EVALUATING THE ROLE OF TRADE OPENNESS AND TRADE OPENNESS RISK ON AGRICULTURAL PRODUCTION TECHNICAL EFFICIENCY: AN EMPIRICAL ANALYSIS OF SUB-SAHARAN AFRICAN COUNTRIES

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ABSTRACT

The impacts of trade openness and trade openness risk on the technical efficiency of agricultural production are examined using an extended stochastic frontier analysis econometric model. This model simultaneously estimates a primal production function equation and a technical efficiency equation. The primal production function estimates the contribution of land, labor, capital and fertilizer inputs to endogenous output. The technical efficiency equation estimates the importance of trade openness, short-run and long-run trade openness risk. A panel of 31 of the 47 Sub-Saharan African countries was used in the estimation over 40 year period, 1970 to 2009.

Empirical findings showed differential impact of trade openness, short-run and long-run trade openness risk on technical efficiency. Results from stochastic frontier analysis econometric model revealed that a one unit increase in trade openness reduced technical inefficiency by 0.695 percent, while a one unit increase in trade openness risk in the short-run and in the long-run increased technical inefficiency level by 0.91 percent and 1.301 percent, respectively.

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TABLE OF CONTENTS

ABSTRACT..iii

ACKNOWLEDGEMENTS iv

LIST OF TABLES…………………………………………………………………………...vii

LIST OF FIGURES……………………………………………………………………………..viii

LIST OF APPENDIX TABLES……………………………………………………………ix

CHAPTER 1. INTRODUCTION……………………………………………………….......1

Background and Context………………………………………………………...1

Need for Evaluating Trade Openness Risk in the Short and Long-run…………....3

Research Objectives…………………………………………………………..5

Thesis Outline…………………………………………………………………...6

CHAPTER 2 . LITERATURE REVIEW…………………………………………………7

Background Literature………………………………………………………..7

Trade Expansion and Efficiency/Productivity……………………………………...9

Trade Liberalization and Trade Risk……………………………………………….19

CHAPTER 3. T H E O R I T I C A L F R A M E W O R K …………………………………25

Primal Production Function..25

Stochastic Frontier Production Function and Trade Model.....................................26

CHAPTER 4. SUB-SAHARA AFRICA AGRICULTURE OUTPUT, INPUTS AND TRADE OPENNESS DATA. ....……28

CHAPTER 5. EMPIRICAL APPLICATION AND RESULTS..51

Empirical Estimates………………………………………………………..........51

Agriculture Production Function………………………………………………52

Stochastic Frontier Analysis of Agriculture Production Function………..........54

With Trade Openness in the Technical Efficiency Model…………………..54

With Trade Openness and Short-run Trade Openness Risk in the Technical Efficiency Model…………………………………………...55

With Trade Openness and Short and Long-run Trade Openness Risk in the Technical Efficiency Model……………………………………57

CHAPTER 6. CONCLUSIONS AND DISCUSSIONS……………………………….62

BIBIOGRAPHY…………………………………………………………………......65

APPENDIX A…………………………..…...…………………..………........................68

APPENDIX B: PRINTOUT RESULTS FOR R-CODE USED IN THE ANALYSIS…......75

LIST OF TABLES

Table Page

1. Complete List of SSA and Actual Countries Used in the Analysis……………………29

2. Description of Variables Used in the Estimation of the SFA Model………………......30

3. Descriptive Statistic of Output for SSA Countries, 1970 – 2009…………………….....31

4. Descriptive Statistic of Land for SSA Countries,1970-2009…………………………..34

5. Descriptive Statistic of Labor for SSA Countries,1970-2009……………………….....37

6. Descriptive Statistic of Capital for SSA Countries,1970-2009……………………........39

7. Descriptive Statistic of Fertilizer for SSA Countries,1970-2009……………………….43

8. Descriptive Statistic of EXIM for SSA Countries,1970-2009………………………......45

9. Descriptive Statistic of GDP for SSA Countries,1970-2009…………………………...49

10. Summary Statistic of Variables Used in the Analysis...………………………………..51

11. Regression Results of Primal Production Function…………………………………....53

12. Regression Results of Stochastic Frontier Analysis Including Trade Openness…….....55

13. Regression Results of Stochastic Frontier Analysis Including Trade Openness and Short-run Trade Openness Risk for SSA 1970-2009…………………………………..56

14. Regression Result of Stochastic Frontier Analysis Including Trade Openness, Short-run and Long-run Trade Openness Risk for SSA 1970 -2009…………………..58

15. Average Technical Efficiency Measure for SFA, SSA Countries, 1970 – 2009……...61

LIST OF FIGURES

Figure Page

1. Trend in trade openness, short-run and long-run risk in trade openness of the Sub-Sahara Africa Countries, 1970 – 2009……………………………………………4

LIST OF APPENDIX TABLES

Table | Page

A1. Regression Estimates for Production Function SSA, 1970-2009…………………………..68

A2. Regression Estimates for Production Function with Individual Country regressed with Trade Openness for SSA, 1970-2009………………………………………………..69

A3. Regression Estimates for Production Function with Individual Country regressed with Trade Openness, and Trade Openness Short-run Risk for SSA, 1970-2009..................71

A4. Regression Estimates for Production Function with Individual Country regressed with Trade Openness and Trade Openness in Short-run and in Long-runs Risk for SSA, 1970-2009...73

CHAPTER 1. INTRODUCTION

Background and Context

Due to increased globalization and free market economies, the last decade of the twentieth century and the first decade of the twenty-first century brought significant increase in trade within and between countries. According to the United Nations Conference on Trade and Development report (UNCTAD, 2007), the value of the world exports increased from US$5 billion to US$14 billion during ten year period 1995 – 2005, as a result of globalization. The study also showed that the contribution of developing countries to the world trade increased from US$1.4 billion to US$4.1 billion, and trade among developing countries increased from US$570 million to US$1.8 billion over the same period. Furthermore, the study examined the economic impact of the international trade by using the ratio of exports plus imports to gross domestic product (GDP), defined as trade openness. Overall, the trade openness increased by 30%; with 29%, 26% and 37% contributed by developed, developing and least developed countries, respectively, 1995 to 2005.

Trade openness has recently gained popularity; scholars argued that a country that opens its market and trades with other countries would increase its efficiency/productivity by receiving productivity-enhancing tools like technology (Altamonte & Beke, 2010; Chortareas, Desli & Pelagidis 2003; Larson, Otsuka, Matsumoto, & Kilic, 2012; Pardey & Leibenberg, 2010; Olajide, 2010; Peluffo, 2012; and Ruttan 2002). International trade is presumed to foster productivity and efficiency through transfer of technology from the advanced countries to the developing countries, and this transfer would confer benefits to recipient developing economies (Bardhan, 2006; Cline, 2004; and Winters, 2002). The efficiency/productivity-enhancing effects of trade have been widely documented in both macro and micro level studies. However, these researches have mainly focused on the manufacturing industry with very limited work on agriculture (Bigsten et al., 2004; and Biesebroeck, 2005). Self and Grabowski (2007) argues that although many scholars recognize the potential for trade to generate agricultural efficiency/productivity gains, they confine their empirical investigations to the link between agriculture, growth, and poverty (Harrison & McMillan, 2007; and Nissanke & Thorbecke, 2006).

It is difficult to make convincing generalizations about how international trade might affect domestic agricultural efficiency/productivity. Increased agricultural production for exports requires the use of input resources more efficiently to spur economic activity down the line in manufacturing, trade, and transportation of these products. International trade has been a hotly debated topic; economists differ on whether there is benefit associated with international trade and how much benefit trading partners reap from the international trade. Though an increase in exports is argued to be beneficial to trading partners' economic growth, an increase in imports is argued to be a threat to countries' economies, particularly to the least developed countries, and policy makers have a hard time striking the right balance between an open trade and the risks associated with an open trade. While international trade drives economic development, developing countries are often outperformed by financially stronger developed countries which put developing countries at a trading disadvantage (Taljaard, 2007).

In addition, agricultural imports could replace domestic production activity or reduce domestic agricultural efficiency/productivity, resulting in a loss of employment and income in rural areas (Edmondson et al., 1996). Trading, particularly between the developed and the developing countries, is the biggest threat to unskilled workers' well-being (Wood, 1995). Wood (1995) argues that trade increases demand for skilled workers and reduces demand for unskilled workers. Shangquan, (2000) argues, though globalization provides development opportunities to the developing countries, it poses enormous risk to the least developed countries. This studies argue that globalization or trade openness has widen the gap between the rich and the poor countries, and the gap between their incomes per capita has increased from 30 times greater in rich countries in 1960 to 70 times greater in 2000. The study further revealed that the value of foreign trade of the poorest countries decreased from 1.4% to 0.4% over 35 years, 1960 to 1995, which is an average of 2.9% per year. Due to this fluctuation or variability in trade openness over time, it is important to examine its impact both in the short-run and in the long-run to understand how it affects the Sub-Saharan African technical efficiency measures.

Need for Evaluating Trade Openness Risk in the Short and Long-run

Risk or variability in trade openness affects producers' decision to produce goods, how much to produce and how to produce it efficiently. It is hard for a producer to initially determine how much to produce and how efficiently to allocate and utilize input resources. An ability to quantify changes in trade openness risk or variability in the short-run and long-run could help not only producers, but also, policy makers. For example, a producer's decision to invest in a new technology that could increase technical efficiency and productivity could be affected by how much trade openness risk is associated with the investment as well as the producer's risk perception (Jemaa, 2007). Even though risk perceptions are important, there is limited research addressing how important, perception is on technical efficiency. An ability to capture trade openness risk or variability will help decision makers understand its impact on technical efficiency and productivity, and thus help them determine how much to produce at certain periods of time and how to efficiently use resources to produce output. Not only is risk or variability in trade openness important for the domestic producer, but its risk is a major concern among trading partners.

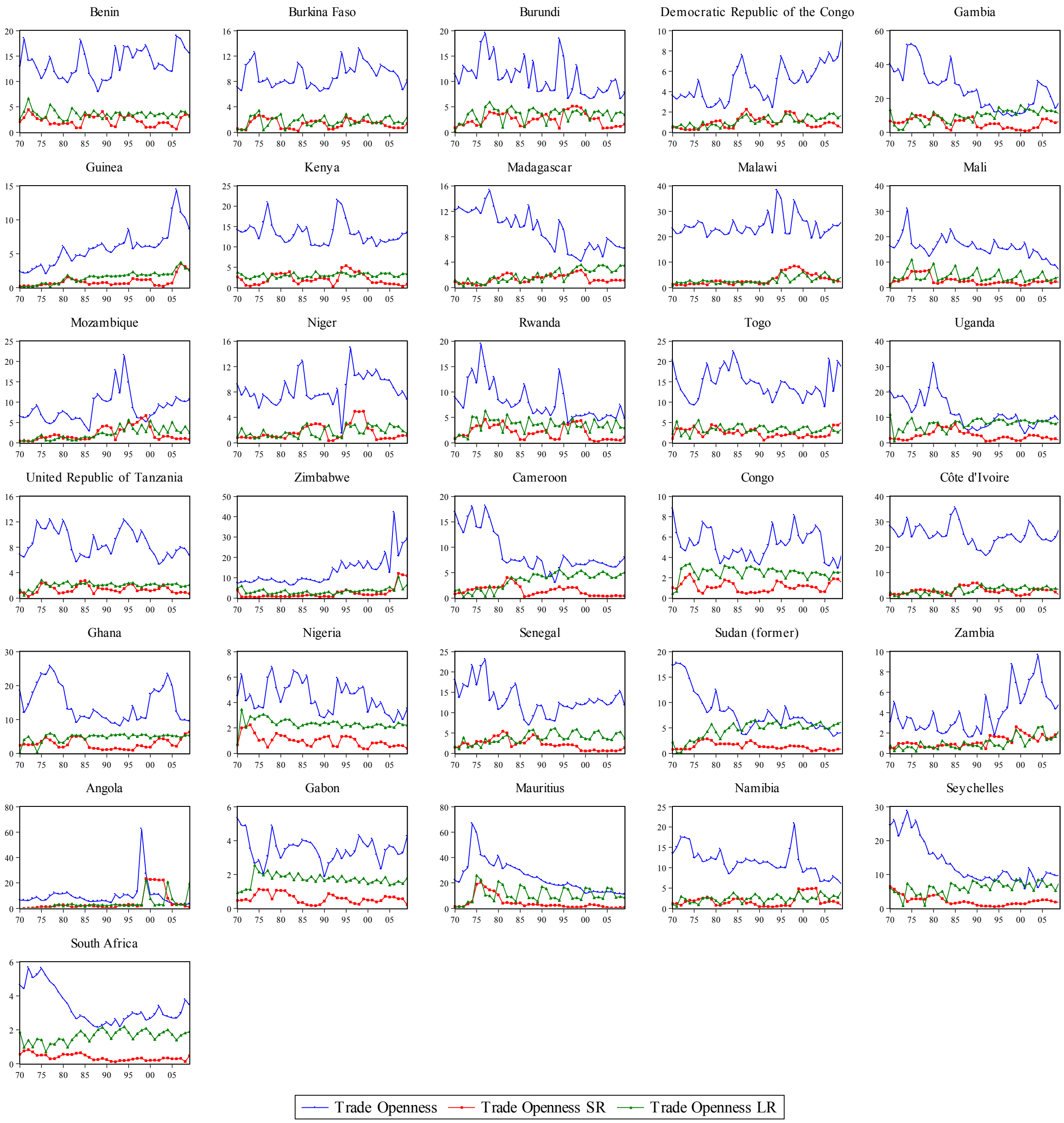

Figure 1: Trends in trade openness, short-run and long-run risk in trade openness of Sub-Saharan African countries.

