the country is so poor that it can’t manage to get out of poverty again. Once the country falls into the poverty trap it will continue to diverge from the frontier instead of converging. The low human capital can for example result from the brain drain that has hit most of the developing countries. However, this brain drain issue has, to some extent, been disregarded by some
researchers, among others, Batista, Lacuesta and Vicente (2007) in their discussion paper, *Brain drain or Brain gain*. For more discussion on Africa and the poverty trap.\(^{13}\)

The arrows in the figure above show the movement in productivity growth, \(\frac{y_t}{y_{t-1}}\) as the follower country experiences very low human capital due to, for example, brain drain as mentioned above. The gap between the frontier technology and the follower therefore widens even further and the trend continues as poverty deepens in that country to the level whereby the equilibrium gap is equal to zero. At the level, \(\frac{y_t}{y_{t-1}}''\), the country is too poor that it can’t manage to innovate, and the only thing it can do is to adopt technology from abroad.

This is probably why we experience that most of poor countries, more particularly, in SSA have either stagnated or worsened in as far as productivity growth is concerned. The straight line in the figure above represents the level of constant technological growth rate, literally referred to as the frontier’s level of technology or the theoretical level of technology. It’s given by \(g\). The sloping curves represent the domestic technological level at a given level of human capital in the country, here Ethiopia. The lower curve represents the low human capital and it can shift even lower if human capital level falls further. \(\frac{y_t}{y_{t-1}} - \frac{y_t}{y_{t-1}}\) Represents the productivity/technology gap which increases with decreasing level of human capital.

The higher the initial technology in a country, the smaller is the gap to the leader, less to learn, and therefore slower growth. Basing on this theory, Ethiopia should be experiencing high productivity growth since it’s far from the frontier.

The logistic formulation which is the alternative to exponential diffusion distinguishes between diffusion as a result of innovation and diffusion as a result of adoption and it is formulated as follows;

\[
\frac{y_t}{y_{t+1}} = g(H) + c(H)\left[1 - \frac{y_t}{y_{t-1}}\right] \\
\frac{y_t}{y_{t+1}} = g(H) + c(H)\left[\frac{y_t}{y_{t+1}^*}\left[\frac{y_t}{y_{t+1}} - 1\right]\right]
\]

\(^{13}\) See Micheal Kremer and Stephen A. O’Connell (2004) for details on Brain drain and poverty trap.
The term $\frac{y_{l(t)}}{y_{f(t)}}$ from equation above is what dampens/reduces the rate of diffusion as the gap between the leader and follower increases, which probably reflects the difficulty of adopting distant technologies, Benhabib and Spiegel (2002). The way out of this trap is achievable only if the follower country invests more in physical and human capital. The question is now what has been done so far using the theory discussed above.

2.3.4 PREVIOUS EMPIRICAL ANALYSES ON THE TOPIC

There is no doubt that different researchers from different corners of the world have tried to find answers to most of the problems regarding economic growth and productivity differences as well as technology transfer and diffusion issues. Various tests have been carried out on several variables of interest and conclusions rejecting or confirming the hypotheses reached. In this section, we are going to present some of the studies made and which we believe can shed some light on our work at a head.

Industrial labor productivity must be understood in the context of the world industrial labor productivity, or something termed as the world technology frontier. Developing countries should look on to the developed world as regards industrial labor productivity growth. The contribution of the world technology frontier to this cause is referred to as The Veblen-Gerschenkron -Effect in development literature. It’s this effect that was later formalized by Nelson and Phelps (1966) in the Human capital and barrier to technology diffusion that we are not going to look at in this thesis due to data problems as will be discussed later. Though most of the studies done on productivity growth have concentrated on the TFP measure, their results can be used in studying the industrial labor productivity as the measure in this thesis.

The catching-up models and studies made these last years have focused mainly on developed countries and lately middle and low income countries. The delay or less interest in these countries is especially due to lack of reliable data. We well know that the strength of economic growth and productivity studies lie in reliable data that can be used to test different models and see how a variety of factors affect productivity growth.

To mention but a few, it’s worth starting with one of the articles that has inspired us to write about this topic; Looking abroad to understand productivity growth: the world technology frontier and industrial sector productivity in South Africa, Harding and Rattsø (2007). The study was made on industrial sector productivity in South Africa and world technology frontier represented by the USA manufacturing sectors. It was found out here that industrial sector productivity in South Africa could not be understood without including the world technology frontier’s effect. In addition, South Africa being a middle income country with reasonable data, it was possible to extend their model to check for the effects of human capital in interaction with the frontier’s productivity. This was in a bid to address the issue of the “barrier model” of economic growth that was first formalized by Nelson and Phelps (1966) and implemented by Benhabib and Spiegel (1994, 2004). The estimated coefficients at around 0.3-0.4 in their preferred specifications imply that a 1% growth in the frontier’s productivity

---14 Total Factor Productivity---
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results in 0.3-0.4 percent growth in South African total factor productivity. The effect of the world technology frontier was very convincing with a positive and statistically significant coefficient at 1% in all models shown and the error corrections done confirming that South Africa has lagged behind the world frontier, Harding and Rattsø (2007).

In addition, the effect of human capital stock in an economy is of great significance in terms of adopting new technologies, Harding and Rattsø (2007). A Study on industrial sector labor productivity in Japan and United States of America as the world frontier whereby results show that sectors with lots of human capital or doing a lot of R&D will have a higher rate of catch-up than a typical sector, Cameron (2005). The fact that we are focusing on a developing country in this thesis, limits our discussion on the issue of R&D. Less research is done in most of the developing countries, due to lack of either resources or motivation.

Studies have also been made on domestic and foreign industries in as far as “catch-up” to the frontier is concerned and of course role played by the technology leader, for example on German and Italian industries. FDI being often considered a channel of diffusion of technological knowledge\textsuperscript{15}, they went ahead to inquire whether the impact of FDI on the productivity of local firms works through a catching-up mechanism that depends on the geographical proximity\textsuperscript{16} and or on technological gap in addition to the presence of foreign direct investment. They used different measures of total factor productivity at the firm level. Each measure was based on different methods and different assumptions. They did use different measures at firm level to address econometric problems among others; endogeneity of foreign ownership and unobserved heterogeneity of firms. Through different tests carried out in this article, it was found out that the FDI-productivity variable always has a positive and significant effect on the productivity growth of domestic firms regardless of different TFP measures, Giovanni Peri and Dieter Urban (2005)

In a study on the South African manufacturing performance in international perspective, Michiel Van Dijk (2002) found out that using different variables to measure labor productivity gives different figures. A measure of value-added per worker/person gave higher labor productivity than one with value-added per hour worked\textsuperscript{17}. They found out that on average, the South African labor productivity is 21.6% of the USA level. They, in their work, choose to construct industry specific purchasing power parities (PPPs) to convert gross value added in both countries into the same currency. This was then used to compute labor productivity which is different from the method we are using in this thesis simply because we are using one dataset for both Ethiopia and USA and therefore, all variables in the dataset have the same classification and definition of value added and employment.

In a related study done on Zambian manufacturing performance in a comparative perspective, it was found out that aggregate real productivity was 5.9% that of the USA in 1990, but had declined to 3.2% that of the USA 8 years later which implies an increasing technology gap

\textsuperscript{15} See also Rachel Griffith, Stephen Redding and Helen Simpson for more on the impact of FDI on the domestic firms.

\textsuperscript{16} The geographical issue is also emphasized by Robert Vigfusson, (2008) in his work on whether the border affects productivity: Case study on Canadian and American manufacturing industries. His study concludes that the border affects productivity despite the fact that countries studied in his work are similar.

\textsuperscript{17} See author table 5 for detailed results.
between the two countries. The results from the study confirmed the existence of enormous technology gap between Zambia and the USA. Labor productivity in the two countries was used as the measure to assess the performance gap, Yamfwa, Szirmai and Lwamba (2002).

All these studies, and looking abroad to understand productivity growth, Harding and Rattsø (2007) in particular, in support of Veblen- Gerschenkron effect have motivated us to make a further study on the theory's applicability on low income countries such as Ethiopia and taking USA as the World Technology Frontier. In almost all cross-country studies made these last years, the USA has been considered the world technology frontier. And we, therefore, intend not to make an exception in this work.

We are going to look at how this Veblen- Gerschenkron effect can be applied on the low income country, Ethiopia, as case study. The hypothesis is; does the industrial sector labor productivity growth in USA have an effect on industrial sector labor productivity in countries like Ethiopia? In other words, how will the productivity spillovers, if any, from industrial sector in USA promote the technological catch-up of the Ethiopian industrial sector? Industrial sector labor productivity in USA is exogenous in this model. This implies that the domestic factors that change labor productivity in Ethiopia and its technology in general will not affect labor productivity in USA. This should help us in our model specification since the explanatory variable in focus; industrial labor productivity in USA in this case, is not in any way correlated with the dependent variable; industrial sector labor productivity in Ethiopia.