Figure 1 shows trend in trade openness and trade openness risk in the short and long-run from 1970 to 2009, gauging the importance of trade risk or trade variability over time. Trade openness is measured as the total of agricultural exports plus imports divided by total GDP. Trade openness risk in short-run is measured as the window rolling variation of trade openness for the last 5 years, and trade openness risk in long-run is measured as the cumulative rolling variation in trade openness starting with 5 years and cumulating over 40 years. Trade openness in an individual country varies widely over the analyzed period. All countries' short-run and long-run risk or variability is positive, suggesting an existence of variation in trade openness, not only in the short run, but also in the long run. Evaluating this trade variability or risk in the short-run and long-run across Sub-Saharan Africa over 40 years could help in understanding the constraints and implications of changes in technical efficiency measures and how those changes influence domestic agricultural technical efficiency production.

There are several factors which are important in understanding farmers' production decision-making; these factors include the ability to measure and examine the impact of short-run and long-run trade openness risk on technical efficiency measures, accurately understand how much risk is associated with a certain investment, and estimate its impact on producer's preference. Di Giovanni and Levchenko (2006) argue that the greatest threat from globalization is an increased insecurity for workers which results in uncertainty over both employment and earning. The study showed that one standard deviation increase in trade openness, increases aggregate volatility by 15% of the average aggregate variance.

Research Objectives

The primary goal for this thesis is to empirically evaluate the role of trade openness and short-run and long-run trade openness risk on agricultural production technical efficiency of the Sub-Saharan African countries from 1970 to 2009. Stochastic frontier analysis (SFA) econometric model of the production function equation along with the technical efficiency equation is used in the analysis. The production function evaluated the importance of input factors apart from estimate the agricultural production technical efficiency. The technical efficiency evaluates the role of trade openness and short-run and long-run trade openness risk on the Sub-Saharan African region's ability to produce efficiently. These objectives will be achieved using agriculture data from the World Bank, International Monetary Fund (IMF), Penn table, and Food and Agriculture Organization (FAO).

Thesis Outline

Chapter 2 provides a literature review evaluating the role of trade openness and trade openness risk on technical efficiency of the Sub-Saharan Africa region agriculture. Chapter 3 presents theoretical framework of the study. Chapter 4 presents the Sub-Saharan African agriculture data and construction of the variables used in the empirical model. In Chapter 5, empirical econometric models and results of the study are discussed. Finally, Chapter 6 presents conclusions and discussion of the study.

CHAPTER 2. LITERATURE REVIEW

Background Literature

Trade has historically been the means through which buyers and sellers' exchange goods and services from the birth of the barter system to modern globalization. Until mid-twentieth century, trade among countries was restricted to avoid competition. However, Salvatore (2004) argues that trade restrictions still exist today through economic policies such as state intervention; he argues that industrialized countries restrict imports of agricultural products, in order to protect their economies while providing subsidies for their high-tech industries to boost their competitiveness.

These restrictive economic policies were later deemed disadvantageous; many early economists, especially from the United Kingdom, later challenged mercantilism's protectionist aspect through classical theories of absolute advantage (Smith, 1776), comparative advantage (Ricardo, 1817) and factor endowment (Heckscher, 1919; and Oline, 1933). These scholars argued that the protectionists' trade policies were bad for economic developments because they hindered what Ricardo call the comparative advantage – produce what one produces at least cost and trade for what is expensive to produce. The argument of these economists is that open trade economies perform better than protected economies because they foster economic growth and productivity (Chortareas, Desli & Pelagidis, 2003).

Despite pro-globalists (Afonso, 2001; Calestous, 2010; Easterlin, 1981; Frankel & Romer, 1999; Moussa, 2002; Mshomba, 2000; Nyangito, 2004; and Pingali, 2006) arguments that open trade enriches and improves economic well-being of countries by increasing specialization of world production and improves economic efficiency, other economists question the benefit of open trade, better known as globalization, particularly to the least developed countries (Giovanne & Levchanko, 2006; Iyoha, 2005; Solarz & Morgan, 1994; Thirlwall, 2000; and Wood, 1995). These anti-globalists argue that globalization threatens wages of workers, increases the wage inequality gap, undermines domestic social relations, and raises an exposure of a country's economy to weakening foreign economies.

Pro-globalists argue that one of the benefits of international trade is its ability to transfer technology from the more developed countries to the least developed countries to help them increase their productivity. These theorists hold that regions like Sub-Saharan Africa, which are in desperate need to increase food productivity for home consumption and for exports, must take advantage of free trade in order to grow their economies (Calestous, 2010; Moussa, 2002; and Mshomba, 2000). Globalization supporters argue that trade leads to productivity, which in turn leads to economic growth (Afonso, 2001; Frankel and Romer, 1999). This belief leads to pro-globalist advocating that it is imperative for Sub-Saharan Africa to pursue its global integration to improve its agricultural productivity and enhance its overall economic growth since it heavily depends on the agricultural sector.

According to the World Bank Development reports (2011), agriculture in Sub-Saharan Africa provides 40% of the continent's exports, employs 70% of the population, and accounts for 35% of the continent's GDP. Nyangito (2004) argues that agriculture will continue to be the continent's primary source of employment, food, household incomes, foreign exchange earnings, and raw materials. Moussa (2002) and the World Bank Report (2008) claims that Africa's population and overall economic growth rate are at 2.7% and 2.6% respectively, and argue that agricultural GDP growth in Sub Saharan Africa are at 3.8% per year. The importance of the agriculture sector to the region's economies prompts a call for an improvement in the region's agricultural production technical efficiency. There is a unanimous consensus that improvement in agricultural productivity through international trade will improve the region's economies (Easterlin, 1981; Frankal & Romer, 1999; and Pingali, 2006) and the region's increased interaction with the world would improve its productivity (Sirgy et al., 2004). Though often, these enhanced linkages are a positive construct that help raise economic efficiency, from time to time, they can play a negative role as conduits for economic contagion (Elwell, 2005). For example, it is said that economic maladies from the other side of the world can spread to the United States and can bring undeserved economic misfortune to U.S. citizens.

The literature review is divided into two main sub-topics: one reviews the link between trade and productivity and the other reviews the trade liberalization and trade risk, or trade variability associated with trade liberalization, particularly from the least developed and developing countries' perspective.

Trade Expansion and Efficiency/Productivity

Over the past few decades, there has been a surge of interest in the relationship between trade and trade variability impact on production technical efficiency across sectors. One view that has gained considerable popularity is that gains in agricultural productivity lead to farm surpluses that enable commercialization (Chapoto et al., 2012). The link between trade and productivity continues to be a topic of wide discussion; most analysts and scholars view these relations as beneficial to trading partners. These scholars argue that international trade allows participating countries to benefit from specializing in products and services in which they have a comparative advantage over other countries (African Comprehensive Report, 2002; Bruckner & Lederman, 2012; Gries & Redline, 2012; Moussa, 2002; Abou-Stait, 2005; Steven, 2005; and World Trade Report, 2008). Comparative advantage theory is more visible when it comes to trade between developed nations and least developed nations. The above authors argue, usually, developed nations have a comparative advantage in the production of technology and developing nations have a comparative advantage in raw materials and labor. These authors argue that developed nations import natural resources, agricultural staples, and simple manufactured goods from developing nations, and in exchange, developed nations export high-tech, investment, and consumer goods; these exchanges necessitate trade as equally crucial both to the poor and the rich economies (Osterfeld, 2007; Peluffo, 2012; and World Trade Report, 2007).

The relationship between trade and productivity does not stop at increasing agricultural productivity, but more importantly, it leads to overall economic growth. Chapoto et.al (2012) argue, "Agricultural productivity gains and associated agricultural commercialization contributes directly to broad sector and spatial transformation; it stimulates demand-led economic diversification into manufacturing and service" (p.1)" Alcala & Ciccone (2003), and Olajide (2010) argue that trade liberalization increases agricultural productivity and that more trade integration is needed to improve Sub-Saharan African agriculture productivity through technological changes. In their study, Alcala and Ciccone (2003) find that, trade significantly drives overall productivity; they find that, an increase of a country's trade openness from a 30th percentile to a median, raises a country's productivity by 80%, and an increase from a 20th percentile to an 80th percentile raises a country's productivity by six factors.

In the last 30 years, globalization, which is a rapid expansion of trade in goods and services, has led to economic interdependence across the world economy. For example, in the United States, the real volume of trade in goods has grown twice as fast as real output, bringing total trade (exports plus imports) from about 10% of Gross Domestic Product in 1970 to 28% in 2001. Also, foreign investment in assets (e.g., bank accounts, stocks, bonds, and real property) has grown even faster with cross-border resource transactions. For example, between 1970 and 2001, there has been an increase in trade value of goods and services from US$5 billion to US$1,123 billion (Elwell, 2005).

Prior to the twentieth century, an increase in agricultural productivity was driven by the size of the land under production; however, by the mid twenty-first century, this started to change, at least in most countries due to the emergence of productivity enhancing-technology (Altomonte & Beke, 2010; Larson, Otsuka, Matsumoto, & Kilic, 2012; Peluffo, 2012; and Pardey & Leibenberg, 2010). According to Ruttan (2002), today increases in agricultural productivity are linked to an improvement in production efficiency – improvement in land productivity, or an increase in output per hectare. An increase in crop yield, for example is argued to be a function of both “mechanical technology,” which is a substitute for manual labor, and “biological and chemical technology,” which is an improvement in land productivity (p.162). Pardey & Liebenberge (2010) agree with Ruttan when assessing South African agricultural production and productivity patterns; they acknowledge that South Africa’s increase in crop yields was driven by an increase in mechanization and improvement in seeds.

Given this correlation between trade and productivity, scholars argue that agricultural productivity could be improved through trading by transferring productivity-enhancing technologies from the developed countries to the least-developed countries. Furthermore, considerable evidence exists that countries with open economies tend to consistently grow faster than those with closed economies (IMF, 2002). Countries that have opened their economies in recent years, for example, India, Vietnam, and Uganda, have experienced faster growth and an increase in poverty reduction. On average, developing countries that lowered tariffs sharply in the 1980s grew more quickly in the 1990s than those that did not.

In the 1960s and 1970s, African countries were skeptical about the virtues of free trade, but since the late 1980s, there has been a developing interest in negotiations in multilateral trade and agreements. This interest has stemmed out of three areas: the slow pace of regional integration has brought about dissatisfaction among African nations that want to liberalize trade; the belief that if trade is well managed, it will play an important role in the development challenges being faced by the continent; and the idea that trade can initiate and foster regional integration efforts (Taljaard, 2007). The economic benefit gains by a country when it opens up its economy to the world encourage the formation of regional and international economic agreements, such as the World Trade Organization (WTO), the Economic Community of West African States (ECOWAS), and the General Agreement on Tariffs and Trade (GATT). These trade benefits prompted Africans policy-makers to form 14 regional economic communities in an effort to foster economic power internally and externally (Iyoha, 2005). Other international institutions are working to help integrate Africa into the international economic community. Chief among them are: the Agreement of Agriculture between the US and the African agricultural producers aimed at giving the African agricultural communities access to the international market by lowering tariff costs (Nyangito, 2004). However, none of these regional economic groups or international agreements has improved African exports, as will be discussed in detail in the next paragraph.

World financial institutions, such as the World Bank and the International Monetary Fund (IMF), have been channeling financial assistances to Africa in order to boost its economic growth and help integrate the continent and improve its economies; but, "neither of these lead to development nor poverty reduction" (Moussa, 2002). Moussa, in his article titled, "Technology Transfer for Agricultural Growth in Africa," discuss why there is no development in the African agriculture sector, despite the world's enormous financial aid to the continent in the last 30 years to stimulate agricultural growth. The author argues that evidence shows that financial and food aid to the continent will not solve the continent's lagging economies, and the author recommends agricultural development through technological transfer to improve farmers' crop yield as the only viable option to elevate poverty and ensure food security. The article urges the region's farmers to adopt the existing technology in order to improve productivity across the continent by; upgrading the existing research institutions, by improving rural infrastructures to enhance markets accessibility, and promoting rural commercial-oriented institutions and rural micro-finance that would ensure farmers accessibility to farm inputs. Despite this well-established argument that globalization helps the least developed countries raise their productivity by utilizing new acquired skills and technology (Abou-Stait, 2005; Kanbur, 1999; and World Trade Report, 2008), anti-globalists argue the opposite, that trade liberalization hurts unskilled, labor-intensive workers (Iyoha, 2005; Stevens, 2005; Thirlwall, 2000; and Wood, 1995).

Koop, Osiewalski, and Steel (2000) studied cross-country economic growth, and specifically, the patterns of efficiency over time and across countries. They used data from 44 countries across the world with different development levels: Latin America, Africa, East Asia, and the industrialized Western countries. They used capital and labor as the two independent variables to model economic growth, and empirical results show difference in both labor and capital elasticity across regional frontiers. Their findings show that the economically free societies (or economically open societies) are more efficient, and Africa continent is the most inefficient region due to differences in regional frontier. These empirical results show that growth in outputs is mainly driven by growth in inputs followed by growth in technology. Bastos and Cabral (2007)'s study found industry-specific changes in labor productivity and relative labor costs as responsible for most changes in trade pattern among countries while Rusu (2010) found that countries such as Sub-Saharan Africa, benefit more by trading with large economies such as the United States or United Kingdom than by trading with Least Developed Countries within the continent or outside of the continent. Kawai's (1994) in his quest to determine whether trade policy has an impact on economic growth among the Asian and the Latin American countries found that productivity change is key in explaining why there is disparity in growth pattern among developing countries.

According to UNCTAD (2003), trade expansion can foster and encourage adaptation of trade policies that can create a favorable environment for investment. However, given the considerable differences among developing countries and the levels of development attained, it can be difficult to arrive at a common view of how trade policies are influenced by a new world trade situation. Crisis is argued to have differential impact on trade among countries; for example, the Asian crisis of the 1997 had a positive impact on the continent but a negative impact on trading partners. It contributed to a substantial widening of the U.S. trade deficit. There was a sizable inflow of Asian capital, seeking high and more certain U.S. asset yields, which pushed up the dollar exchange rate, weakening exports and encouraged imports. Several sectors dealing with tradable goods of the economy were affected negatively by these changes; agriculture and commercial aircraft exports experienced damped export sales. On the import side, the steel industry, the textile and apparel industries came under considerable pressure from low priced competition from the crises-affected countries. Economic benefits were derived from this crisis, on the other hand. One example is that lower import prices raised real income in the United States and reduced inflation pressures. In addition, large capital inflows kept domestic interest rates lower than they otherwise would have been which also led to a gain for U.S. borrowers and interest sensitive sectors such as housing and consumer durables (Elwell, 2005).

In another study conducted on the effect of international openness on the labor productivity, the natural logarithm of labor productivity was taken as a dependent variable; import and export dependency ratio, and the ratio of FDI to GDP and human capital as independent variables, and had an empirical analysis based on the model for panel data. Results showed that human capital was the first important positive factor among all the independent variables affecting the labor productivity growth; FDI also had a strong positive impact on the labor productivity and so was the second important influencing factor. Export had positive effect, but was very weak and almost nonexistent, and import's effect on the labor productivity was negative. Stochastic Frontier Analysis method was used to examine the effect of the international openness on the technical efficiency, technology progress and TFP growth, and impact of the human capital, international import and export, and FDI were examined using the technical effect model and Maximum Likelihood Estimation. An estimated result of the technical efficiency, technology progress and TFP growth of 28 states of the United States during 1985-2003 was calculated, and the effect of the four factors mentioned above on technology progress and TFP growth was checked using panel data series.

To compare the effects of these factors, Data Envelopment Analysis (DEA) method was used to recalculate technical efficiency, technology progress and AFP growth for 28 provinces of China during the same period, 1985 – 2003 using the same data series. Analytical results based on the two data sets calculated from SEA and DEA methods showed that on one hand, human capital, export, and FDI can promote the technical efficiency. However the effect of the import on the technical efficiency was negative, but the positive effect of FDI was larger than import by far. On the other hand the lagged effect of international import and export and FDI on the technical efficiency and technology progress was insignificant. As far as TFP growth was concerned, exports had a little negative impact on it and the positive effect of import was also weak, but it showed that human capital and FDI can promote the TFP growth largely, and the synthetic effect of international openness was positive and significant. With the data sets about the scale economy obtained from SFA and DEA, the effect of international openness on the scale economy was investigated based on the linear regression model. The empirical results showed that the exports from the United States did not bring the scale effect; however, the import limited scale effect and the effect of FDI was insignificant. Finally, the synthetic effect of international openness on scale economy was negative. (www.latest-science-articles.com).

In yet another study, a panel-data stochastic production frontier model was used to estimate technical inefficiency indices whose conditional mean was expressed as a function of FDI and its interaction with the degree of openness of the economy. Using maximum likelihood and an annual panel of 46 countries, of which 28 are developing and 18 are developed for the years 1981–2001, the translog frontier and the associated mean technical inefficiencies were jointly estimated. The findings suggested that increased in FDI, increased output in both developed and developing countries, but the effect was more profound in the developed economies than in the developing countries. It was also observed that increased in FDI, reduced technical inefficiencies in a more open or developed economies than in a close or developing economies. Thus, the findings support that productivity does not depend only on openness to international trade but also on the degree of development of the host country (Nourzad, 2008).

The relationship between trade and productivity has not been theoretically established, even though some researchers support the view that increasing openness has a positive impact on productivity. Mann (1998) found that increases in the import share of consumption are associated with increases in the trend of productivity growth in the manufacturing sector. Bernard and Jensen (1999) found that mainly through reallocation of resources from less efficient to more efficient plants, manufacturing exporters within the same industry do grow faster than non-exporters. Lawrence (2000) found that trade with developing countries boosts TFP growth in manufacturing industries with a relatively large share of imports from developing countries. Coe and Helpman (1995) also found that a country's TFP depends not only on its own R&D capital stock, but also on the R&D stock of its trade partners. Most recently, Keller and Yeaple (2003) found that there is some evidence for imports-related spillover of technology.

Nevertheless, neither theory nor empirical evidence on this subject is definitive so far. In one of his papers, Gordon (2000a) argues that openness to trade may have an adverse effect on productivity. One major potential benefit of trade liberalization is a resulting increase in the productivity of domestic firms (Nataraj, 2009). Having a clear understanding of whether trade liberalization affects firm productivity is important because increases in total factor productivity are linked to growth. Bosworth and Collins (2003) suggested that the entry and exit among small firms can contribute significantly to aggregate productivity changes.

In another setting, trade liberalization is seen as able to change the opportunity cost of leisure in such a way that managers work harder. That is, the return to entrepreneurial effort is increased by exposure to foreign competition, inducing managers to make an extra effort at eliminating inefficiency. Second, the existence of economies of scale implies that a widening of the market through trade should lead to reductions in real production costs, mainly in terms of increased demand through export expansion. The same argument holds for increased capacity utilization. Third, in a protected market dominated by several firms, trade modification will lead to increase competition and hence a reduction in monopolistic incompetence. The final angle to this is that the transformation is likely to accelerate the transition of state-of-the-art technologies since domestic producers are exposed to more foreign competition (Haddad, 1993).

An addition was made to the existing literature by examining the effect of international trade on productivity at a micro level using a unique unpublished Indonesian data set of establishment data. In line with the new theories on international trade and economic growth, the main focus was on examining the connection between the share of international trade and productivity growth. This was a follow up to a previous micro level studies, and set out to examine the connection between shares of inter-national trade and levels of productivity. The article also examined the effect on productivity of not only exports but also imports. New theoretical results suggest that knowledge transfers through both imports and exports increases productivity, but imports have, in general, been left out of empirical studies. One exception is Blomström et al. (1994), which examined growth in real per capita income from imports of capital equipment in 78 developing countries; this study found that imports had no effect. Levine and Renelt (1992) study used either exports or imports as a share of GDP to measure the degree of openness; they did not include both measures simultaneously in their regressions, which prevented a direct comparison of their effects. The result was that the two measures were highly correlated and their respective coefficients were of equal size. However, this could depend on the use of aggregated cross-country data, since countries' imports and exports are likely to be highly correlated. The use of disaggregated data was intended to help avoid all these problems.

The results from the econometric estimations above showed establishments participating in exports or imports to have relatively high levels of productivity. Moreover, there was a positive connection between exports and productivity growth. This suggested that participation in exports increased productivity growth, but a causality link also in the other direction was not left unconsidered. Some indications pointed to a positive growth effect from imports, but the result was delicate to changes in the specification of the variables and test equation (Sjoholm, 1997). The analysis revealed that international trade clearly raised economies of scale, but its impact on the technical efficiency of the manufacturing process was ambiguous. The increase in the scale of production induced firms to increase their spending on R&D, thereby creating adverse market structure effects. The sign of the technical efficiency effect depended on how the R&D intensity, defined as expenditures on R&D over variable manufacturing costs, changed. If the R&D intensity fell, the technical efficiency effect was positive and aggregate productivity clearly increased. But if the R&D intensity increased, the technical efficiency effect would be negative and aggregate productivity could fall. The main point was that while excessive investment in R&D clearly raised returns to scale at the firm level, it could also lower aggregate productivity through adverse market structure effects (Eckel, 2006).

Trade Liberalization and Trade Risk

Trade liberalization is argued to drive economic growths. Thirlwall (2000) argues that there is no denial that trade has been the engine of growth for many countries at different stages of development. He further argues that trade, in addition to providing more efficient allocation of resources within a country; also help transmit growth from one part of the world to another. Alacala and Ciccone (2003); and Chapoto etal. (2012) agree with Thirlwal that international trade has an economical significance and statistical robust effect on productivity, and that an increase in agricultural productivity increases households' specialization, income per capita, rural purchasing power, and encourages movement to high value activities.

However, despite argued beneficial relationship between international trade and productivity, the impact of trade liberalization has not been uniform cross the world and throughout time. Though some argue that trade liberalization is the best way countries can get what they are not able to produce or what is too expensive to produce in exchange for what they produce cheaply, trade benefit varied over time (Giovanne & Levchanko, 2006; Iyoha, 2005; Solarz & Morgan, 1994; Thirlwall, 2000; Wood, 1995). These anti-globalists argue that, though trade could raise productivity through technological transfer and improved high crop yield, the least developed countries such as the Sub-Saharan Africa are at disadvantage. According to these theorists, an introduction of free trade has caused variability in both prices and volume of trade, which resulted in whole new dimension of risk. In his study of the South Africa, Taljaard (2007) concluded, South African agriculturalists were always put at disadvantage and not prepared to manage the resulting external competition.

The variability in international trade affects productivity of the least developed trading partners that depend heavily on a few primary commodities for export and renders them less competitive in the world market. The variation, or risk in the international trade among trading partners, has long been a subject of interest and controversy in the international trade literature. Despite the economic benefits that nations reap from international trade, there is a risk associated with trade across regions. International trade variability poses risks, both to a country's exports and imports. The main exports risks facing developing countries as result of trade liberalization are heavy external trade dependence, high dependence on few exports commodities, declining terms of trades, and a low share of the world market (Iyoha, 2005). On the imports side, reducing trade barriers or liberalizing trade in order to boost global trading can negatively impact countries' economic well-being. Imports could compete with domestic goods and services or even replace them. Substitute of domestic products with cheap imports can result in loss of employment opportunities and income to rural communities (Edmondson et al., 1996). This is particularly true to the third world countries, such as the Sub-Saharan Africa countries that produce the highest unskilled, labor-intensive population.

Risks in the international trade are major barriers that impede nations' ability to attain the same economic growth level. Economists have differed on the real benefits of international trade and who benefits the most; economists argue that an increase in country's exports compared to its imports might be beneficial to that nation's economic growth, but higher imports compared to exports could threaten that nation's economy, especially the small economies countries. More imports compare to exports would mean a country would have less to pay for imports and would mean loss of employment and incomes, as more and cheap goods and services flood the domestic markets. The imbalance in trade has been a worry of policy makers, as they try to determine how to strike the right balance between free trade and trade balance (Ackah & Morrissey, 2005). Kanbur (1999) argues that although trade liberalization can help the least developed countries to access more production-enhancing technologies, it is to the unskilled workers' disadvantage. Kanbur (1999) argues that technical progress is biased against labor-intensive workers who are seen uneducated and less profitable. Davis (1996) in his study of trade liberalization and income distributions finds that countries with labor abundance will see wages decline as a result of trade openness compared to capital abundant, rich countries.

Trade liberalization does not equitably benefit all trading partners. The less developed countries such as Sub-Saharan African, gain the least due to their non-competitiveness in the world market and due to developed countries' heavy subsidization of their exports (Iyoha, 2005; Moussa, 2002; and Stevens, 2005).Wood (1995) argues, "The main cause of the deteriorating situation of unskilled workers in developed countries has been expansion of trade with developing countries." Though the study looks at unskilled workers in the developed countries, the reverse is true; developing countries produce the highest number of unskilled workers that could easily be affected by trade liberalization. Trade liberalization could open domestic market to less expensive goods and services that could replace locally produce goods, causing job to local workers. Expansions in trade could also lead to manual labor-replacing technologies and decreased demand for unskilled workers since they do not possess technical skill to operate the technologies. To anti-globalists, this risk or trade variability associated with trade liberalization, weighs more heavily on the least developed countries compare to the developed countries.

According to Nyangito's (2004) study of African agricultural export and access to international market, the two biggest hindrances to the African agricultural exporters are the developed countries heavy subsidies on their exports that distort market competitiveness and the continent's heavy dependence on few primary commodities. Nyangito look at Africa's share of world trade from 1948 – 2002, both in trade value and in percentage share, and finds that the continent's trade share in exports grew minimally from US$5.6 million – US$138 million, but in percentage, declined from 7.3% - 2.2%. However, in Europe, which is leading African trading partner, trade exports grew from 31.5% - 42.4%. The study also compared the continent's share of world market by commodities from 1992 – 2002. The study found, the two primary commodities (agricultural and mining) used to capture the continent's exports, account for 77% in 1992, and went down to 75% in 2002, while Latin American and Asian primary commodities exports, account for 40% and 20%, respectively in 2000. Ackah and Morrissey (2005)'s article titled "Trade Policy and Performance in Sub-Saharan Africa since the 1980s" compare the Africa's trade performance in the global market from 1990 – 2000 and found that the continent's exports declined from 3.1% to 2.3%. The study also found the Africa's overall trade balance declined by 24.5%, and agricultural trade balance decline by 20.9%.

Ng and Yeats' (undated), article investigates whether the recent trade and economic policies changes in the Sub-Saharan African countries have increased the regional global competition and their exports. The article's objective was to find out whether trade has a positive impact on industrialization and growth and if a high domestic trade barrier reduces a country's ability to benefit from trade and restricts a country from improving its economic growth. Imports statistics from OECD and other countries in the COMETRADE Database were used to reconstruct the African countries' profiles. Fourteen major African countries which represent 90 % of the Sub-Saharan exports in 1998 and whose exports exceed $1 million were used. Empirical evidence shows that the Sub-Saharan African's exports and imports in the 1990s dropped to 1.0% and 1.1% respectively compare to 3.1% of the world exports and 2.9% of the world's imports in 1950s. Authors concluded that African countries continue to be marginalized in the world market and that their share of market has decreased due to lack of competition.

Pro-globalists argue Sub-Saharan African countries export traditional commodities only to specific trading partners, and this exposes the region to the risks of monopoly and price volatility in the world market. They argue the best way to solve the continent's trade marginalization and improve its growth is to adopt trade-friendly policies that improve its comparative advantage; they call on the African governments to adopt policies that encourage trade liberalization in order to improve economic performances. This call is prompted by the empirical findings that show the continent's worsening exports performance compared to imports. These theorists conclude inappropriate trade and poor government's policies are responsible for the continent's poor trade performance.

Pingali (2006), investigate the factors that promote or constrain agricultural transformation, and if globalization helps or hinders agriculture growth in a given region. The article used qualitative methods to address the global trading role in agricultural growth of the LDC and concluded the least developed countries including the Sub-Saharan Africa region are the least beneficiaries of the global trading for two main reasons; first, low productivity makes them less competitive to the rest of the world, and second, availability of low priced goods in the world market makes the poor rural and agriculturally-based societies less competitive. The study argues globalization hurts the least developed countries more than it helps them due to their exports' lack of competitiveness in the world market. The article recommends that the low income countries need to improve domestic competitiveness through policies, institutional changes, and most importantly, more dramatic reduction in cost per production unit in order to benefit from trade liberalization.