2:3.5 HYPOTHESIS

In this work, our main focus is to test the productivity spillovers from the technology frontier. How does a change in the frontier’s labor productivity affect Ethiopian labor productivity? If it does, how strong is this effect? Can we conclude that Ethiopia is capable of learning from abroad or otherwise? Is Ethiopia, given the empirical results, capable of closing the gap to the frontier in the long-run?

3. ECONOMETRIC METHOD

3:1 STRATEGY AND METHOD

We choose to use a simple model in this thesis whereby we assume that labor productivity in Ethiopia is explained by labor productivity at the frontier. This follows Rattsø and Harding (2007)’s approach. This is also echoed in Eeckhout and Jovanovic (2002)’s approach in which they argue that all imitators can only implement the frontier’s technology with a lag. We are therefore going to focus mainly on the method in which technology is implemented with a lag. However, we will briefly go beyond this specification to see what would happen in case imitators did have a chance to implement it without a lag. This is a simple, but strong model. By choosing this simple model where we have one explanatory variable of interest that we assume is strictly exogenous and no endogenous explanatory variable, we avoid the problem
of endogeneity that is quite common in models of productivity growth. Endogeneity problems arise when we can’t identify causality between variables, a situation that would for example lead to explaining productivity by productivity. We shall briefly discuss this problem below.

This strategy is, however, not free from problems. We have already indicated that we are working on one of SSA countries that are characterized by poor or bad data collecting and reporting due among other things to political and institutional problems. In addition, productivity growth in a country is as a result of a combination of many factors. It is, therefore, evident from this point that we are likely to have problems associated with the model we have chosen. We can, among other things, have measurement error and missing variable problems. Since we have assumed that the frontier’s labor productivity is strictly exogenous and using fixed effects estimation in addition, these problems can be reduced to a minimal level of no significant effect to our final results, thus getting consistent and unbiased estimations.

3.2 MODEL SPECIFICATIONS

The question here now is how we can move from all the theory given above to the method. We have therefore to make as many assumptions as we can and of course discuss how we are going to solve problems that normally occur in econometric analyses. First and foremost, we have decided to use the fixed effects estimation as mentioned, and we are going to give a brief discussion on how we plan to go about it. It’s mostly about how we can eliminate the unobserved fixed effects in the error term from our regressions so as to be able use Ordinary Least Square (OLS) estimation that will give unbiased and consistent estimates.

We have chosen to deal with a panel data that gives us more degrees of freedom and thus robust analysis. We concentrate on two countries only, the USA and Ethiopia, though the results we get can be used to support existing work on productivity spillovers in SSA and more generally in all less developed countries. With our dataset for 15 years and 23 industrial establishments, in addition to the assumptions in the following sections, we are certain that using OLS and fixed effects estimations will give consistent and unbiased estimates of how the frontier’s labor productivity affects Ethiopian labor productivity.

Our model includes an individual constant term that checks for the individual specific effects. We know well that there is always heterogeneity between sectors. To mention but a few, situations whereby some sectors can enjoy political favors, such as tax holidays etc. or easily access skilled workers. Accessing exclusive skilled workers or enjoying tax holidays for some sectors makes them more competitive than those without access. This in turn will lead to differences in productivity. These factors affect sector differently, but they are difficult to control or observe in the datasets made and therefore impossible to measure empirically. The best way to deal with them is therefore to transform them through within group estimation. Through this transformation we solve the bias problem commonly faced due to excluded variables.
Furthermore, we are well aware that Ethiopia is one of SSA countries that are greatly affected by climate change. Drought seasons have for example crippled production in many parts of the country and therefore left those areas largely dependent on food aid. This has an enormous effect on the country’s productivity in general. This therefore compels us to check for seasonal variations in the period we are studying so as not to inflate or deflate our data set and final estimates. To do this, we have included time dummies (T-1) years as defined in chapter 4.

### 3:2.1 FIXED EFFECTS ESTIMATIONS

There are two ways to eliminate fixed effects: 1. First differencing and 2. Fixed effects transformation that is also commonly known as the within transformation. Let us assume that we have a one-way error component model for the disturbances as given below.

\[ u_{it} = v_i + e_{it} \]  

(11)

\( v_i \) is the unobservable individual-specific effects. This is time-invariant and it accounts for any individual-specific effects which are not included in the model/regression. The fact that this variable has no 't' subscript tells us that it does not change over time. We can for example talk of unobservable entrepreneurial or managerial problems in some sectors that are not included in the regression, but which can affect labor productivity in different sectors.

\( e_{it} \) is the stochastic residual that is independent and identically distributed (IID). The frontier’s labor productivity is assumed independent of this stochastic residual.

The unobserved residuals consist of the explanatory variables which are not included in the regression and therefore have to be transformed through fixed effects estimation. This helps us in getting better estimates. To have a fixed effect model, we assume that \( v_i \) is a fixed parameter that will individually affect labor productivity in the sectors we are studying and that \( e_{it} \sim IID(0, \sigma_e^2) \), with expected mean=0 and variance=\( \sigma_e^2 \). We have therefore to transform away the individual-specific effects of fixed effects.

We here follow the general formulation of the world technology frontier whereby it, the world frontier, is the determinant of domestic productivity given sector and time fixed effects as presented in equation (5) in Harding and Ratto (2007). We therefore formulate our equation that estimates the average relationship between the world frontier’s labor productivity and labor productivity in Ethiopia as given in (12) below. The equation expresses the relationship between labor productivity in Ethiopia and USA. \( \ln y_{it} \) is labor productivity in Ethiopia and \( \ln y_{it-1} \) is labor productivity in USA. It is through this equation that we will be able to tell changes in the domestic country, Ethiopia, when labor productivity at the frontier changes. We are mostly interested in parameter \( \alpha_1 \) in this case. This parameter gives the level at which the follower country can adopt new productivity techniques in relation to the frontier’s innovation. In other words, if it is through this parameter that we tell whether there are productivity spillovers to the follower country. We are specifically interested in situations where Ethiopia is either capable of adopting technology from the frontier or not. This will be given by \( \alpha_1 \) estimates which are either greater, equal or less than 1. In addition to the
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frontier’s variable, we include a variable for capacity utilization, $\ln KU_{it}$ that will help check for production variations or shocks. In almost all SSA countries weather plays a big role in production, since the greater part of their production is in agriculture sector. Ethiopia is one of the countries most affected by drought in this region and hence needs to be checked before estimating our model. Lastly but not least, we include the summation of time dummies for all years, $\sum_{t=1}^{T} D_{zt}$, with 1980 as the reference year. $D_{zt} = 1$ if $z = t$ and 0 otherwise. Below, we formulate our model:

$$lny_{it} = \alpha_0 + \alpha_1 lny_{i,t-1}^* + \delta \sum_{t=1}^{T} D_{zt} T_z + \alpha_2 \ln KU_{it} + u_{it}, u_{it} = v_i + e_{it}$$

$$lny_{it} = \alpha_0 + \alpha_1 lny_{i,t-1}^* + \delta \sum_{t=1}^{T} D_{zt} T_z + \alpha_2 \ln KU_{it} + e_{it},$$ \hspace{1cm} (12)

$i = 1, 2, ..., 23$ indicating the 23 industrial sectors that are to be studied in this work, and $t = 1980, 1981, ..., 1995$ the time frame. $v_i$ is the individual constant term. $\alpha_0$ stands for the autonomous technological progress that is independent of technology at the frontier. The individual-specific intercept in our model captures the individual-specific heterogeneity.

To transform this equation, we are going to leave out capacity utilization and time dummy variables and then concentrate on the variables of interest by looking at their global averages. The regression we are going to transform is therefore:

$$lny_{it} = \alpha_0 + \alpha_1 lny_{i,t-1}^* + e_{it}$$

$$\bar{y}_i = \alpha_0 + \alpha_1 \bar{y}_{i,t-1}^* + e_i$$ \hspace{1cm} (13)

We have that $\bar{y}_i = \frac{1}{n_t} \sum_{i=1}^{N} \sum_{t=1}^{T} y_{it}$, and

$$\bar{y}_{i,t} = \frac{1}{n_t} \sum_{i=1}^{N} \sum_{t=1}^{T} y_{i,t-1}$$ \hspace{1cm} (14)

We then subtract equation (13) from (12) and get (15)

$$y_{it} - \bar{y}_i = \alpha_1 \left( y_{i,t-1}^* - \bar{y}_{i,t}^* \right) + e_{it} - e_i$$ \hspace{1cm} (15)

This can be written as (16) by assuming that $y_{i,t} - \bar{y}_i = \bar{y} l$, $y_{i,t-1}^* - \bar{y}_{i,t}^* = \bar{y} \hat{r}$ and $e_{it} - e_i = \hat{e}$

$$\bar{y} l = \alpha_1 \bar{y} \hat{r} + \hat{e}$$ \hspace{1cm} (16)

We have therefore undertaken a within groups transformation and $v_i$, which is fixed over time, as well as the autonomous technological process term, $\alpha_0$, have disappeared from our regression. This is so because the two appear in both equations (12) and (13) above. This means that using an OLS on the equation above would give unbiased and consistent estimates, given that the residual assumptions which we shall be discussing below are met.