CHAPTER 3. METHODOLOGY AND DATA

In this chapter, the theoretical stochastic frontier analysis (SFA) econometric model of the production function along with the technical efficiency equation are presented, building upon primal production theory. Specifically, the primal production function is estimated using stochastic frontier analysis that decomposes the error term into random error and one-sided error, i.e., technical efficiency. Following Fuss and McFadden (1987), the production function evaluates the relationship between exogenous inputs and endogenous output. In the technical efficiency equation, following Shaik and Mishra, (2010), the short-run and long-run trade openness risk or variability along with trade openness is evaluated.

Primal Production Function

Primal production theory assumes that the relationship between nonallocable exogenous input vector, $\mathbf{x}$, is used in the production of an endogenous output, y. The primal Cobb-Douglas production function[1] can be represented as:

$$y = f\left(\mathbf{x};\boldsymbol{\beta}\right) + \varepsilon \qquad \text{(Eq. 1)}$$

where y is the aggregate output, $\mathbf{x}$ is a vector of inputs used in the production function, and $\boldsymbol{\beta}$ is a vector of parameter coefficients associated with inputs. SFA was introduced by Aigner Lovell and Schmidt (1977). Meeusen and van den Brubeck (1977), and Bates and Corra (1977) simultaneously decomposed the error term, ε, into a symmetrical random error, v, and a one-sided error or technical inefficiency, u. Since 1977, the stochastic frontier analysis has been evolving theoretically with a surge in empirical application.

[1] Alternative flexible functional form like Translog production function is also estimated. However, the return to scale was not within the normal range and the likelihood ratio tested rejected in favor of Cobb-Douglas production function for Sub-Saharan African countries.

The stochastic frontier Analysis (SFA) model for Cobb-Douglas production function can be represented as:

$$y = f(\mathbf{x};\boldsymbol{\beta}) + v - u \qquad \text{(Eq. 2)}$$

where y is the output, $\mathbf{x}$ is a vector of inputs used in the production function, and $\boldsymbol{\beta}$ is a vector coefficients associated with inputs, $v \sim N(0,\sigma_v^2)$, represents the random error, and $u \sim N(0,\sigma_u^2)$ represents the one-sided technical efficiency or technical inefficiency (1-efficeincy).

In the last decade, progress has been made with stochastic frontier analysis models and research has investigated the influence of a broader set of determinants of technical efficiency, namely geographic variables, market structure conduct, and performance hypothesis (Shaik et al, 2007), financial risk (Shaik and Mishra, 2010), policy (Shaik, 2011) and size of the firm on inefficiency. In addition, the importance of trade openness on technical efficiency has been evaluated in the context of developed countries (Shaik and Miljkovic, 2010). Here, an extended stochastic frontier analysis model was used to estimate the importance of both trade openness and trade openness risk in the short-run and in the long-run on technical efficiency measures.

Stochastic Frontier Production Function and Trade Openness Model

Following Shaik and Mishra, (2010), equation 2 can be extended by introducing heterogeneity in the one-sided technical inefficiency, u as:

$$\begin{aligned} y &= f(\mathbf{x};\boldsymbol{\beta}) + v - u \\ \sigma_{\mathrm{u}}^2 &= \exp(\delta'\mathrm{z}) \end{aligned} \qquad \text{(Eq. 3)}$$

where σ_{u}^2 is the variance in the technical inefficiency term and modeled as a function of risk or variance in variables z. Here we defined the variances as a function of variance of short-run and long-run trade openness risk apart from trade openness.

Next, three alternative specifications of the extended stochastic frontier analysis (SFA) model or equation 3 with the production function equation and the one-sided technical efficiency equation are presented. This includes country fixed effects in the production function equation and one-sided technical efficiency equation, and trade openness in the technical efficiency equation. This is represented as:

$$\begin{aligned} y &= f\left(\alpha_i, \mathbf{x}; \boldsymbol{\beta}\right) + v - u \\ \sigma_{\mathrm{u}}^2 &= \exp\left(\alpha_i, \delta' Topen\right) \end{aligned} \qquad \text{(Eq. 4)}$$

where α_i represents one-way fixed effects related to country, i.e., $i-1$ country dummies in the production function equation.

The second extended SFA model includes country fixed effects in production function equation and one-sided technical efficiency equation. In addition, the one-sided technical efficiency equation includes trade openness and short-run trade openness risk or variation. This is represented as

$$\begin{aligned} y &= f\left(\alpha_i, \mathbf{x}; \boldsymbol{\beta}\right) + v - u \\ \sigma_{\mathrm{u}}^2 &= \exp\left(\alpha_i, \delta'\left(Topen, TopenSR\right)\right) \end{aligned} \qquad \text{(Eq. 5)}$$

Finally, in equation six below, in addition to trade openness and short-run trade openness risk, long-run trade openness risk is also included in the one-sided technical efficiency equation and is represented as

$$\begin{aligned} y &= f\left(\alpha_i, \mathbf{x}; \boldsymbol{\beta}\right) + v - u \\ \sigma_{\mathrm{u}}^2 &= \exp\left(\alpha_i, \delta'\left(Topen, TopenSR, TopenLR\right)\right) \end{aligned} \qquad \text{(Eq. 6)}$$

In the next chapter, the econometric estimation of the production function equation and the technical efficiency equation using extended stochastic frontier analysis is presented.

CHAPTER 4. SUB-SAHARAN AFRICAN AGRICULTURE OUTPUT, INPUT AND TRADE OPENNESS DATA

This study uses stochastic frontier analysis (SFA) to quantify the importance of trade openness and short-run and long-run trade openness risk. To estimate the extended SFA model data on output, input, export, import and gross domestic product, variables data was collected from the Food and Agriculture Organization (FAO), World Bank (WB), International Monetary Fund (IMF) and Penn table. The data was collected for 47 Sub-Saharan African countries from 1970 to 2009. But, due to missing data, only 31 out of 47 Sub-Saharan African countries were used in the analysis. Table 1 below shows the completed list of the 47 Sub-Saharan African countries on the left, and the list of the 31 countries used for the analysis on the right.

Four categories of inputs and one category of output are used to estimate the primal production function. The four inputs used include a) land variable (area harvested), excluding the area from which, although sown or planted, there was no harvest due to damage or failure, b) labor variable including farm population, a measure of hired and self-employed, and unpaid family labor, c) capital variable including capital stock, machinery and machinery archives used in agriculture production, and d) fertilizer variable which is a sum of nitrogen (N), phosphorous (P) and Potassium (K) expressed in thousands of metric tons. The output used in this analysis is the gross agriculture production index published by the Food and Agriculture Organization (FAO) which is the output from the agriculture sector. Detail on the construction of output and inputs variable is available on the Food and Agriculture Organization (FAO) webpage, http://www.fao.org

Table 1: Complete List of SSA Countries and the actual Countries Used in the Analysis

Complete List of SSA Countries		**Actual Countries Used in the Analysis**	
Angola	Madagascar	Angola	Seychelles
Benin	Malawi	Benin	South Africa Togo
Botswana	Mali	Burkina Faso	Sudan (former)
Burkina Faso	Mauritania	Burundi	Tanzania
Burundi	Mauritius	Cameroon	Togo
Cameroon	Mozambique	Congo	Uganda
Cape Verde	Namibia	Côte d'Ivoire	Zambia
Central African Rep	Niger	DRC	Zimbabwe
Chad	Nigeria	Gabon	
Comoros	Rwanda	Gambia	
Congo	Sao Tome and Principe	Ghana	
Côte d'Ivoire	Senegal	Guinea	
DRC	Seychelles	Kenya	
Equatorial Guinea	Sierra Leone	Madagascar	
Eritrea	Somalia	Malawi	
Ethiopia	South Africa	Mali	
Gabon	Sudan (former)	Mauritius	
Gambia	Swaziland	Mozambique	
Ghana	Togo	Namibia	
Guinea	Uganda	Niger	
Guinea-Bissau	Tanzania	Nigeria	
Kenya	Zambia	Rwanda	
Lesotho	Zimbabwe	Senegal	
Liberia			

The annual time-series data for the Sub-Saharan African countries was used to estimate the stochastic frontier analysis model. The other variables used in the technical efficiency equation included: exports, imports and GDP. These variables were used in the computation of trade openness (Topen), trade openness risk in the short-run (TopenSR) and trade openness risk in the long-run (TopenLR). Trade openness was computed as a ratio of exports plus imports (EXIM) divided by GDP. Each variable is defined in Table 2 below.

Table 2: Description of the Variables Used in the Estimation of the Stochastic Frontier Analysis (SFA) Model

Variables	Definitions
Output	Output (agriculture production in gross production index)
Land	The area in thousands hectares from which a crop is gathered excluding the area from which, although sown or planted, there was no harvest due to damage, failure
Labor	All those employed (thousands), including people above a specified age who, during the reference period, were in paid employment, at work, self-employed or with a job but not at work, and unemployed, including people above a specified age who, during the reference period, were without work, currently available for work and seeking work
Capital	Number of machinery and machinery archives and value of capital stock used in agriculture production in thousands
Fertilizer	Amount of fertilizer (metric tons) used in production; sum of three type of fertilizer (N, P and K)
Export plus Imports	Export and Import values in thousands (total sum of country agricultural exports and imports in current value of the US dollars)
GDP (Constant)	GDP (country total Gross Domestic Product in current value of the US dollar values)
Trade openness	Trade openness is defined as sum of agricultural exports and imports divided by total Gross Domestic Products (GDP)
Trade openness in Short-run	Trade openness risk in short-run (TopenSR) is defined as window rolling variation in trade openness for the last 5 years
Trade openness risk in long-run	Trade openness risk in long-run (TopenLR) is defined as cumulative rolling variation in trade openness starting with 5 years and cumulating

Table 3: Descriptive Statistics of Output for Sub-Saharan African Countries, 1970-2009

Country Name	Average	Standard Deviation	Minimum	Maximum
Low income	**271.75**	**149.81**	**60.49**	**1,044.29**
Benin	313.29	115.60	173.98	503.89
Burkina Faso	331.83	145.12	127.86	627.82
Burundi	169.19	25.57	131.50	225.58
DRC	119.88	10.32	103.87	140.36
Gambia	273.59	62.29	138.70	412.29
Guinea	254.85	135.40	112.39	510.36
Kenya	295.53	109.81	128.09	491.78
Madagascar	237.27	46.05	156.71	315.28
Malawi	330.74	142.69	165.89	715.25
Mali	274.96	141.84	130.53	615.92
Mozambique	182.13	55.81	121.49	343.51
Niger	375.77	216.29	147.81	879.52
Rwanda	403.77	215.27	166.56	1,044.29
Togo	198.95	65.19	115.85	322.15
Uganda	119.88	47.22	60.49	204.39
Tanzania	283.29	100.88	146.21	517.38
Zimbabwe	454.86	139.23	242.77	663.61
Low mid income	**352.40**	**192.47**	**128.08**	**1,175.02**
Cameroon	438.29	230.40	174.55	930.18
Congo	225.27	43.52	143.75	326.56
Côte d'Ivoire	435.37	145.46	186.39	653.59
Ghana	324.52	143.10	181.63	695.19
Nigeria	304.24	156.79	128.08	574.77
Senegal	313.91	110.14	164.18	565.21
Sudan	242.15	101.86	142.20	443.37
Zambia	535.45	276.71	163.70	1,175.02

Table 3: Descriptive Statistics of Output for Sub-Saharan African Countries, 1970-2009 (continued)

Country Name	Average	Standard Deviation	Minimum	Maximum
Upper mid income	**199.91**	**94.02**	**82.33**	**636.43**
Angola	140.84	28.51	110.96	227.32
Gabon	284.99	96.29	118.41	401.72
Mauritius	126.27	26.66	82.33	185.56
Namibia	295.74	121.82	163.89	636.43
Seychelles	176.01	29.07	108.28	218.15
South Africa	175.64	22.68	125.11	205.04
Grand Total	**278.66**	**161.78**	**60.49**	**1,175.02**

Tables 3 to 8 present the summary statistics of the dependent output variable, the four independent variables and the two additional independent variables, GDP and EXIM, used in the evaluation of trade openness and trade openness risk on technical efficiency measures. The summary statistics include the average, standard deviation, minimum and maximum.

Table 3 shows the average, standard deviation, minimum and maximum of the output index variable (output) for the 31 countries used in the analysis for the period 1970 to 2009. The table provides average, standard deviation, minimum and maximum values for individual country, by income group (low income, lower middle income and upper middle income) and by grand total. Under the low income countries, 10 of the 17 countries (Benin, Burkina Faso, Gambia, Kenya, Malawi, Mali, Niger, Rwanda, Tanzania and Zimbabwe) produced higher output than the total average for the low income countries while 7 countries in the group (Burundi, Democratic Republic of Congo, Guinea, Madagascar, Mozambique, Togo and Uganda) produced an output lower than the group overall average. But, out of the 17 low income countries, only two, Niger and Rwanda, have relatively higher deviation than the overall standard deviation for the low income group. Uganda produced the minimal output (60.49) while Rwanda produced the maximum output (1,044.29) among the low income countries.

For the lower middle income group, only 3 countries, Cameroon, Côte d'Ivoire and Zambia out of eight, produced above the group total average. Five countries (Sudan, Senegal, Nigeria, Ghana and Congo) produced below the group total average. On the variability, only 2 countries, Cameroon and Zambia, have higher deviation than the group total variability; the other six countries have lower deviation rate than the group average deviation value. Nigeria produced the minimal output (128.08) while Zambia produced the highest output (1,175.02) in the lower middle income group. For upper middle income group, only Gabon and Namibia out of the six upper middle income countries produced above the total group average and the same two countries have higher deviation than sum of the group deviation value. The other four countries in the group produced below the group average and deviate less than the group average deviation rate. Mauritius and Namibia produced the lowest (83.23) and the highest (636.43) outputs, respectively.