The problem with this transformation is that we use less variation in the data compared to the standard OLS, since individual specific variations are transformed away. Another problem,
most especially in short-time series like ours in this case, is that we can have a situation with imprecise estimates, when the variable in point varies less over time. On the other hand, the advantage with this transformation is that we get rid of individual-specific factors that can be correlated with the frontier’s labor productivity and hence make it impossible to get consistent and unbiased estimates by using OLS.

We have therefore that

$$\hat{\alpha}_i = \frac{\sum_{t=1}^{T} \sum_{s=1}^{N} [y_{it-1} - \bar{y}_{it}] [y_{it} - \bar{y}_{it}]}{\sum_{t=1}^{T} \sum_{s=1}^{N} [y_{it-1} - \bar{y}_{it}] [y_{it-1} - \bar{y}_{it}]}$$  \(17\)

We have further that;

$$\bar{y}_{it} = \hat{\alpha}_i = \alpha_i + \alpha_1 \bar{y}_{it}^* + \tilde{e}_i$$  \(18\)

$$\bar{y}_i = \bar{y}_{it} - \alpha_i - \alpha_1 \bar{y}_{it-1}^*$$  \(19\)

We can find the variance as well. As we know well from before, our time series is short. It’s only from 1980-1995. This will give biased estimates if no further precautions are taken. To solve this problem we divide the within sums of squared deviation by \(N(T-1)\)

$$\hat{\sigma}^2 = \frac{1}{N(T-1)} \left( \sum_{t=1}^{N} \sum_{s=1}^{T} y_{it} - \bar{y}_i - \alpha_1 \bar{y}_{it-1}^* \right)^2$$  \(20\)

At this point, with all the above specifications, we can formulate our regression as follows

$$\ln y_{it} = \alpha_0 + v_i + \alpha_1 \ln y_{it-1}^* + \delta \sum_{t=1}^{T} D_{zt} T_{z} + \alpha_2 \ln KU_{it} + e_{it}$$  \(21\)

We have included time dummies \(D_{zt} = 1\) if \(z = t\) and 0 otherwise. The base year is 1980. \(21\) is the model we are going to use with the help of our dataset to estimate the frontier’s effect on Ethiopia’s labor productivity.

### 3:2.2 THE EQUILIBRIUM POINT AND THE ERROR CORRECTION MODEL

It is theoretically indicated in chapter 2 that in the long-run the economy is going to experience a stable productivity growth rate. In other words, the productivity growth rate will move towards an equilibrium whereby the productivity growth rate in the domestic/follower country will be at the same level with the frontier’s productivity growth rate. We can from this point with help of the logistic formulation, \(\left( \frac{y_{lt}}{y_{l(t)}} \right) = g(H) + c(H) \left[ 1 - \frac{y_{l(t)}}{y_{l(t)}} \right]\) above,
show theoretically that the country will in the long-run adapt to an equilibrium whereby the domestic country’s productivity level will be given by a share $\Omega$ of the frontier’s productivity level. If $\Omega$ is close to one, then we theoretically say that the equilibrium will be reached.

Consider; \[
\left( \frac{y_{l(t)}}{y_{l(t)}^*} \right) = g(H) + c(H) \left[ 1 - \frac{y_{l(t)}}{y_{l(t)}^*} \right]
\]

We then assume that; 
\[
\left( \frac{y_{l(t)}}{y_{l(t)}^*} \right) = \frac{y_{l(t)}^*}{y_{l(t)}^*} = g^*
\]

And by assuming that $g(H) = g$ and $c(H) = c$, we rewrite (22) as;

\[
g^* = g + c \left[ 1 - \frac{y_{l(t)}}{y_{l(t)}^*} \right] \tag{23}
\]

\[
g^* = g + c - c \left( \frac{y_{l(t)}}{y_{l(t)}^*} \right) \tag{24}
\]

And we finally have that

\[
c \left( \frac{y_{l(t)}}{y_{l(t)}^*} \right) = g + c - g^*
\]

\[
y_{l(t)} = \frac{g + c - g^*}{c} y_{l(t)}^* \tag{25}
\]

Let \[
\frac{g + c - g^*}{c} = \Omega
\]

We therefore rewrite (24) as follows:

\[
y_{l(t)} = \Omega y_{l(t)}^* \tag{25}
\]

The size of $\Omega$ will therefore depend on $g, c$ and $g^*$. By assuming that $\Omega < 1$, it implies that the higher the innovation and adoption, the closer to the frontier the country is. If $\Omega = 1$, then the two countries’ labor productivity is at the same level and the issue of the frontier and the follower is no more.

From this point, we can estimate the long-run relationship by using the Error Correction Model (ECM). This is an autoregressive distributed lagged model. It labors to explain the relationship between our two variables of interest over time. (In this case, variables that grow over a 15 years period). We are therefore, going from this point, to expand our standard model (21) with lags for both productivity in Ethiopia and productivity in USA. That is, $lny_{l(t-1}$
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and \( \ln y_{lt} - \ln y_{lt-2}^* \). It is this (ECM) that captures the long-run relationship between labor productivity in Ethiopia and the frontier. It will in other words show whether Ethiopia is capable of closing the productivity gap in the long-run or continue to lag behind the frontier.

\[
\ln y_{lt} = \alpha_0 + v_i + \alpha_3 \ln y_{lt-1} + \alpha_2 \ln y_{lt-1}^* + \alpha_3 \ln y_{lt-2}^* + \alpha_4 \ln KU_{lt} + e_{lt} \tag{26}
\]

We then define that;

\[
\partial \ln y_{lt} = \ln y_{lt} - \ln y_{lt-1}, \text{ and } \partial \ln y_{lt-1}^* = \ln y_{lt-1}^* - \ln y_{lt-2}^*
\]

By subtracting the domestic lag, \( \ln y_{lt-1} \) from both sides of our extended model, adding \( \ln y_{lt-1}^* \) to the right side and subtracting it again, we rearrange and get (27).

\[
\partial \ln y_{lt} = \alpha_0 + v_i + \partial \ln y_{lt-1}^* + (\alpha_1 - 1) \ln y_{lt-1} + (\alpha_2 - \alpha_3) \ln y_{lt-2}^* + \alpha_4 \ln KU_{lt} + e_{lt} \tag{27}
\]

Equation (27) allows us to study the short-run dynamics in the relationship between the frontier’s productivity and productivity in Ethiopia. From this equation we must impose the stability condition by letting change in domestic labor productivity equal change in the frontier’s labor productivity, \( \partial \ln y_{lt} = \partial \ln y_{lt-1}^* = 0 \). It is this stability/equilibrium condition that determines the long-run effect of a unit change in the frontier’s labor productivity. We then get;

\[
0 = \alpha_i + (\alpha_1 - 1) \ln y_{lt-1} + (\alpha_2 - \alpha_3) \ln y_{lt-2}^* + \alpha_4 \ln KU_{lt} + e_{lt}, \alpha_i = \alpha_0 + v_i
\]

From here, we can solve for the domestic lag, \( \ln y_{lt-1} \). This predicts the Ethiopian productivity level in long-run in relation to the frontier.

\[
\ln y_{lt-1} = - \frac{(\alpha_2 - \alpha_3)}{(\alpha_1 - 1)} \ln y_{lt-2}^*, \alpha_1 \neq 1
\tag{28}
\]

The equilibrium is therefore given by

\[
\frac{(\alpha_2 - \alpha_3)}{(\alpha_1 - 1)} \text{ and whereby } - \frac{(\alpha_2 - \alpha_3)}{(\alpha_1 - 1)} = \tilde{\Omega}
\]

This can be done by estimating our extended standard model and set in for the parameters in the above equation (28) or estimating the differentiated model direct. To achieve this, we have to assume that countries continue to grow at the same rate. In case of any changes in the growth rate, we will not get the same results.

In case we use only one lag at the frontier, a situation where we assume the follower country to be accessing the newest technology available at the frontier, (28) will be written as (29). In this case our standard model is only extended with one lag for the frontier and one lag for the follower country. Following the same procedures as in the above process (26) to (28), we get (29) below.

\[
\ln y_{lt-1} = - \frac{(\alpha_2 - \alpha_3)}{(\alpha_1 - 1)} \ln y_{lt-1}^*
\tag{29}
\]
To achieve the above derived formulations empirically, we have got to make and discuss residual assumptions. In other words, how are we going to deal with the fact that we restrict our study to just one explanatory variable, well knowing that productivity growth is influenced by a combination of many variables, both domestic and external? Making the assumptions below will help us isolate variables that we are not interested in now, but which may be of significant effect in other studies.

3.2.3 RESIDUAL ASSUMPTIONS

We have the residual error term/ composite error, $u_{it}$, in our simple model (12). This term can be decomposed into:

$$u_{it} = v_i + e_{it}$$

as shown in the equations that followed (12).

As mentioned before, the first term, $v_i$, on the right hand side is the sector specific stochastic that is constant over time. This term is generally composed of unobservable heterogeneity that is a result of the excluded variables. The heterogeneity between sectors here can for example be advantages accruing from managerial to political policies favoring some sectors. In most of SSA countries, succeeding in entrepreneurship has to do with which political camp you belong to or you support. Such issues are not easy, if at all possible, to estimate empirically, since they are not documented. It’s, therefore, upon this term’s features that we have decided which method to use. Herein, OLS and fixed effects estimation.

$e_{it}$ This is often called the idiosyncratic error or time-varying error, since it represents unobservable factors that change over time and sector that affect Ethiopian industrial labor productivity, and will therefore choose to define them as “white noise”. However, even if we assume that this idiosyncratic error is uncorrelated with the frontier’s industrial labor productivity, pooled OLS is biased and inconsistent if $v_i$ and frontier’s labor productivity are correlated. The resulting bias in this case is often called heterogeneity bias, due to the omitted time-constant variable.

Let’s assume that the following Gauss-Markov assumptions for $e_{it}$ are fulfilled.

(i) $E(e_{it}/\ln y_{it-1}^*) = 0$

This implies that the time variant error term is independent of our explanatory variable, the frontiers labor productivity. $E(e_{it}/\ln y_{it-1}^*) = E(e_{it}) = 0$, and var($e_{it}$) = $\sigma_e^2$

(ii) $E(e_{it}, e_{js}/\ln y_{it-1}^*) = \sigma_e^2$ for $i=j$ and $t=s$

\[ 0 \text{ otherwise} \]

Here, the time variant error term has a constant variance and is independent both between sectors and over time. This is one of the reasons why we can’t include lagged endogenous
variable, since doing so would contradict the assumption that the frontier’s labor productivity is independent of $e_{it}$ all the time. This therefore excludes the possibility of serial correlation.

\[(iii) \quad E(\nu_i / \ln y_{it-1}) \neq 0\]

Assuming that (iii) is the case here, then, something has to be done in order to get unbiased and consistent estimates. There are three ways to overcome this problem, Woolridge (2003). It’s therefore due to (iii) that we decided to use the OLS and fixed effects or within groups transformation alternative. We assume that (iii) is not fulfilled, and since we have transformed away $\nu_i$, heterogeneity is of no value as regards the estimated effect of the frontier’s labor productivity. By doing this, we have solved the situation whereby $\nu_i$ could be correlated with the explanatory variable. We know well that a situation where they are correlated and using OLS, would give biased and inconsistent estimates.

### 3.3 OTHER ECONOMETRIC PROBLEMS

Apart from the above discussed econometric questions, there are a number of other possible problems in econometric analyses that we can face in the process of testing our hypotheses empirically. We have among other things, endogeneity problems, serial correlation problems, measurement error problems, how to measure our success and so on. Below, we give a summarized overview of these problems, how they can affect our results and finally how we think we can go about them.

#### 3.3.1 ENDOGENEITY PROBLEMS

We have endogeneity problems in the econometric analyses if the independent/explanatory variable is, for some reason, correlated with the residual term in the regression. In this case we have what is called the endogenous explanatory variable. It means that OLS estimates will be inconsistent and biased. The way out of this problem is to find convincing instrument variables that can be used to instrument endogenous explanatory variables. Since we have assumed that the frontier’s labor productivity in our model is strictly exogenous, we won’t be worried about the endogeneity problem and there will be no need to discuss it further.

#### 3.3.2 SERIAL CORRELATIONS

Since we’re dealing with panel data, it’s imperative to think about serial correlation. Serial correlation refers to the situation whereby errors in period $t$ are correlated with errors in the previous period, $t-1$. We can test serial correlation by the equation below.

\[u_{it} = \rho u_{it-1} + e_{it}\]

whereby we assume that this error term, $e_{it}$, fulfills all standard assumptions and therefore call it “white noise”. This equation is the one we use to test for first order serial correlation. If $\rho > 0$, it’s positive first order serial correlation, whereas $\rho < 0$ is
negative first order serial correlation. The null hypothesis is that $\rho = 0$. Since we have assumed that the explanatory variable, the frontier’s labor productivity, is strictly exogenous, we will still get unbiased and consistent estimates, regardless of whether the error term is serially correlated or not. However, this will of course affect the standard deviations and estimations run. In case of serial correlation in the data, the random effects method is preferred.

### 3.3.3 MEASUREMENT ERROR PROBLEMS

The measurement error is defined as the difference between the observed value and the actual value. In other words, if we use an imprecise measure of an economic variable in our regression model, then our model contains measurement error. As indicated in the source of our data, it’s hard to assume that our dataset does not suffer from a measurement error problem.

The measurement error can either be in the explanatory or explaining variables. We’ve first of all seen that the original dataset is a result of merged data from different sources. Secondly, it is individual countries that report their annual data, the quality of which leaves a lot to be desired, most especially data from developing countries to which Ethiopia belongs.

So given the difficulties in generating variables in our dataset and the above problems, we’re compelled to make some assumptions so as to solve the problem of bias and inconsistency in our estimates. We therefore assume that the measurement error here is statistically independent of our variables, hence getting unbiased and consistent estimates.

### 3.3.4 GOODNESS-OF-FIT

In econometric analyses one has to indicate how well the explanatory variable explains the dependent/explained variable. In this case, we want to explain how well the productivity spillovers explain the Ethiopian industrial labor productivity growth. In most cases, it is $R^2$ that has been used to explain this. $R^2$ is always between zero and one, since the explained sum of squares cannot be greater than the total sum of squares which is one. This means that when $R^2$ is equal to one, we have a perfect fit to the data. On the other hand, if $R^2$ is close or equal to zero, we have a poor fit to the data. This implies that very little, if any, of the variation in the dependent variable is captured by the variation in the dependent variable estimates. It is usually interpreted by multiplying it by 100 to change it into percentages. Neither do we have a perfect nor a poor fit in this case as we can see from our results in chapter 5, table 1 and table 2.

However, it is worth noting that a low $R^2$ does not necessarily mean that an OLS regression equation is useless. If taken for granted, this measure can lead to trouble, most especially in panel data estimations. The $R^2$ never decreases, but increases with increasing independent variables. The fact that $R^2$ never decreases when any variable
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is added to the regression makes it a poor tool for deciding whether one variable or several variables should be added to a model. This is not going to bother us since we are mainly interested in the effect of one independent variable, the frontier’s industrial labor productivity. We are in this case interested in the R-squared within since we decided to use the fixed effects estimations.

With all the above assumptions and checked econometric problems, we assume that the estimations and results presented in chapter 5 are consistent and unbiased thereby contributing to the existing studies on the productivity growth before this thesis and not least, strengthening the productivity spillovers’ effect on productivity growth in low income countries.

4 DATA

This section gives a more detailed picture of our dataset and how we are going to manipulate it such that we remain with a more reliable one that we can use to achieve our goal. We present the general picture of the original dataset, we introduce and define our variables and then discuss unbalanced panel data, its challenges and how to go about them.

4:1 THE ORIGINAL DATASET

The original dataset is composed of data on trade flows, domestic production and trade protection for 100 countries over the period 1976-2004 obtained from www.worldbank.org/trade under Data and Statistics. The data is the result of merged data from different sources and converted to the common 3-digit level of the international standard industrial classification (ISIC). The production data, which we are most interested in, in this work, is got from UNIDO\textsuperscript{18}. This is annual data from member countries. The problem encountered in this data is the sporadic reporting of data, most especially by developing countries.

It is an unbalanced panel data from WDI\textsuperscript{19} for the period 1976–2002(2004)\textsuperscript{20} covering 28 industrial establishments over a period of 26 years. It’s, however, worth noting that all data is not recorded nor are all establishments represented in our countries of study. It is evident from the original dataset that most of all observations before 1980 and after 1997 for the study country, Ethiopia, were either not recorded or there was no production in such sectors or else non-existent sectors. In cases where data is reported, it is too sporadic to be used for analysis purposes. On the other hand, data on the frontiers production and employment in all sectors, with exception of three years period (1996 and 2003-2004), is available and it of course has more sectors covered than the country of study. In the dataset, we find sectors with negative

\textsuperscript{18} United Nations International Development Organization

\textsuperscript{19} World Development Index

\textsuperscript{20} Missing data for (2003-2004) for both countries
or zero value-added observations. Note that the missing data for the years given above applies for all sectors.