In the grand total of the output index variable, 16 countries out of the total 31 used for the analysis have higher averages than the grand total average; and only 4 (Niger, Rwanda, Cameroon and Zambia) have relatively higher deviation compared to the grand total average of all 31 countries combined. Thirteen countries produced at lower than grand total average and twenty five of them deviated less than the grand total standard deviation rate. The countries that produced minimal and maximal values in the region are Uganda (60.49) and Zambia (1,175.02), respectively.

Table 4 provides the average, standard deviation, minimum and maximum of the land index variable (land) broken down by income level (low, lower middle and upper middle) used in the analysis for the period 1970 to 2009. Under the low income group, only 7 countries out of the 17 low incomes group (Burkina Faso, DRC, Kenya, Mozambique, Niger, Tanzania and Uganda) allocated more land for agriculture production than the average of low income countries, and only one country (Niger) out of the 17 low incomes has relatively higher variation in land use than the low income average. In other words more than 50% of low income countries allocated less land to agriculture production than the group average and up to 94% of the group saw less variation in land used compared to the group variability average.

Table 4: Descriptive Statistics of Land for Sub-Saharan African Countries, 1970-2009

Country Name	Average	Standard Deviation	Minimum	Maximum
Low income	**3,206,436**	**2,492,447**	**114,604**	**16,044,574**
Benin	1,518,390	613,893	763,736	2,700,844
Burkina Faso	3,673,114	1,056,193	2,390,927	6,470,845
Burundi	1,037,647	114,269	807,357	1,180,412
DRC	5,669,447	801,060	4,276,127	7,327,054
Gambia	210,483	75,532	114,604	457,338
Guinea	1,798,304	661,373	1,099,500	3,136,771
Kenya	3,459,769	671,288	2,320,877	4,881,154
Madagascar	2,507,309	294,349	1,911,393	3,247,012
Malawi	2,447,659	504,417	1,809,848	3,592,672
Mali	2,980,175	1,092,511	1,557,434	5,056,078
Mozambique	3,536,919	973,059	2,692,550	6,277,798
Niger	8,499,626	3,620,918	3,719,169	16,044,574
Rwanda	1,251,235	338,329	747,233	1,811,299

Table 4: Descriptive Statistics of Land for Sub-Saharan African Countries, 1970-2009 (continued)

Country Name	Average	Standard Deviation	Minimum	Maximum
Togo	1,056,179	358,153	507,843	1,611,005
Uganda	5,426,641	1,015,573	3,643,300	7,243,866
Tanzania	6,926,171	2,052,015	4,532,520	12,014,114
Zimbabwe	2,510,337	377,151	1,814,529	3,254,215
Low mid income	**6,846,033**	**9,552,691**	**181,395**	**44,991,328**
Cameroon	3,494,420	583,278	2,812,359	5,440,417
Congo	224,228	31,221	181,395	308,768
Côte d'Ivoire	5,257,458	1,196,185	2,941,121	7,337,924
Ghana	4,108,832	1,141,133	2,682,850	6,285,061
Nigeria	28,971,956	10,298,505	13,878,366	44,991,328
Senegal	2,346,730	217,903	1,904,554	3,105,891
Sudan	9,217,050	2,908,366	4,831,611	15,635,924
Zambia	1,147,590	247,462	673,800	1,810,194
Upper mid income	**1,674,650**	**2,770,308**	**1,901**	**9,051,551**
Angola	2,030,895	590,651	1,489,900	4,047,271
Gabon	167,260	34,396	101,365	219,245
Mauritius	84,422	6,070	68,552	91,831
Namibia	236,306	60,737	149,400	358,382
Seychelles	6,432	3,758	1,901	16,238
South Africa	7,522,588	1,253,794	4,659,431	9,051,551
Grand Total	**3,849,212**	**5,642,863**	**1,901**	**44,991,328**

Gambia allocated the less land (114, 604 hectares) for agriculture production while Niger allocated most land (16,044, 574 hectares) for agriculture production among the low income countries. Among the lower middle income group, only 2 countries (Nigeria and Sudan) allocate more land than the total lower middle income average for agriculture production and only Nigeria among the lower middle income group sees higher variation in land use compare to the total lower middle income aggregate average. Congo allocated the least land (181, 395 hectares) to agriculture in the group while Nigeria allocated the most land (44, 991, 328 hectares) for agricultural production in the lower middle income group. And, for the upper middle income group, only Angola and South Africa out of six upper middle income groups allocated more land for agriculture production than the group total average, and no country in this group has seen higher land use variation than the group average. In this group, Seychelles allocated the least land (1,901 hectares) to agriculture production and South Africa allocated the most hectares of land (9, 051,551) for agriculture production among the upper middle income group.

In the grand total of the land index variable, only 9 countries (South Africa, Nigeria, Ghana, Côte d'Ivoire, Sudan, Tanzania, Uganda, Niger and DRC) out of the total 31 countries used for the analysis have allocated more land than the grand total average; but only one country (Nigeria), out of the 31 countries has seen higher variation than grand total average in land use. Seychelles allocated the minimal land (1,901 hectares) for agriculture production and Nigeria allocated the maximal hectares of land (44, 991,328) for agriculture production among the 31 Sub-Saharan Africa countries used for this analysis.

Table 5: Descriptive Statistics of Labor for Sub-Saharan African Countries, 1970-2009

Country Name	Average	Standard Deviation	Minimum	Maximum
Low income	**4,087**	**3,308**	**193**	**16,453**
Benin	1,093	308	712	1,584
Burkina Faso	3,978	1,266	2,409	6,682
Burundi	2,415	601	1,599	3,660
DRC	9,519	2,555	5,504	13,951
Gambia	353	124	193	588
Guinea	2,618	675	1,911	3,760
Kenya	8,068	2,854	4,066	12,971
Madagascar	4,257	1,299	2,564	7,022
Malawi	3,206	839	1,893	4,767
Mali	2,066	415	1,527	2,978
Mozambique	5,944	1,271	4,263	8,502
Niger	2,416	809	1,378	4,101
Rwanda	2,644	744	1,586	4,232
Togo	898	218	574	1,270
Uganda	6,713	2,074	3,725	10,720
Tanzania	10,686	3,182	6,129	16,453
Zimbabwe	2,604	630	1,521	3,295
Low mid income	**3,965**	**3,481**	**344**	**12,870**
Cameroon	2,978	480	2,236	3,568
Congo	443	55	344	521
Côte d'Ivoire	2,435	501	1,464	2,949
Ghana	3,755	1,126	2,241	5,921
Nigeria	12,289	615	10,510	12,870
Senegal	2,390	649	1,516	3,714

Table 5: Descriptive Statistics of Labor for Sub-Saharan Africa Countries, 1970-2009 (continued)

Country Name	Average	Standard Deviation	Minimum	Maximum
Sudan	5,319	987	3,572	7,014
Zambia	2,109	618	1,230	3,137
Upper mid income	**920**	**1,335**	**22**	**5,718**
Angola	3,504	1,060	2,209	5,718
Gabon	208	10	186	233
Mauritius	77	16	50	100
Namibia	209	40	141	265
Seychelles	25	3	22	30
South Africa	1,494	134	1,221	1,655
Grand Total	**3,442**	**3,315**	**22**	**16,453**

Table 5 provides the average, standard deviation, minimum and maximum of the labor index variable (Labor) broken down by income level (low, lower middle and upper middle) used in the analysis for the period 1970 to 2009. Under the low income group, only six countries out of 17 (DRC, Kenya, Madagascar, Mozambique, Tanzania and Uganda) have the highest labor force in agriculture than the group total average, and no country in this income group has seen variation above the group total average. About 65% of the low income countries employed less work force in agriculture than the group average and up to 100% of the group sees less variation in labor use compare to the group overall variability rate. Gambia used the less labor force (193 thousands) in agricultural production while Tanzania allocated the most labor force (16,543 thousands) in agricultural production among the low income countries.

For the lower middle income group, only Nigeria and Sudan allocate more workforces (labor) to agriculture than the group total average and no country in this group has seen higher variation in labor force above the group total average. Congo allocated the least labor (344 thousands) to agriculture production in the group while Nigeria allocated the most labor (12,870 thousands) toward agriculture production in the group. And, for the upper middle income group, Angola and South Africa in this group allocated more labor for agriculture production than the group total average, and no country has seen labor variability above the group total average. In this group, Seychelles allocated the least labor force (22 thousands) in agricultural production while Angola allocated the most labor force (5,718 thousands) toward agricultural production in the upper middle income group.

For the grand total labor index variable, 11 countries (Angola, Nigeria, Ghana, Sudan, Tanzania, Uganda, Mozambique, Madagascar, Burkina Faso, Kenya and DRC) out of the total 31 used for the analysis have allocated more workforces (labor) toward agricultural production than the grand total average; but none of the 31 countries has seen variability in labor force above the group grand total average. Seychelles used the least workface (22 thousands) in the agricultural section while Tanzania allocated the most workforces (16,543 thousands) toward the agricultural production in Sub-Saharan Africa region.

Table 6: Descriptive Statistics of Capital for the Sub-Saharan African Countries, 1970-2009

Country Name	Average	Standard Deviation	Minimum	Maximum
Low income	**6,254.59**	**5,619.79**	**202**	**21,916**
Benin	2,023.18	562.53	1,232	2,960
Burkina Faso	5,570.10	2,547.44	1,948	10,187
Burundi	1,285.20	296.77	455	1,687
DRC	4,980.48	590.91	3,467	5,784
Gambia	297.68	242.37	202	1,759
Guinea	2,938.60	1,209.84	1,399	5,404
Kenya	15,390.25	2,440.69	11,008	18,619
Madagascar	16,556.58	1,882.47	12,133	19,436
Malawi	2,046.38	505.73	1,305	3,128
Mali	7,691	2,478.26	4,021	12,655
Mozambique	3,644.03	866.74	2,111	4,958
Niger	8,841.15	2,271.67	4,717	13,109
Rwanda	1,384.30	297.36	9,63	2,009
Togo	1,267.90	306.17	8,19	1,776
Uganda	6,123.05	1,527.05	3,313	8,738
Tanzania	17,560.28	2,657.15	13,178	21,916
Zimbabwe	8,727.88	622.86	6,916	9,787
Low mid income	**13,090.65**	**15,384.18**	**419**	**60,932**
Cameroon	5,953.60	1,391.44	2,346	7,431
Congo	521.20	65.53	419	636
Côte d'Ivoire	5,963.93	1,685.53	2,545	8,070
Ghana	4,931.25	1,125.81	3,729	7,216
Nigeria	41,402.10	11,747.74	15,930	60,932
Senegal	8,201.43	1,594.63	5,408	10,571

Table 6: Descriptive Statistics of Capital for the Sub-Saharan African Countries,1970-2009

Country Name	Average	Standard Deviation	Minimum	Maximum
Sudan	33,127.68	1,1032.08	12,363	54,466
Zambia	4,624.05	994.44	2,699	5,993
Upper mid income	**8,754.24**	**15,720.87**	**9**	**46,677**
Angola	5,996.55	516.64	4288	6,691
Gabon	404.65	61.28	241	467
Mauritius	244.60	24.01	204	282
Namibia	2,369.13	220.70	1,977	2,928
Seychelles	14.05	1.84	9	16
S. Africa	43,496.48	1,590.30	39,084	46,677
Grand Total	**8,502.54**	**11,581.85**	**9**	**60,932**

Table 6 provides the average, standard deviation, minimum and maximum of the capital index variable (capital) grouped by individual country, income level (low, lower middle and upper middle) grand total of 31 countries used in the analysis of this thesis for a period 1970 to 2009. Under the low income group, only 5 countries out of the 17 (Kenya, Madagascar, Niger, Tanzania and Zimbabwe) allocated more capital to agricultural production than the group total average, and no country in the group has variability in capital allocation higher than the group overall variation average. Gambia allocated the least capital (202 thousands) toward agricultural production while Tanzania allocated the highest capital (21,916 thousands) toward agricultural production among the low income countries.

In the lower middle income group, only Nigeria and Sudan used more capital toward agricultural production above the group total average and no country in this group has seen higher variability in capital use above to the group total average. Congo allocated the least capital (419 thousand) toward agricultural production while Nigeria allocated the most capital (60,932 thousand) in agricultural production in the lower middle income group. And for the upper middle income group, only South Africa allocated more capital for agriculture production above the group total average, and no country in the group has seen higher variation in capital use above the group average. In this group, Seychelles allocated the least capital (9 thousand) for agricultural production and South Africa allocated the most capital (46,677 thousand) toward agricultural production among the upper middle income group.

In the grand total for the capital index variable, only 8 countries (South Africa, Nigeria, Kenya, Zimbabwe, Madagascar, Sudan, Tanzania, and Niger) out of the total 31 countries used for the analysis allocated higher capital above the region grand total average; but only one country (Nigeria) in the Sub-Saharan Africa region has seen higher variation in capital use above the region grand total average. Seychelles allocated the least capital (9 thousand) toward agricultural production while Nigeria allocated the highest capital (60,932 thousand) for agricultural production among the 31 Sub-Saharan Africa countries used for the analysis.

Table 7 provides the average, standard deviation, minimum and maximum of the fertilizer index variable (fertilizer) used to produce agriculture output. The table is grouped by individual country, income level (low, lower middle and upper middle) and by the grand total of all 31 countries used in the analysis for the period 1970 to 2009. Under the low income group, only 4 out of the 17 countries (Kenya, Mali, Tanzania and Zimbabwe) applied more fertilizer in agricultural production above the group total average, and only one country (Mali) in the group has seen higher variability in fertilizer use above the group overall average. Thirteen out of seventeen countries in this group used less fertilizer in their agriculture production compare to the group total average, and 94% of this income group has seen lower variability in fertilizer use below the group overall variability average use. Rwanda and Mali used the least (976) and the most (132,876) metric tons of fertilizer compare to low income group average, respectively.

Table 7: Descriptive Statistics of Fertilizer for Sub-Saharan African Countries, 1970-2009

Country Name	Average	Standard Deviation	Minimum	Maximum
Low income	**37,765**	**61,860**	**16**	**311,060**
Benin	11,050	12,913	33	49,463
Burkina Faso	25,091	21,425	688	74,694
Burundi	1,255	799	277	3,390
DRC	1,460	1,157	130	6,347
Gambia	4,913	3,339	1,033	13,746
Guinea	1,607	1,044	148	3,830
Kenya	104,303	46,529	37,306	192,895
Madagascar	7,229	2,508	4,026	16,352
Malawi	34,343	36,910	4,664	125,156
Mali	132,876	87,936	13,622	311,060
Mozambique	14,110	12,632	1,709	61,653
Niger	4,608	3,822	270	17,149
Rwanda	976	2,271	16	10,753
Togo	7,025	5,496	314	20,336
Uganda	3,448	4,177	105	18,976
Tanzania	123,535	55,653	31,818	221,137
Zimbabwe	164,180	36,602	85,018	219,158
Low middle income	**57,439**	**68,466**	**26**	**427,110**
Cameroon	52,386	18,960	20,455	87,588
Congo	12,938	12,381	26	41,791
Côte d'Ivoire	43,034	19,598	16,314	87,650

Table 7: Descriptive Statistics of Fertilizer for Sub-Saharan African Countries, 1970-2009 (continued)

Country Name	Average	Standard Deviation	Minimum	Maximum
Nigeria	186,599	116,263	6,387	427,110
Senegal	25,261	11,451	6,116	50,913
Sudan	54,620	24,542	9,599	158,470
Zambia	67,977	19,985	32,430	117,980
Upper mid income	**159,574**	**286,868**	**11**	**1,071,167**
Angola	36,251	29,172	4,304	115,969
Gabon	4,296	4,488	127	16,921
Mauritius	30,357	5,690	18,222	42,760
Namibia	2,076	1,022	229	3,185
Seychelles	379	314	11	1,262
South Africa	718,314	111,997	484,546	1,071,167
Grand Total	**63,152**	**137,391**	**11**	**1,071,167**

In the lower middle income group, only Nigeria and Zambia used more fertilizer than the group total fertilizer average for agricultural production; but only Nigeria among the eight members of lower middle income has seen higher variability in fertilizer use above the group total variability average. Congo applied the least fertilizer (26 metric tons) toward agriculture production while Nigeria applied the most fertilizer (427,110 metric tons) in its agricultural production among in the group. And for the upper middle income group, only South Africa applied more fertilizer above the group total fertilizer average use toward agriculture production; all members of the group have seen lower variability in fertilizer use below the group variability average. Seychelles applied the least fertilizer (11 metric tons) toward agricultural production while South Africa applied the most fertilizer (1,071,167 metric tons) for agricultural production among the upper middle income group.

And for the grand total of the fertilizer index variable, only 7 countries (South Africa, Nigeria, Kenya, Zimbabwe, Zambia, Mali, and Tanzania) out of the total 31 countries used for the analysis applied more fertilizer above the region grand total average; however, no country in the region has seen higher variation in fertilizer use above the region grand total variability average. Seychelles applied the least fertilizer (11 metric tons) toward agricultural production while South Africa applied the highest fertilizer (1,071,167 metric tons) toward its agricultural production among the Sub-Saharan Africa countries.

Table 8 provides the average, standard deviation, minimum and maximum of the exports and imports index variable (EXIM) used to measure output. The table is broken down by individual country, income level (low, lower middle and upper middle) and by the grand total for the 31 Sub-Saharan African countries used in this analysis for the period 1970 to 2009.

Table 8: Descriptive Statistics of EXIM for Sub-Saharan African Countries, 1970-2009

Country Name	Average	Standard Deviation	Minimum	Maximum
Low income	**370,536**	**418,720**	**16,594**	**4,096,234**
Benin	299,160	272,584	43,085	1,093,754
Burkina Faso	237,283	166,966	31,387	676,283
Burundi	93,021	39,799	23,804	183,739
DRC	399,485	177,824	175,584	1,068,913
Gambia	83,458	41,753	19,777	174,136
Guinea	165,042	116,159	28,820	465,968
Kenya	1,285,272	907,177	227,267	4,096,234
Madagascar	292,753	107,637	135,516	594,321

Table 8: Descriptive Statistics of EXIM for Sub-Saharan African Countries, 1970-2009

Country Name	Average	Standard Deviation	Minimum	Maximum
Malawi	410,191	262,582	67,277	1,318,116
Mali	343,476	176,745	58,676	763,873
Mozambique	331,267	221,816	147,204	1,024,184
Niger	179,009	94,018	22,535	432,271
Rwanda	117,181	61,714	16,594	350,231
Togo	187,244	124,937	43,314	633,744
Uganda	478,124	297,685	178,691	1,507,387
Tanzania	601,246	323,822	214,846	1,600,207
Zimbabwe	795,896	454,702	138,402	2,291,342
Low middle income	**976,180**	**1,057,818**	**20,345**	**6,439,587**
Cameroon	701,675	341,397	178,785	1,769,550
Congo	130,197	95,713	20,345	437,550
Côte d'Ivoire	2,450,380	1,285,496	412,527	6,439,587
Ghana	927,879	674,991	288,732	2,812,612
Nigeria	1,956,974	1,322,952	502,959	5,876,066
Senegal	600,267	391,804	144.077	2,039,935
Sudan	857,892	387,188	362,870	2,151,478
Zambia	184,177	182,376	50,832	637,903
Upper middle income	**875,457**	**1,520,507**	**4,521**	**10,327,619**
Angola	678,503	492,503	324,855	2,611,663
Gabon	158,234	106,020	17,220	474,854
Mauritius	535,823	244,502	89,263	1,118,088
Namibia	330,802	140,481	153,885	707,632
Seychelles	38,394	27,775	4,521	107,122
South Africa	3,510,988	2,236,349	828,512	10,327,619
Grand Total	**624,558**	**953,777**	**4,521**	**10,327,619**

Under the low income group, six countries (DRC, Kenya, Malawi, Tanzania, Uganda and Zimbabwe) trade above the group total average, but only two countries (Kenya and Zimbabwe) in this group have seen higher variability in trade above the group overall average variability. More than 64% of the low income countries are trading below group average and 88% of the low income group have seen lower variability in trade below the group overall average variability. Rwanda has seen the least trade (16,594) in goods and services while Kenya has seen the highest trading volume (4,096,234) in goods and services in the among the low income Sub-Saharan African countries.

For the lower middle income group, only Nigeria and Côte d'Ivoire have seen trade volume above the group total trading average; the same two countries have seen higher agricultural trading variability above the group total average variability. Congo has seen the lowest agricultural trade volume (20,343) while Côte d'Ivoire realized the highest agricultural trade volume (6,439,587) among the lower middle income group. And for the upper middle income group, only South Africa has seen higher agricultural trading volume (3,510,988) above the group trading average volume; also only South Africa has seen the highest variability in agricultural trade volume above the group average variability. Seychelles and South Africa have seen the least (4,521) and the highest (10,327,619) agricultural trade volume among upper middle income group, respectively.

And for the grand total value for the exports and imports index variable, 9 countries (South Africa, Angola, Nigeria, Zimbabwe, Cameroon, Côte d'Ivoire, Ghana, Kenya and Tanzania) out of the total 31 countries used for the analysis have seen higher agricultural trade volume above the region grand total average; but only three countries (South Africa, Nigeria and Côte d'Ivoire) have seen higher variability in their agricultural trade volume above the region grand total average variability. Seychelles trade the least agricultural produce (4,521) while South Africa traded the highest agricultural produce (10,327,619) in the region.

Table 9 provides the average, standard deviation, minimum and maximum of the gross domestic product index variable (GDP) used to measure the Sub-Saharan African region productivity. The gross domestic product table measures the productivity of the total value of goods and services for individual country, countries by income level (low, lower middle and upper middle) and the grand total of the 31 countries used in the analysis over the period, 1970 to 2009. Under the low income group, only seven countries (Burundi, DRC, Kenya, Tanzania, Uganda and Zimbabwe) out of seventeen have seen higher average gross domestic product value above the group overall average gross domestic product, and only two countries (Kenya and Tanzania) in the group have seen higher average variability in gross domestic product above the group average variability. Almost 60% of the region low income countries have gross domestic product value of less than the average GDP. Also, about 88% of the group have seen lower variability in their GDP value compare to the group overall average variability. Gambia has the least GPD (52,296,084) while Kenya has the highest GDP (30,580,367,979) among the low income Sub-Saharan African countries.

For the lower middle income countries, only Nigeria and Sudan have seen average gross domestic product value greater than the group overall average; but only Nigeria has seen higher average variability in gross domestic product above the group total average variability.

Table 9: Descriptive Statistics of GDP for Sub-Saharan African Countries, 1970-2009

Country Name	Average	Standard Deviation	Minimum	Maximum
Low income	**3,687,940,533**	**3,808,677,148**	**52,296,084**	**30,580,367,979**
Benin	2,096,886,850	1,603,077,777	333,627,713.30	6,633,561,835
Burkina Faso	2,682,487,290	1,940,054,425	458,404,268.60	8,350,710,389
Burundi	896,225,905	353,158,829	242,732,571.40	1,815,182,228
DRC	8,607,609,562	3,010,061,669	4,305,296,502	15,372,607,995
Gambia	442,675,609	302,934,222	52,296,084	965,771,303
Guinea	2,547,260,983	935,559,181	1,288,335,796	4,209,332,040
Kenya	10,070,771,433	7,316,645,020	1,603,447,357	30,580,367,979
Madagascar	3,577,582,005	1,753,946,503	1,111,859,570	9,394,896,990
Malawi	1,692,834,504	1,056,438,889	290,520,116	5,030,639,934
Mali	2,565,665,829	2,093,332,003	359,772,315	8,964,480,933
Mozambique	3,934,160,427	1,933,704,553	1,968,901,450	9,891,003,405
Niger	2,128,337,605	1,067,240,540	646,858,208	5,369,911,346
Rwanda	1,724,549,314	1,102,159,355	219,900,007	5,252,677,065
Togo	1,280,965,013	688,923,361	25,3976,592	3,163,416,556
Uganda	4,964,904,929	3,480,789,639	1,244,610,000	15,803,499,657
Tanzania	7,428,911,671	4,700,830,154	3,226,207,906	21,368,165,400
Zimbabwe	6,053,160,134	1,789,781,079	1,884,206,350	8,783,816,666
Low middle income	**12,941,034,207**	**22,565,278,706**	**274,960,700**	**207,116,000,000**
Cameroon	9,627,406,788	5,594,529,423	1,160,002,329	23,735,537,026
Congo	2,795,811,453	2,554,277,577	274,960,700	11,859,015,181
Côte d'Ivoire	10,051,866,109	5,198,472,733	1,455,482,795	23,414,253,327
Ghana	7,117,000,087	6,367,896,734	2,112,593,380	28,528,046,011
Nigeria	50,541,545,737	46,164,847,428	9,181,769,912	207,116,000,000
Senegal	4,837,603,165	2,966,421,968	1,024,832,778	13,386,346,544

Table 9: Descriptive Statistics of GDP for Sub-Saharan African Countries, 1970-2009 (continued)

Country Name	**Average**	**Standard Deviation**	**Minimum**	**Maximum**
Sudan	14,382,099,291	12,331,224,931	2,100,229,759	53,621,081,452
Zambia	4,174,941,026	2,993,013,413	1,653,259,297	14,640,792,101
Upper middle income	**23,528,166,456**	**52,313,974,193**	**18,432,031**	**286,172,000,000**
Angola	12,592,080,061	18,030,910,108	907,212,672.6	79,620,700,694
Gabon	4,685,254,816	2,993,479,296	323,802,475.5	14,534,823,245
Mauritius	3,066,677,545	2,478,819,463	419,306,943.9	9,641,063,862
Namibia	3,297,610,737	2,206,027,153	1,355,065,230	8,859,203,056
Seychelles	391,911,216	314,584,573	18,432,031	1,033,635,773
South A	117,135,000,000	74,526,359,114	17,907,392,934	286,172,000,000
Grand Total	**9,915,879,402**	**26,953,760,276**	**18,432,031**	**286,172,000,000**

Congo has the lowest average gross domestic product (274,960,700), while Nigeria has the highest average gross domestic product (207,116,000,000) among the lower middle income group. And for the upper middle income group, only South Africa has seen higher average gross domestic product (117,135,000,000) above the group overall average gross domestic product. Seychelles has the lowest gross domestic product (18,432,031), while South Africa has the highest gross domestic product (286,172,000,000) and highest variability (74,526,359,114) in gross domestic product compare to other countries in Sub-Saharan Africa region.

Finally, for the grand total, six countries (South Africa, Angola, Nigeria, Côte d'Ivoire, and Kenya) have gross domestic product value greater than the grand total average; but only South Africa and Nigeria have higher variability above the grand total average variability. Seychelles has the lowest gross product (18,432,031) while South Africa has the highest GDP (286,172,000,000) among the 31 Sub-Saharan African countries used for the analysis.

CHAPTER 5. EMPIRICAL APPLICATION AND RESULTS

Empirical Analysis

The theoretical methodology presented in Chapter 3 estimates both the impact of trade openness and trade openness risk on technical efficiency for 31 Sub-Saharan African countries from 1970 to 2009. In addition, the primal production function helps evaluate the role of input factors on agriculture production for 31 Sub-Saharan African countries. The effect of trade openness on technical efficiency, and the extent of trade openness risk or variation in the short-run and long-run are examined. Table 10 summarizes the minimal, median, mean, and maximal values for the output, four inputs, GDP, EXIM, trade openness (Topen), trade openness short-run risk (TopenSR) and trade openness long-run risk (TopenLR) used in this analysis.

Table 10: Summary Statistics of the Variables Used in the Analysis for Sub-Saharan African Countries, 1970 - 2009

Variables	Minimum	Median	Mean	Maximum
Output	60.49	224.06	278.66	1175.02
Land	0.002	2.479	3.849	44.991
Labor	22.3	2,583.50	3,442.40	16,453.00
Capital	9	4,860	8,503	60,932
Fertilizer	11	14,867	63,152	1,071,167
GDP (Billions)	0.018	3.331	9.916	286.2
EXIM (millions)	0.005	0.334	0.625	10.277
Topen	1.442	9.612	11.428	66.647
TopenSR	0	1.481	2.078	23.338
TopenLR	0	2.713	3.525	25.957

The extended stochastic frontier analysis model includes two equations: the primal production function equation and the technical efficiency equation. The following four models are estimated:

1) Traditional primal production function with output, four inputs, technology and individual country dummies

2) Stochastic frontier analysis with the production function equation includes output, four inputs, technology (trend) and individual country dummies. The technical efficiency equation includes technical inefficiency as endogenous variable with trade openness (Topen), technology (trend) and individual country dummies as exogenous variables.