Sectors like professional and scientific equipment, miscellaneous petroleum and coal products, pottery china earthenware and non-ferrous metals are either non-existent in Ethiopia or in their infancy stage with no data recorded for scientific use. In addition, data coverage in sectors such as: Machinery except electrical, transport equipments and petroleum refineries is minimal. The original dataset as presented here requires some adjustments to be used in our analyses and these adjustments are discussed in section 4:3 below. However, before we proceed to the adjustments, we choose to present and define the variables we are going to use in our new dataset and estimations.

4:2 CHOICE OF LABOR PRODUCTIVITY MEASURE

We use value-added, n-employees and output to generate the required variables. We equated Y, production, to sum value-added, and L, labor, to sum n-employees and finally x, to sum output. The World Bank dataset does not give detailed information about the type of labor, skilled or non-skilled, recorded. We therefore assume that the figures recorded are for the aggregated productive labor in the industrial sector

Production: We decided to use value-added as a measure of production. This is because we wanted that portion of sales that is not accounted for by the use of inputs and supplies from other industries or use of intermediate inputs, Alessandro Nicita and Marcelo Olarreaga (2006).

Labor: Labor refers either to the headcount of all workers or a count of number of hours worked. We decided to use the number of employees in the World Bank dataset which gives the total number of persons who worked in or for the establishment during the period 1980-1995. The dataset does not give figures as regards the skilled and unskilled labor. This is therefore a problem as far as the quality of labor and the rate at which technology diffusion is done are concerned. It’s widely believed that skilled workers find it easy to imitate already existing methods of production something that would obviously increase productivity, Nicita and Marcelo Olarreaga (2006).

Trend variable: We have used output as the measure for trend variable since it represents the value of goods produced in a year, regardless of whether they are sold or stocked, Alessandro Nicita and Marcelo Olarreaga (2006).

Capacity utilization: We’ve generated this variable as a difference from the production trend. The variable will help us in adjusting for variations/shocks in production. In the short-run, this variable will shade light on the country’s economic situation. In long-run, high unutilized capacity will lead to high unemployment, leading to high labor reserves. To generate this variable, we estimate the production trend using the lowess function in STATA. We then take the difference from the trend and then get the capacity utilization variable. The variable measures the difference from the trend in year t for sectors i.
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**Time dummies:** We made time dummies, $T_g$, named _1year in our dataset to check for time effects in our model. 1980 is the reference year in this case.

### 4:3 THE UNBALANCED PANELDATA

We are working on an unbalanced panel data. The main challenge with this type of data is determining why the panel is unbalanced. As mentioned earlier, we have data on employment, value-added and output for 100 countries over a period of 28 years, but we are focusing on only two countries, Ethiopia and USA. The original dataset in our work is called an unbalanced panel data because it involves many randomly missing observations for some sectors and or, missing observations for a period of time. In the original dataset the length of time series vary from one country to another and from one sector to another. Our dataset is therefore going to be given by $\sum_{t=1}^{N} T_t$ instead of $N*T$, whereby $N$ is the total number of variables and $T$ is the time frame. Missing observations, non-existent sectors, and lags in establishing some sectors in addition to years without reported data have to be dealt with so as to get a balanced dataset that can be used to produce reasonable estimates to use in our analysis.

The reason for all above problems might be due to different economic situations in the reporting countries and of course political priorities in so far as sectors are concerned. Data collection has to be financed by either governments or interested bodies. Most developing countries, Ethiopia of course inclusive, choose to ignore data collection and reporting simply because it requires them to earmark some finance to do so, or put differently, to forgo some commitments in order to do so. They choose to finance the assumed more pressing issues in their economies rather than collecting data and they therefore pretend to or forget that the collected data can help in research and in further planning and improving their performance.

Most of the work in such areas is left to international organizations like the World Bank and international monetary fund for example. In order to make good use of the data available, we have decided to reduce time frame and number of industrial establishments to suit the analysis of these countries we want to study. We are therefore, going to work on data from 1980-1995 and 23 industrial establishments for this reason. All adjustments made are discussed in the following section.

### 4:3.1 HOW TO COUNTER CHALLENGES IN THE ORIGINAL DATASET

We have used a statistics program called STATA 9.0 to reduce the original and unbalanced dataset into a balanced sub-dataset and in all our estimations. This is because STATA is the best program to use in this case which equips us with tools we need to organize and manage our data. Using this program, we are going to reduce the years of study and not least, the number of establishments. There have of course been problems in the process of learning this program, but we are satisfied and it was therefore worth it, given the end results.
Many attempts to include all years, that is, from 1976-2004 gave negative coefficients for the USA effect on Ethiopian industrial sector labor productivity, something that would probably mean a poverty trap or an opposite of the conclusions reached from many previous studies on the topic as discussed above, henceforth, a rejection of the Veblen - Gerschenkron effect hypothesis. Negative coefficients for the frontier would imply a negative spillover effect. The reason for such negative coefficients might be, as mentioned above, missing data for Ethiopian production, value-added in this case, and employment or many non-existing manufacturing industries in Ethiopia.

Inclusion of non-existent or unproductive sectors other than these (23) above would make comparison purposes impossible. We’ve therefore decided to limit our analysis to this period for both countries. Automatic exclusion of years: 2003-2004, is due to the fact that no observations were recorded for both countries in the original dataset. Inclusion of these years in our tests would in one way or another affect the results. In the same spirit, Sectors with zero or negative value-added observations in our dataset have been dropped. We assume such sectors were in their infancy stage and just incurring costs. Sectors like: professional and scientific equipment, miscellaneous petroleum and coal products, pottery china earthenware, non ferrous metals have been left out in our analysis. Some other sector’s observations have been reduced to a minimum number for the same reason given above. These include among others: Machinery except electrical, transport equipments and petroleum refineries.

To avoid distortion of results, we decided to use the information given in this dataset only. This is one of the reasons why we have not been able to estimate the effect of education through interaction between education in the country of study and the frontiers industrial labor productivity in as far as increasing labor productivity is concerned. Alternatively, we could have used World Bank index data on education, but this is normally affected by GDP computations in the respective countries and it is therefore difficult to give the real picture of the education situation in the country.

In summary, we have deleted sectors with missing observations, reduced the number of sectors for study and of course the time frame. However, this brings in another problem of deleting some useful data. To overcome this, we delete data with missing observations in the explanatory variable and leave data with missing observations in the explained variable. In so doing, we are left with a dataset that has much lesser missing observations than before. We assume that the reasons we have missing data for some sectors is not correlated with the idiosyncratic errors $u_{it}$, and the unbalanced panel should cause no problem. With these adjustments we assume therefore that we will get unbiased and consistent estimates in the following chapter and therefore reasonable conclusions.

5. ANALYSIS

Through this work, we have got clear and reasonable results given the country we are studying. The hypothesis has been to find out whether Ethiopia does learn from the frontier or not. In other words, does a change (increase) in USA’s industrial labor productivity positively
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affect Ethiopia’s industrial labor productivity or it has no positive effect at all? Below, we are going to present the results in two different tables. The first table presents the frontier’s effect on Ethiopian industrial labor productivity and the second one presents the error correction method. It is important to note though, that we did include another regression checking for what we called the newest technology at the frontier. It is brief, but we thought it is important to see the cost of imitating or advantage of leading whereby the innovators find it optimal to maintain their lead over imitators, Eeckhout and Jovanovic (2002). We have therefore assumed that \( \ln y_{it}^* \) represents the latest technology that imitators cannot practically access “today”. We did consider this in our error correction model as well. Let’s consider our basic equation (21) that we derived in chapter 3. We rewrite the equation below.

\[
\ln y_{it} = \alpha_0 + \nu_i + \alpha_1 \ln y_{it-1}^* + \delta \sum_{t'=1}^{T} D_{zt} + \alpha_2 \ln KU_{it} + e_{it}
\]

Whereby, \( i = 1,2,\ldots,23 \) and \( t = 1980,\ldots,1996 \).

This model is going to help us explain how the frontier’s industrial labor productivity affects industrial labor productivity in Ethiopia. We are in this case mainly interested in \( \ln y_{it}^* \)’s effect on \( \ln y_{it} \), given by \( \frac{\partial \ln y_{it}}{\partial \ln y_{it-1}^*} = \alpha_1 \). Other variables are included in the model to improve on its explaining power. This implies that we are specifically interested in the parameter \( \alpha_1 \). Since the model is in logarithm form, \( \alpha_1 \) is explained as the elasticity of \( \ln y_{it} \) with respect to \( \ln y_{it-1}^* \). It implies that \( \alpha_1 \) will give the percentage by which Ethiopian industrial labor productivity will increase/decrease by given a 1 percent increase in the frontier’s industrial labor productivity. We’re therefore interested in three relationships here, whether we get (i) \( \alpha_1 > 1 \), (ii) \( \alpha_1 < 1 \), or (iii) \( \alpha_1 = 1 \), and of course, the long-run relationship through the error correction model that will either confirm the results in table 1 or otherwise.