3) Stochastic frontier analysis with the production function equation includes output, four inputs, technology (trend) and individual country dummies. The technical efficiency equation includes technical inefficiency as endogenous variable with trade openness (Topen), short-run trade openness risk (TopenSR), technology (trend) and individual country dummies as exogenous variables.

4) Stochastic frontier analysis with the production function equation includes output, four inputs, technology (trend) and individual country dummies. The technical efficiency equation includes technical inefficiency as endogenous variable with trade openness (Topen), short-run trade openness risk (TopenSR), long-run trade openness risk (TopenLR), technology (trend) and individual country dummies as exogenous variables.

The regression results of the four models are presented in Tables 11, 12, 13 and 14. Regression results in each table include parameter coefficient, standard error, Z-value and probability value.

Agriculture Production Function

The production frontier is estimated using gamma simulated maximum likelihood estimation of stochastic frontier function using the Sub-Saharan African regional level data. The production frontier function with four main inputs is represented as:

$$Output_{it} = \beta_0 + \beta_1 land_{it} + \beta_2 labor_{it} + \beta_3 capital_{it} + \beta_4 fertilizer_{it} + \beta_t trend + \alpha_{i-1} Cdum_{i-1} + \varepsilon_{it} \quad \text{(Eq. 7)}$$

Since the input and output variables are estimated in logarithmic form, the parameter coefficient represents input elasticities. Table 11 below presents detailed representation of the parameters coefficient, standard errors, Z-value and probability for each variable used in the analysis.

Table 11: Regression Results of Primal Production Function for Sub-Saharan African Countries, 1970 – 2009

Variable	Estimate	Std. Error	Z-value	pr (>/z/)
Intercept	-6.27	0.407	-15.391	<2.2e-16***
Land	0.395	0.028	14.019	<2.2e-16***
Labor	0.229	0.038	6.071	1.268e-09***
Capital	0.378	0.365	10.358	<2.2e-16***
Fertilizer	0.028	0.005	5.334	9.627e-08***
Trend	0.009	0.001	9.602	<2.2e-16***

Significant. Codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1**

Based on the table above, all four inputs (land, labor, capital and fertilizer) and technology (trend) showed positive effect on the Sub-Saharan African agricultural production and all five variables were highly significant at greater than 99 percent confidence interval. Land had the highest influence on agricultural production, followed by capital, labor, fertilizer and technology in that order. This means, a one percent increase in land, holding the other four variables' effects constant, would increase Sub-Saharan Africa's output by 0.395 percent. Similarly, a one percent increase in labor, capital, fertilizer or technology would increase Sub-Saharan Africa's output by 0.229, 0.378, 0.028 and 0.009 percent, respectively. Next, the three remaining regressions results presented are from the extended stochastic frontier analysis that includes production function equation and technical efficiency equation.

Stochastic Frontier Analysis of Agriculture Production Function

With Trade Openness in the Technical Efficiency Model

The first of the three stochastic frontier analyses includes a production function similar to equation (7) and a technical efficiency equation that includes trade openness, trend and individual country dummies. The extended stochastic frontier analysis model is represented as:

$$\begin{aligned} Output_{it} &= \beta_0 + \beta_1 land_{it} + \beta_2 labor_{it} + \beta_3 capital_{it} \\ &\quad + \beta_4 fertilizer_{it} + \beta_t trend + \alpha_{i-1} Cdum_{i-1} + v_{it} - u_{it} \qquad \text{(Eq. 8)} \\ u_{it} &= \delta_0 + \delta_1 Topen_{it} + \delta_t trend + \alpha_{i-1} Cdum_{i-1} + \varepsilon_{it} \end{aligned}$$

Where Cdum represents the individual country dummy, Topen represents trade openness, and ε represents the error term.

The results of equation (8) are presented next. Table 12 shows the variables from the technical efficiency function and production function equation. Under the technical efficiency equation, trade openness is regressed with technology (trend) to measure the impact of trade openness on technical inefficiency measure. All five variables from the production equation, (land, labor, capital and fertilizer and technology) showed positive impact on output and all five were highly significant at greater than 99 percent confidence interval. Capital had the highest impact on agriculture output, followed by labor, land, fertilizer and technology. For the technical efficiency equation, a one unit change in trade openness would lead to decreases in technical inefficiency measures, -0.007, or 0.7 percent increase in technical efficiency level. A one unit change in technology would lead to 0.003 increases in technical inefficiency measures, or a 0.3 percent decrease in technical efficiency level.

Table 12: Regression Results of Stochastic Frontier Analysis Including Trade Openness for Sub-Sahara Africa Countries, 1970 – 2009

Variable	Estimate	Std. Error	Z-value	pr (>/z/)
		Production function equation		
Intercept	-3.806	0.363	-10.393	<2.2e-16***
Land	0.273	0.036	7.672	1.690e-14***
Labor	0.278	0.037	7.615	2.644e-14***
Capital	0.307	0.029	10.578	<2.2e-16***
Fertilizer	0.014	0.003	4.120	3.791e-05***
Trend	0.013	0.001	15.610	<2.2e-16***
		Technical efficiency equation		
Intercept	0.567	0.107	5.302	1.15e-07***
Topen	-0.007	0.002	-3.031	0.002***
Trend	0.003	0.002	1.486	0.137
Significant. Codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1**				

The impacts of trade openness and technology (trend) on technical efficiency measure showed mixed effects; trade openness showed positive impact on technical efficiency while technology showed negative effects on technical efficiency measures. However, only trade openness was highly significant, and technology was insignificant even at a 95 percent confidence interval.

With Trade Openness and Short-run Trade Openness Risk in the Technical Efficiency Model

Stochastic frontier model along with short-run trade openness risk is defined as:

$$\begin{aligned} Output_{it} &= \beta_0 + \beta_1 land_{it} + \beta_2 labor_{it} + \beta_3 capital_{it} \\ &\quad + \beta_4 fertilizer_{it} + \beta_t trend + \alpha_{i-1} Cdum_{i-1} + v_{it} - u_{it} \\ u_{it} &= \delta_0 + \delta_1 Topen_{it} + \delta_2 TopenSR_{it} + \delta_t trend \\ &\quad + \alpha_{i-1} Cdum_{i-1} + \varepsilon_{it} \end{aligned} \quad \text{(Eq. 9)}$$

Where Cdum represents the individual country dummy, Topen represents trade openness, TopenSR represents the short-run trade openness risk, and ε represents the error term.

Table 13: Regression Results of Stochastic Frontier Analysis Including Trade Openness and Short-run Trade Openness Risk for Sub-Saharan African Countries, 1970 – 2009

Variable	Estimate	Std. Error	Z-value	pr (>/z/)
		Production function equation		
Intercept	-3.703	0.290	-12.774	<2.2e-16***
Land	0.246	0.025	9.784	<2.2e-16***
Labor	0.295	0.034	8.562	<2.2e-16***
Capital	0.321	0.028	11.500	<2.2e-16***
Fertilizer	0.012	0.003	3.874	0.000***
Trend	0.012	0.001	17.238	<2.2e-16***
		Technical efficiency equation		
Intercept	0.529	0.080	6.585	4.546e-11***
Topen	-0.010	0.003	-3.932	8.409e-05***
TopenSR	0.009	0.005	1.976	0.048*
Trend	0.001	0.001	0.620	0.535
Significant. Codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1**				

Table 13 shows two equations (production and technical efficiency). Four inputs (land, labor, capital and fertilizer) and technology (trend) used for the production equation and two variables; trade openness and trade openness risk in short run, with trade openness in short run regressed with technology. For the production function, all variable coefficients showed positive effect on the Sub-Saharan African production and all five variables were highly significant at greater than 99 percent confidence interval. Capital had the highest effects on production (0.321), followed by labor (0.2945), land (0.2461), fertilizer (0.01248) and technology (0.01247). The results showed, a one unit change in capital, labor, land, fertilizer, or technology, holding other variables' effects constant, would lead to 0.3207, 0.2945, 0.2461, 0.01248 or 0.01247 percentage changes in the region's agricultural production, respectively.

For the technical efficiency equation, trade openness, trade openness risk in short-run and technology showed mixed effects on technical efficiency measure. A one unit change in trade openness would lead to negative (-0.010) change on technical inefficiency measure while a one unit change in trade openness in short run and a one unit change in technology show positive (0.009 and 0.001) change on technical inefficiency measure, respectively. In other word, trade openness decrease technical inefficiency level by 1.0 percent, while trade openness in short run and technology increase technical inefficiency level by 0.9 and 0.1 percent, respectively. However, only trade openness and trade openness risk in short run are significant at 99 percentile level while technology is insignificant even at 95 percent confident interval.

With Trade Openness and Short and Long-run Trade Openness Risk in the Technical Efficiency Model

The stochastic frontier model with short- and long-run trade openness is defined as:

$$\begin{aligned} Output_{it} &= \beta_0 + \beta_1 land_{it} + \beta_2 labor_{it} + \beta_3 capital_{it} \\ &\quad + \beta_4 fertilizer_{it} + \beta_t trend + \alpha_{i-1} Cdum_{i-1} + v_{it} - u_{it} \\ u_{it} &= \delta_0 + \delta_1 Topen_{it} + \delta_2 TopenSR_{it} + \delta_3 TopenLR_{it} \\ &\quad + \delta_t trend + \alpha_{i-1} Cdum_{i-1} + \varepsilon_{it} \end{aligned} \quad \text{(Eq. 10)}$$

Where Cdum represent individual country dummy, Topen represents trade openness, TopenSR represents the short-run trade openness risk, TopenLR represent the long-run trade openness risk and ε represents the error term.

In table 14, results from technical efficiency equation show four variables (trade openness, trade openness in short run and trade openness in long run risk with trade openness in long run regressed with technology) and four variables under production function equation. All variables under production function show positive effect on the region's outputs and are statistically significant. Capital has the highest effects on output, follow by labor, land, while technology and fertilizer has the same and the least effect on output.

Table 14: Regression Results of Stochastic Frontier Analysis Including Trade Openness, Short-run Trade Openness Risk and Long-run Trade Openness risk for Sub-Sahara Africa Countries, 1970 – 2009

Variable	Estimate	Std. Error	Z-value	pr (>/z/)
		Production function equation		
Intercept	-3.689	0.293	-12.592	<2.2e-16***
Land	0.243	0.025	9.760	<2.2e-16***
Labor	0.297	0.035	8.450	<2.2e-16***
Capital	0.322	0.028	11.419	<2.2e-16***
Fertilizer	0.012	0.003	3.885	0.000***
Trend	0.012	0.001	16.726	<2.2e-16***
		Technical efficiency equation		
Intercept	0.511	0.083	6.178	6.504e-10***
Topen	-0.010	0.002	-4.100	4.127e-05***
TopenSR	0.006	0.005	1.276	0.202
TopenLR	0.013	0.005	2.741	0.006**
Trend	0.000	0.001	-0.001	0.999
Significant. Codes:	**0 '***' 0.001 '**'**	**0.01 '*' 0.05 '.'**	**0.1 ' ' 1**	

Finally, under the technical efficiency equation, the effect of trade openness, trade openness risk in short and long-run on technical efficiency measure are evaluated. Trade openness showed positive impact on technical efficiency while trade openness risk in short and long run showed negative effects on technical efficiency and technology has no impacts on technical efficiency. Trade openness and trade openness risk in long run are highly significant at more than 99 percentile, while trade openness risk in short run and technology are insignificant. The results showed that a one unit change in trade openness would increase technical efficiency level by 1.00 percent, while a one unit change in trade openness risk in short and long run would decrease technical efficiency level by 0.60 and 1.30 percent, respectively. Finally, a one unit change in technology would have no effect on technical efficiency measure.

The three stochastic frontier analysis regression models also included the average technical efficiency scores by year from 1970 to 2009. The three tables (12), (13) and (14) and three equations (Eq. 8), (Eq. 9) and (Eq. 10) present the difference in technical efficiency measures using trade openness, trade openness in short run and trade openness in long run. The results indicated that Sub-Saharan Africa's technical efficiency measure was impacted by trade openness as well as trade risk or trade variability over time. Table 12 revealed that trade openness had negative effects (-0.007) on technical inefficiency measure, and its effects increased to 0.010 when it was regressed with trade openness risk in short run and trade openness risk in long run (table 13 and 14), respectively.

Table 13 and 14 shows trade openness risk in short run and trade openness in long run and their effects on technical efficiency measures. The two tables show that both variables increased technical inefficiency level by 0.6 and 1.3 percent, respectively. In other words, trade openness risk in short and in long run reduced the Sub-Saharan African technical efficiency level. But, when trade openness risks in short and in long run interacted with trade openness and technology (table 14), short run trade openness risk's effect on technical inefficiency measures decreased from 0.9 percent to 0.6 percent, while trade openness's effect on technical efficiency measures increased from 0.7 percent to 1.0 percent. Equation 10 combines all three technical efficiency variables: trade openness, trade openness risk short-run and trade openness risk in long-run; the results of equation 10 present in Table 14 are more telling compared to the two prior equations (Eq. 8 and Eq.9). The results showed that when the three variables (trade openness, trade openness risk in short run and trade openness risk in long run) interacted, their effects on technical efficiency dramatically changed.

Trade openness risk in long run had the highest effect on technical efficiency measures; it reduces Sub-Saharan Africa's technical efficiency level by 1.3 percent followed by trade openness at 1.0 percent, and trade openness risk in short run came third; it reduce technical efficiency level by 0.6 percent. Technology had no effect on Sub-Saharan African's technical efficiency level; Table 14 showed technology effect on technical efficiency level at 0.00 percent. The three stochastic frontier analysis regression models' average technical efficiency scores are shown in Table 15 for each of the 40 years analyzed. The average technical efficiency scores estimated are from equation 8, 9 and 10.