The situation given by (i) implies that a 1% increase in the frontier’s labor productivity will lead to a more than 1% increase in the Ethiopian labor productivity. This means that the follower has a possibility of learning from the frontier. In other words, Ethiopia is taking advantage of productivity spillovers from the frontier. According to Benhabib and Spiegel (2002)’s argument discussed in chapter 2, to experience (i), the sum of innovation and adoption in Ethiopia must be greater than innovation at the frontier. It is however difficult in this situation since we are dealing with a low-income country that does less research and development, hence limiting the contribution of innovation. We here consider innovation to be a function of research and development and education attainment. We are therefore left with adoption contribution. That is, technology adoption in Ethiopia must be greater than innovation at the frontier to achieve the situation given by (i).

The situation given by (ii) implies that a 1% increase in the frontier’s labor productivity will lead to a less than 1% increase in the Ethiopian labor productivity. This means that the follower’s productivity levels will continue to be less than the frontier’s productivity. Here, we have countries that are close to 1 and those that are far below. Those that are far below can be interpreted as a situation tending to the poverty trap discussed in chapter 2. This situation will lead to increased divergence since the frontier will strengthen her position as far as
innovation is concerned. It will in other words strengthen its advantage of lead. To get out of this situation, poverty trap, according to Benhabib and Spiegel (2002), discussed in chapter 2, the country has to use more of its factor inputs or improve what Abramovitz (1979) calls the “absorptive capacity”. It is this situation that is going to dominate in as far as our results given below are concerned.

The situation given by (iii) implies that a 1% increase in the frontier’s labor productivity will lead to a 1% increase in the Ethiopian labor productivity. This means that countries are at the same level in as far as technology is concerned. They have in other words experienced convergence and no more talk about the frontier and the follower.

The situations (i) and (iii) above according to Benhabib and Spiegel as discussed in chapter two require that the sum of innovation and adoption in a country be greater than or equal to innovation at the frontier. We have further seen that innovation plays a minimal role in this work and to the extreme end, no role at all. Since we are left with just adoption as the only means by which the follower country can acquire new technology from the frontier, the Benhabib and Spiegel condition to realize the two situations above will be reduced to adoption greater than or equal to innovation at the frontier.

To look for the long-run relationship or equilibrium with the frontier, we employed the error correction method on which we imposed the stability condition and the results are presented in section 5:2 of this chapter. We employ the derived equation (28) in chapter 3 to test the empirical equilibrium which is given by \( \frac{\alpha_2 - \alpha_3}{\alpha_1 - \lambda} \). The theoretical equilibrium is given by \( \Omega = \frac{g+c-g^*}{c} \) in (25).

**5:1 RESULTS**

As we have already indicated, the main objective of this thesis is to find out whether what happens at the world frontier is of significant importance to Ethiopian industrial labor productivity. Is there any possibility of learning from and catch-up to the frontier by a low-income country like Ethiopia, or should such countries forget all about learning from abroad since they are poor and have little, if any, means to spend on research and therefore have a low level of innovation? How do productivity spillovers affect productivity in low income countries?

We can now try to answer the questions above using the results we got from our estimations. As regards the frontier’s effect on Ethiopian industrial labor productivity, we use results in table 1 below. The results of interest are in column (2). Regressing the frontier’s labor productivity on Ethiopian labor productivity gives positive and significant coefficients at 5% significance level. The question remains however, is Ethiopia learning from the frontier? The coefficient of approximately 0.2 indicates that Ethiopia is learning from the frontier. A
1% increase in the frontier’s labor productivity leads to approximately 0.2 increase in Ethiopian labor productivity. This is positive as far as learning is concerned, but still too little in relation to productivity at the frontier and given the gap between the two economies.

**TABLE 1**

**The frontier’s effect on Ethiopian labor productivity**

<table>
<thead>
<tr>
<th>Dependent variable:</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\ln y_{it}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\ln y_{it}__1$</td>
<td>0.169***</td>
<td>0.0398</td>
<td>0.0398</td>
</tr>
<tr>
<td></td>
<td>(0.091)</td>
<td>(0.0412)</td>
<td></td>
</tr>
<tr>
<td>$\ln y_{it}__2$</td>
<td></td>
<td></td>
<td>0.0398</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.0412)</td>
</tr>
<tr>
<td>$\ln y_{it}$</td>
<td>0.208***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.042)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\ln KU_{it}$</td>
<td>0.524***</td>
<td>0.475***</td>
<td>0.4733***</td>
</tr>
<tr>
<td></td>
<td>(0.0296)</td>
<td>(0.041)</td>
<td>(0.0412)</td>
</tr>
<tr>
<td>Konstant</td>
<td>2.413</td>
<td>2.345</td>
<td>3.0334</td>
</tr>
<tr>
<td></td>
<td>(0.154)</td>
<td>(0.435)</td>
<td>(0.2335)</td>
</tr>
<tr>
<td>Fixed effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Time dummies</td>
<td>no</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Number of observations</td>
<td>345</td>
<td>345</td>
<td>343</td>
</tr>
<tr>
<td>R²</td>
<td>0.5109</td>
<td>0.5335</td>
<td>0.5293</td>
</tr>
</tbody>
</table>

Note: Robust standard deviations in the parantheses. Model (1) and model (2) give the frontiers effect.

***: significant at 1%

**: significant at 5%
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We observe from our results that in all tests carried out for the period 1980-1995, all USA coefficients on Ethiopian labor productivity range between 0.03-0.2. They are positive and significant at 1% and 5% significance levels with exception of \( \ln y_{it-2} \) in the third regression which is not significant at all significance levels. \( \ln y_{it-1} \) is only significant at 5% and 10%. This is somewhat bad news since it is the main variable of interest in this section. A test of the frontier’s second lag gave no significant effect on the follower’s productivity as shown above and we are therefore not going to discuss it any further in this section. The estimates above imply that the frontier’s 1% increase in industrial labor productivity results in a 0.1-0.2 percent increase of the follower’s, Ethiopia’s, industrial labor productivity ceteris paribus. We cannot, in other words, reject the hypothesis that the explanatory variable, in this case, the frontier’s labor productivity is of significant effect to Ethiopian labor productivity.

Testing the effect of the frontier’s “advantage of lead” alone, that is \( \ln y_{it} \), on the Ethiopian industrial labor productivity, as we can observe from table (1), gave an effect of 0.2. The t-value in this case is 4.97 and therefore significant at 10%, 5% and 1% significance levels. It is called the advantage of lead because the frontier is not willing to let the follower access its newest technology. The above results are a further confirmation that the Veblen_Gerschenkron effect can be applicable on the low income countries as well. In other words, it implies that industrial sector labor productivity in Ethiopia can’t be studied without including the world frontier’s effect, and any attempts to do so would give biased results. The problem with this alone is that it is not easy, if at all possible, to copy/imitate the newest technology available at the frontier. As mentioned above, letting imitators access the latest technology would deprive the leaders of their leading position which they are not willing to give up easily. This is therefore what Eeckhout and Jovanovic (2002) term as the “Cost of imitation”. This test alone implies that Ethiopia would benefit a little more from the newest technology available at the frontier than it is doing through our test of interest as given in column (2) in table 1, but this will depend on the leader’s willingness to let the follower access this knowledge. Cost of imitation her is given by 0.208-0.167=0.041. Any improvement in the parameter of interest means a reduction in this cost of imitation and improved productivity ceteris paribus.

In other words, the results indicate that an increase in industrial labor productivity of the world frontier increases industrial labor productivity of the follower by approximately 10-
20%. In all tests, $R^2$-within is above 0.5. If we rely on $R^2$ as a measure of success as discussed in chapter three, it means that the variables included in our models explain at least more than a half of the factors that positively affect industrial labor productivity in Ethiopia.

In the estimations we have, as mentioned above, tested the logs of dependent and independent variables as well as the differences of these logs as shown in table 2. It means that we are looking at both short- and long-run spillover effects on the industrial labor productivity in Ethiopia. To account for this, the long-run effect, we have included the lags. One lag for the country of study and two lags for USA, world technology frontier and imposed the stability condition after differentiating. In addition we have looked at the difference in USA’s lags. The results got are robust and the USA effect remains positive throughout all checks. All this makes it practical to even check for the delay in technology diffusion that would have led to increased industrial labor productivity. The results are positive and significant at 10% and 5% significance levels for both first lags.

In addition, it is important to note that to get the positive coefficients above, we had to employ the capacity utilization variable in all our regressions. We did therefore, regress industrial labor productivity in the USA and $\ln KU_t$/capacity utilization on Ethiopia’s industrial labor productivity. $\ln KU_t$ or adjustment variable is a variable that accounts for the deviation from the trend. This variable is commonly termed as capacity utilization. The variable corrects for the short-term effects or shocks. This is because unobserved, trending factors that affect labor productivity might also be correlated with the explanatory variables and including them corrects for the spurious relationships between dependent and explanatory variables. We have, therefore, included it in all tests done. In all these tests, this variable is positive and significant at both 10%, 5% and 1% significance levels. This means that we have better results partly because of its inclusion. Its coefficients are between 0.3-0.4 and low standard errors compared to the variables of interest and this makes it more significant than all these other variables. It implies that industrial labor productivity in Ethiopia is increasing over time due to some other reasons other than just labor productivity in the world frontier. In other words, industrial labor productivity in Ethiopia is not only influenced by the world frontier, but also by other factors that are captured in the adjustment variable.

$\ln KU_t$ has in this case made our estimates more significant, most especially because $\ln y_{lt}$ and $\ln y_{lt}^*$ have different kinds of trends. Movement in $\ln y_{lt}^*$ about its trend line causes movement in $\ln y_{lt}$ away from its trend line. From both figures c and d in the appendix we observe that productivity in some sectors has been diverging/increasing throughout and hence an increased gap. While industrial labor productivity in the USA has been increasing throughout in almost all sectors studied, Ethiopian sectors have, on the contrary, been either constant or falling. These include among others sectors such as textiles, paper and products, industrial chemical, iron and steel.

In addition we observe that almost all sectors, with exception of petroleum refineries and transport equipments, have been diverging from the frontier since around 1990s. Even more
surprisingly, food products, beverages and tobacco, are diverging from the frontier, well knowing that agriculture production is the dominant sector in Ethiopia and therefore it should have been easier for this sector to learn from the frontier. The divergence in agricultural sector can partly be explained increased subsidized agricultural products from the developed world that have outcompeted locally produced products. Much as we see that it is possible or Ethiopia is experiencing productivity spillovers from the frontier, it is still expensive for local producers to acquire the latest technology and not least, the government is poor to subsidize them. This is in line with Paul Bennell (1998)'s finding and in line with the possible reasons given for further decline in manufacturing productivity in our introduction, that is, wear and spare-part shortages. With a new government and the time needed to introduce policy reforms, the decline in productivity was inevitable in the early 1990s.

5:2 THE ERROR CORRECTION MODEL AND TECHNOLOGY ADOPTION

In this section, we are going to use the equation (26) derived in chapter 3 above to discuss the dynamics in our model over the time period covered in our dataset. We can here write it as:

\[ \partial \ln y_{it} = \alpha_{t} + \partial \ln y_{it-1} + \beta_{1} \ln y_{it-1} + \beta_{2} \ln y_{it-2} + \beta_{3} \ln KU_{it} + e_{it} \]  
(30)

We let \( \beta_{1} = \alpha_{1} - 1 \), and \( \beta_{2} = \alpha_{2} - \alpha_{3} \)

\[ \ln y_{it-1} = - \frac{\beta_{2}}{\beta_{1}} \ln y_{it-2} \]  
(31)

As we have seen above, given that Ethiopia is closing the technology gap between her and the technology leader and the long-run equilibrium reached, the equilibrium will be theoretically given by \( \Omega \) as given by equation (25). Since the work is all about empirical analysis, we have to use the equation above in order to get this relationship, and therefore, the long-run equilibrium will be given by \( - \frac{\beta_{2}}{\beta_{1}} \) in (31). To do more analysis in as far as long-run dynamics is concerned, we need a long time series which we lack in this case, since we had to reduce our dataset to be able run the regressions we are using now. This does not favor our analysis here though. The size of the productivity gap between Ethiopia and the frontier is given by difference between what Ethiopia increases with and productivity at the frontier. In this case, the gap is 1−0.15= 0.85. This implies that labor productivity in Ethiopia will be 15% that at the frontier over time. And the gap is 85%. Table 2 below gives the error correction estimations.
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TABLE 2

The error correction estimates

<table>
<thead>
<tr>
<th>Dependent variable:</th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$lny_{lt-1}$</td>
<td>-0.691*** (0.0404)</td>
<td>-0.6769*** (0.041)</td>
</tr>
<tr>
<td>$\Delta lny_{lt}$</td>
<td>0.4976*** (0.1588)</td>
<td></td>
</tr>
<tr>
<td>$lny_{lt-1}^*$</td>
<td>0.1378*** (0.0394)</td>
<td></td>
</tr>
<tr>
<td>$\Delta lny_{lt-1}$</td>
<td>0.1037*** (0.0398)</td>
<td>0.1002** (0.0431)</td>
</tr>
<tr>
<td>$lny_{lt-2}^*$</td>
<td>0.1002** (0.0431)</td>
<td></td>
</tr>
<tr>
<td>$lnKU_{lt}$</td>
<td>0.4013*** (0.0312)</td>
<td>0.388*** (0.0317)</td>
</tr>
<tr>
<td>Konstant</td>
<td>1.764 (0.1617)</td>
<td>1.8949 (0.179)</td>
</tr>
<tr>
<td>Fixed effects</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Time dummies</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Number of observations</td>
<td>343</td>
<td>341</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.5125</td>
<td>0.4972</td>
</tr>
</tbody>
</table>

Note: Robust standard deviation in the paranthese. Both models refer to the frontier.

***: significant at 1%

**: significant at 5%

The dynamics of the Ethiopian industrial labor productivity link to the USA is given by the formulations in table 2 above, separating the short and long run effects. In doing this, like the formulation by Harding and Rattsø (2007), we set all difference terms equal to zero which is the equilibrium condition and order the Ethiopian industrial labor productivity on the left hand side as derived in (chapter 3) above. The effect on Ethiopian labor productivity is positive and
approximately equal to 0.1 for both specifications of USA which is weak, but partly in line with the previous estimates in table 1, since the spillover effect is positive, and of course reasonable since the long-run equilibrium is approximately 0.15. The values are significant at 1% and 5% significance levels and therefore we cannot reject the hypothesis that labor productivity at the frontier will affect Ethiopian labor productivity in due course. This further emphasizes the productivity spillover effect on the Ethiopian industrial labor productivity but at the same time emphasizing the fact that Ethiopia has and will always lag behind the world technology frontier, regardless of whether it implements imitation with or without a lag.

Considering the difference between these two in the first table, it is quite evident that productivity growth in Ethiopia will be less and less over time. The results indicate therefore that productivity growth over time is not enough or near to closing the gap between the leader and follower, but instead falling/diverging and therefore increasing the gap. Increasing gap in labor productivity rules out the possibility of catching-up to the frontier hypothesis. There is however a possibility that some sectors will experience a much bigger effect than what we have in our aggregate results and others will “sink deep”. This gives ground for further research that is based on individual sectors so as to control for differences in sector absorptive capabilities.

Despite all the above and the positive long-run effect, the catching-up to the frontier still seems to be out of reach for Ethiopia. It is definitely slowly learning from the frontier, but not able to close or reduce the gap between her and the world technology frontier. In most of the sectors, apart from petroleum refinery, the gap between the two countries has been increasing and therefore contradicting the Veblen-Gerschenkron effect discussed above. This gap increase/divergence is shown in the descriptive results in figures (c) and (d) in the appendix which compares the development in labor productivity over time for the two economies.

### 5.3 How do we marry results above with the theory discussed

From chapter 2 of this thesis and the results presented in sections 5.1 and 5.2 above, we can now try to position our country of interest, Ethiopia. Despite her low adoption capacity, Ethiopia is, according to the results presented, learning from the frontier. This means in other words that adoption is greater than zero but far less than one and therefore having situation (ii) discussed above. We have got that the productivity gap between Ethiopia and the frontier is approximately 0.85. This implies therefore that Ethiopian labor productivity is approximately 15% or less than a fifth the level at the frontier. It is small, but promising provided the situation doesn’t continue to be as it is, or worse, with the data we are using today.
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This productivity is therefore too low and gives reason to believe that Ethiopia is tending towards the poverty trap equilibrium in the long-run as according to Benhabib and Spiegel discussed in the theory part of this thesis, this implies that Ethiopia is far from keeping track with the frontier in as far as productivity growth is concerned.

Nevertheless, it is too early given our results to conclude that Ethiopia is already in the poverty trap. So long as we can get positive spillover effect on labor productivity in Ethiopia as productivity at the frontier increases, we assume it is a necessary condition to be above the poverty trap, but on the margin. This means that with any slight fall in this effect or any other shock for example oil prices or the current ongoing recession caused by collapse in financial institutions, that affect both Ethiopia and the Frontier, the country will slip into the trap. The reason i use oil prices as an example here is due to the fact that this is the sector that shows some reasonable trend that is in line with the frontiers’. Whereas most of all other sectors show a divergent trend from the frontier, the petroleum refinery shows the opposite and hence reason to believe that it is one of the sectors that make the aggregate results more positive.

Having ruled out the discussion on the contribution of education to labor productivity in Ethiopia in this thesis, due to lack of data, it means that innovation is of minimal contribution to productivity growth here and we are therefore remaining with adoption as the only possible means to close the gap between the follower and the leader. It’s effect is however minimal and it implies that Ethiopia will continue to lag far behind the frontier and the gap will keep increasing as the frontier keeps inventing new technologies that make it even much easier to produce now than before and henceforth strengthening her leading position in relation to the follower.

In Solow- Swan growth model, it is predicated that in the long-run, there will be convergence in growth. From our error correction model, this doesn’t seem to be the case. Productivity growth at 15% of the frontier’s increase in productivity growth is far from convergence prediction and very close to divergence instead. This we decide to interpret as a tendency to the poverty trap. It confirms Nelson and Phelps (1966) idea that productivity growth increases with increased relative gap as given by equation (12) in chapter 2 but this increase is not convincing. Ethiopia has therefore not enjoyed fully the benefit of being far from the frontier and this can be interpreted as a failure to put into right practice the existing technology at the frontier, Nelson and Phelps (1966).

It is against this background that we believe that our model is best explained by Benhabib and Spiegel’s approach that distinguishes the technology diffusion model into innovation and adoption channels. Leaving out innovation as assumed due to the fact that we are dealing with a less developed country, implies that we are left with adoption as the only means possible to improve productivity in Ethiopia, represented by the estimates obtained above if we are to check for the Veblen- Gerschenkron effect here. Assuming that the results we got represents both innovation and adoption channels, it would weaken the Ethiopian capacity to learn and close the gap even further. Benhabib and Spiegel’s approach gives hope for improvements in
productivity growth, given that Ethiopia invests in the factors that can make it easy to leap productivity spillovers at the frontier. In this case the appropriate innovation at the frontier.

There are, however, a number of reasons apart from those discussed above that can explain why most SSA countries and Ethiopia in particular are continuing to lag behind the frontier. To begin with, we should not forget that Sub-Saharan African countries are countries with a bigger percentage of their labor employed in the agriculture sector. Most of their exports are agricultural products whose elasticity of demand is low and facing competition from the developed world. As if this is not enough, the majority of labor in this sector is less qualified in terms of education and this therefore makes it difficult to acquire the new knowledge that would improve their productivity. Benhabib and Spiegel (2005) argue that if we are to experience catch-up, then the sum of the follower’s innovation and technology adoption should be greater than the frontier’s innovation. Since less, if any, is spent on research and development in Ethiopia, we expect less or in extreme cases no “visible” innovation in this country. The only option through which the country can improve on its labor productivity is through technology adoption.21

Ethiopia is one of the countries in the region (SSA) that are greatly affected by climate changes partly due to its location. As a result, a bigger percentage of her population is living under the poverty level and hunger in the country is the order of the day particularly in rural areas. We in addition know that diseases like malaria and Aids excel in such conditions and are therefore crippling the productivity of labor in such areas and the country at large.

As discussed above, we observe an increasing gap between the frontier and the follower in sectors like industrial chemicals which require skilled workers, something that in a way emphasizes the human capital barrier. This is in line with Cameron (2005)’s discussion on relevancy of his study on the growth experience of other countries. He argues that lack of skilled manpower for research can in one way or another hinder/limit attempts to increase capacity. This could have been another area of interest to extend our study provided we had data on education in Ethiopia.

In general, Ethiopian labor productivity is positively affected by what happens at the frontier. However, it is worth noting that this effect is too small in relation to what happens at the frontier and is therefore far from closing the productivity gap between them and hence equilibrium. No steady state in this case if the situation continues as we observe it from our estimates. Worth noting is that this thesis is a drop in a broad analysis of economic and productivity growth. The additional factors discussed above are just examples to shade light on possible reasons why we got the exact results we are discussing in this work and the possible eventual extensions in future.

21 For more on technology adoption and its barriers, see Stephen L. Parente and Edward C. Prescott (1994).
5.4 COMPARISON WITH PREVIOUS STUDIES

As in many other studies done on productivity growth, some element of learning from the world technology frontier is observed in this one as well. What all these studies have in common is that omission of the world technology frontier’s effect in attempts to measure productivity growth would give biased estimates regardless of whether labor productivity or total factor productivity is the measure of productivity used. The point to have in mind here is that we have used a different measure for productivity growth and labor productivity, and should therefore expect some degree of variation in the results. These two different measures, labor productivity and total factor productivity, set different restrictions on the data to be used and that is one of the reasons why we should expect variations in estimates.

In this work, we used value-added and the number of employees to calculate the labor productivity, whereas dealing with TFP would require us to include other inputs as well and of course estimating their effect on TFP. Total factor productivity is what has been preferred in most of the previous studies. We choose to ignore different definitions here to make comparison of our work and previous studies possible. We have seen above that Ethiopia has not managed to keep pace with the world technology frontier as far as catching-up is concerned, despite positive results.

In our introduction we mentioned among others isolation from FDI as one of other factors that can help explain lacking economic and productivity growth in Ethiopia and as a channel through which technology is transferred. Studies made however, indicate that productivity advantages latent in foreign direct investment (FDI) are subject to human capital threshold effect. Barro (1999) finds that school attainment at secondary and higher levels of males aged in 25s and over has a positive effect on the subsequent rate of the economic growth. This means improved capabilities to absorb technological advances. This emphasizes how important it is if this work on productivity growth and productivity spillover effect is to be compared to other previous works, most especially those done on developed or middle income countries.

6. CONCLUSIONS AND REMARKS

This thesis is based on the previous work that studies the role of the world technology frontier on the productivity growth across countries. The main objective here is to contribute to the vast existing empirical work through one of the measures of productivity growth, labor productivity, and of course extending the study to low income countries in this case Ethiopia.

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22 See Borensztein, De Gregorio and Lee (1998) for a more detailed discussion on threshold calculation and estimations.
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We however choose a simple approach by not integrating the frontier variable into other factors affecting labor productivity in the above mentioned country and this is mainly because of lack of reliable data on almost all other variables. We therefore choose to solely study the frontier’s effect on Ethiopian industrial labor productivity and its growth.

Our key findings in this study are first, the growth in labor productivity at the frontier has a somewhat significant effect on the domestic labor productivity in Ethiopia. However, this effect is far less than expected/ desired. Coefficients between 0.1-0.2 imply that it is a nightmare for Ethiopia to dream about catching-up to the frontier. These results imply that with a 1% increase in labor productivity at the frontier, labor productivity in Ethiopia increases by far less than a half. This is such a small increase despite being positive and statistically significant.

We have in addition checked the long-run relationship between these countries provided the economic trend continues to be like it is in the period we are studying now. We found out that Ethiopia’s productivity growth rate in the long-run will be approximately 15% the level at the frontier which is slightly below what we got in table 1. This implies that the gap between the frontier and Ethiopian labor productivity will continue to grow over time something we have chosen to associate with low levels of “absorptive capacity”. We can therefore conclude from the results we have that productivity convergence is out of reach for the countries in focus. The frontier’s technology is far above what Ethiopia can manage as far as technology adoption is concerned and we assume that if the trend continues like it is, Ethiopia can eventually slip into the “poverty trap equilibrium”.

To achieve all the above used results, we were prompted to reduce the number of years and sectors given in the original dataset. In so doing, we make sure that the sectors studied in Ethiopia correspond to those in the frontier. There are however, some sectors that have less time series relative to the corresponding sectors at the frontier and surprisingly enough, it is these sectors that have somehow fared better than others.

Much as we limited ourselves as far as the contribution of education in interaction with the frontier’s labor productivity to the growth in Ethiopian productivity, we recommend it in the near future to come, for this would probably improve on the estimates and make it even much easier to compare the results with previous studies on productivity spillovers and productivity growth. In addition, it can also be interesting to make this study but concentrating on the heterogeneity between sectors, since our descriptive results indicate that there are certain sectors showing a positive productivity trend throughout, though not to the frontier’s level.
7. REFERENCES


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http://www.lib.utexas.edu/maps/africa/ethiopia_rel99.jpg

www.worldbank.org/trade

8. APPENDIX

The descriptive results of the study period (1980-1995)

Figure a

Descriptive results for USA’s labor productivity by sector

Graphs by sector
Figure b: Descriptive results for Ethiopia’s labor productivity by sector
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Figure c: A combination of the two figures above (1980-1995)

Graphs by sector
Figure d: Descriptive results for both countries for the period (1976-2000)