Appendix A which consists of Tables A1, A2, A3 and A4, provides print out results for the production function and the technical efficiency function for trade openness, trade openness risk in the short run and in the long run for the Sub-Saharan African countries from 1970-2009. Regression estimates for the production function and the technical efficiency function with each country dummy are regressed with trade openness, trade openness risk in the short run and trade openness risk in long run for Sub-Saharan African countries, over the 40 year period (1970 – 2009). Appendix B provides a printout results for R-code used in the analysis for the Sub-Saharan African data over the 40 year period 1970 – 2009 for the 31 countries.

Table 15: Average Technical Efficiency Measure for the Three Stochastic Frontier Analysis for Sub-Saharan African Countries, 1970 – 2009

YEAR	Topen	Topen and TopenSR	Topen, TopenSR andTopenLR
1970	0.818	0.774	0.762
1971	0.820	0.785	0.772
1972	0.803	0.769	0.757
1973	0.799	0.766	0.753
1974	0.800	0.769	0.757
1975	0.792	0.762	0.752
1976	0.789	0.760	0.752
1977	0.779	0.750	0.744
1978	0.778	0.752	0.745
1979	0.766	0.739	0.733
1980	0.764	0.737	0.730
1981	0.761	0.737	0.731
1982	0.754	0.730	0.726
1983	0.745	0.721	0.719
1984	0.750	0.727	0.725
1985	0.753	0.731	0.731
1986	0.762	0.740	0.740
1987	0.759	0.738	0.738
1988	0.768	0.748	0.749
1989	0.771	0.752	0.753
1990	0.753	0.734	0.736
1991	0.756	0.740	0.744
1992	0.742	0.725	0.732
1993	0.760	0.741	0.746
1994	0.752	0.737	0.744
1995	0.752	0.738	0.744
1996	0.760	0.743	0.750
1997	0.755	0.743	0.750
1998	0.751	0.740	0.748
1999	0.752	0.741	0.749
2000	0.748	0.738	0.748
2001	0.750	0.741	0.750
2002	0.751	0.742	0.752
2003	0.754	0.747	0.755
2004	0.763	0.756	0.763
2005	0.745	0.738	0.749
2006	0.750	0.745	0.756
2007	0.744	0.738	0.748
2008	0.740	0.735	0.746
2009	0.729	0.726	0.735
Grand	**0.763**	**0.744**	**0.745**

CHAPTER 6. CONCLUSIONS AND DISCUSSIONS

This chapter provides an overview of the thesis, summary of procedures used and conclusions drawn based on empirical econometric results in Chapter 5. The extended stochastic frontier analysis model with two equations – a one-way fixed effects primal production function equation and a technical efficiency equation were used to measure the impact of trade openness and trade openness variability or risk on technical efficiency measures for the Sub-Saharan African region from 1970 to 2009.

Unlike previous studies that assume technical efficient production function, stochastic frontier analysis accounts for technical efficiency and estimates the relationship between input factors and output. In additional, the extended stochastic frontier analysis evaluates the importance of trade openness, trade openness risk in the short-run and trade openness risk in the long-run. Quantifying trade openness and trade openness risk on technical efficiency measures is important; it helps producers decide how much to produce and how to produce it efficiently using their limited resources.

Based on the Chapter 5 empirical findings plus the graphical representation (Figure 1) in Chapter 1, trade openness varied across Sub-Saharan Africa and it varied over time; this affected the Sub-Saharan African countries' technical efficiency measures. Table 11 examines the four inputs (land, labor, capital and fertilizer) plus technology (trend), and shows that all inputs have positive effects on Sub-Saharan African's agricultural production function. Furthermore, all five variables, technology included, show statistically significance at greater than 99 percent confidence interval. Land has the highest impact on agricultural production function, followed by capital, labor, fertilizer and technology in that order.

To evaluate the role of trade openness and trade openness risk on technical efficiency measures for Sub-Saharan African region over the 40 year period, trade openness was used to model trade openness. Trade openness risk in the short-run and trade openness risk in the long-run were used to model trade risk or trade variability over time. Each of the three variables was regressed with technology (trend) to examine its effect on technical efficiency level. Empirical evidence showed that trade openness had a positive effect on technical efficiency while trade openness risk in the short-run and in the long-run had a negative effect on technical efficiency measures. These results mean trade openness would reduce the Sub-Saharan African technical inefficiency level, while trade openness risks both in short-run and in the long-run would increase the region's technical inefficiency level. Table 12 shows that, a one unit change in trade openness would reduce the region's technical inefficiency level by 0.7 percent, while a one unit change in trade openness risk in the short-run and in the long-run (Table 13 & 14) would increase the region's technical inefficiency level by 0.9 percent and 1.3 percent, respectively.

When all three trade openness variables were regressed together with technology (Table 14), trade openness and trade openness risk in the short-run's effects changed from 0.007 to 1.0 percent (Table 12 to 14) and 0.009 to 0.6 percent (Table 13 to 14), respectively. These results showed that trade openness's effect on technical efficiency measures increased; in other word, trade openness reduced technical inefficiency levels more when it interacted with trade openness risk in short-run and trade openness risk in the long-run variables. Trade openness risk in the short run's effect on technical inefficiency measures decreased by 0.3 percent (0.009 to 0.006) when it interacted with trade openness and trade openness risk in the long run. Table 14 shows both trade openness and trade openness in the long-run are highly significant at greater than 99 percent confidence interval while trade openness in the short run and technology are insignificant even at the 95 percent confidence interval.

In conclusion, an examination of the effects of trade openness and trade openness risk on Sub-Saharan African's technical efficiency levels revealed that, the region's openness to a free trade would reduce its technical inefficiency measures while its trade openness risk or trade variability in the short-run and in the long-run would increase its technical inefficiency measures. However, according to Table 14, only trade openness and trade openness risk in the long run were significant, while trade openness risk in the short run and technology were insignificant. All three variables' effects on the region's technical inefficiency levels changed when all three interacted; trade openness reduced technical inefficiency measures by 43%, (0.7 to 1.0), while trade openness risk in the short run's effects on technical inefficiency decreased by 33% (0.9 to 0.6). Trade openness risk in the long-run's effects on technical inefficiency measure was at 1.3 percent. The empirical results were as expected; trade openness increases Sub-Saharan African's technical efficiency measures, while trade variability or trade risk both, in the short-run and in the long-run, decrease the region's technical efficiency levels. The effect of trade openness risk in the short run was insignificant, which means producers do not respond to the short-run changes in trade variability, but a persistent trade openness variability or trade openness risk beyond five years would impacts region's technical efficiency levels and cause producers to respond; this is shown by a high significance in trade openness risk in the long run.

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APPENDIX A

Table A1: Regression Estimates for Production Function for Sub-Saharan African Countries, 1970 – 2009

Parameter	**Estimate**	**Std.error**	**z-value**	**Probt**
Intercept	-6.270	0.407	-15.391	<2.2e –16***
Land	0.395	0.028	14.019	<2.2e –16***
Labor	0.229	0.038	6.071	1.268e – 09
Capital	0.378	0.037	10.358	<2.2e –16***
Fertilizer	0.028	0.005	5.334	9.627e – 09***
trend	0.009	0.001	9.602	<2.2e –16***
Burundi	1.241	0.366	3.391	0.001***
Benin	1.592	0.649	2.454	0.014*
Burkina Faso	0.573	0.907	0.632	0.528
Cote d'Ivoire	0.760	0.190	3.992	6.554e –05***
Cameroon	0.845	0.079	10.646	<2.2e – 16***
Congo	2.745	0.480	7.224	5.053e –13***
Gabon	3.363	0.214	15.715	<2.2e –16***
Ghana	0.560	0.691	0.812	0.417
Guinea	0.956	0.747	1.279	0.201
Gambia	3.321	0.714	4.654	3.260e –06***
Kenya	-0.133	0.565	-0.203	0.839
Madagascar	0.010	0.549	0.019	0.985
Mali	0.412	0.694	0.594	0.553
Mozambique	0.106	0.204	0.517	0.605
Mauritius	3.227	0.274	11.796	<2.2e –16***
Malawi	1.125	0.675	1.668	0.095.
Namibia	2.780	0.116	23.878	<2.2e –16***
Niger	0.306	0.417	0.733	0.464
Nigeria	-1.447	0.443	-3.264	0.001**
Rwanda	1.896	0.634	2.990	0.003**
Sudan (Former)	-0.862	0.303	-2.843	0.004**
Senegal	0.650	0.842	0.772	0.440
Seychelles	6.166	0.255	24.223	<2.2e –16***
Togo	1.515	0.601	2.520	0.012*
Tanzania	-0.554	0.303	-1.825	0.068.
Uganda	-0.701	0.294	-2.386	0.017*
South Africa	-0.979	0.498	-1.967	1.268e – 09
DRC	0.378	0.037	10.358	<2.2e –16***
Zambia	0.028	0.005	5.334	9.627e – 09***
Zimbabwe	0.009	0.001	9.602	<2.2e –16***
SIGMASQ	**0.042**	**0.005**	**8.682**	**<2.2e –16*** **
GAMMA	**0.663**	**0.090**	**7.384**	**1.530e –13*** **
SIGNIF CODES:	**0 '***'**	**0.001 '**'**	**0.01 '*'**	**0.05 '.' 0.1 ' '**

Table A2: Regression Estimates for the Production Function with Individual Country Regressed with Trade Open for Sub-Saharan African Countries, 1970-2009

Parameter	Estimate	Std.error	z-value	Probt
	Production Function Equation			
Intercept	-3.806	0.363	-10.493	<2.2e –16***
Land	0.273	0.036	7.672	1.690e –14***
Labor	0.278	0.037	7.615	2.644e –14***
Capital	0.307	0.029	10.578	<2.2e –16***
Fertilizer	0.014	0.003	4.120	3.791e – 05***
trend	0.013	0.001	15.610	<2.2e –16***
Burundi	0.965	0.141	6.856	7.081e-12***
Benin	0.991	0.098	10.134	<2.2e –16***
Burkina Faso	0.113	0.096	1.177	0.239
Cote d'Ivoire	0.360	0.101	3.553	0.000***
Cameroon	11.920	5.743	2.075	0.038*
Congo	1.906	0.110	17.394	<2.2e –16***
Gabon	2.574	0.128	20.169	<2.2e –16***
Ghana	0.182	0.101	1.810	0.070
Guinea	0.435	0.099	4.399	1.088e-05***
Gambia	2.629	0.126	20.846	<2.2e –16***
Kenya	-0.515	0.096	-5.344	9.081e-08***
Madagascar	-0.322	0.101	-3.205	0.001**
Mali	0.127	0.110	1.151	0.250
Mozambique	0.032	0.112	0.286	0.775
Mauritius	2.639	0.144	18.364	<2.2e –16***
Malawi	0.595	0.101	5.897	3.709e-09***
Namibia	2.229	0.169	13.224	<2.2e –16***
Niger	0.151	0.130	1.162	0.245
Nigeria	-1.288	0.133	-9.721	<2.2e –16***
Rwanda	7.087	2.857	2.480	0.013*
Sudan (former)	-0.886	0.105	-8.402	<2.2e –16***
Senegal	0.205	0.095	2.160	0.031*
Seychelles	4.758	0.192	24.743	<2.2e –16***
Togo	0.906	0.101	8.966	<2.2e –16***
Tanzania	-0.899	0.097	-9.277	<2.2e –16***
Uganda	-1.091	0.101	-10.806	<2.2e –16***
South Africa	-1.130	0.118	-9.572	<2.2e –16***
DRC	-0.531		-3.469	0.000***
Zambia	1.882	9.013	2.088	0.037*
Zimbabwe	0.506	0.097	5.208	1.911e –07***

Table A2: Regression Estimates for the Production Function with Individual Country regressed with Trade Open for SSA Countries, 1970 – 2009 (continued)

Parameter	**Estimate**	**Std. error**	**Z-value**	**Probt**
	Technical efficiency Equation			
Intercept	0.567	0.107	5.302	1.147e –07***
Topen	-0.007	0.002	-3.031	0.002**
trend	0.003	0.002	1.486	0.137
Burundi	-0.021	0.148	-0.139	0.889
Benin	-2.464	1.390	-1.773	0.076.
Burkina Faso	-2.054	0.765	-2.683	0.007**
Cote d'Ivoire	-183.100	99.040	-1.849	0.064.
Cameroon	11.020	5.756	1.915	0.056.
Congo	-1.297	0.406	-3.195	0.001**
Gabon	-0.709	0.148	-4.797	1.610e –06***
Ghana	-0.820	0.185	-4.443	8.885e-06****
Guinea	-0.812	0.167	-4.872	1.102e-06***
Gambia	-0.242	0.131	-1.851	0.064.
Kenya	-1.625	0.452	-3.596	0.000***
Madagascar	-0.748	0.215	-3.484	0.000***
Mali	-0.604	0.184	-3.279	0.001**
Mozambique	-0.083	0.129	-0.639	0.523
Mauritius	-0.062	0.133	-0.466	0.641
Malawi	-1.245	0.314	-3.963	7.416e-05***
Namibia	-0.445	0.271	-1.641	0.101
Niger	-0.496	0.160	-3.104	0.002**
Nigeria	-0.352	0.135	-2.603	0.009**
Rwanda	5.392	2.589	1.886	0.059.
Sudan (former)	-0.432	0.147	-2.947	0.003**
Senegal	-1.829	0.654	-2.779	0. 005**
Seychelles	-0.604	0.154	-3.919	8.895e –05***
Togo	-0.962	0.337	-2.253	0.010*
Tanzania	-204.100	111.000	-1.840	0.066.
Uganda	-0.899	0.220	-4.413	1.018e-05***
South Africa	-149.300	81.090	-1.842	0.066.
DRC	0.055	0.164	0.339	0.735
Zambia	17.210	9.010	1.910	0.056.
Zimbabwe	-1.449	0.436	-3.321	0.000***
SIGMASQ	0.058	0.005		<2.2e –16***
GAMMA	0.940	0.009		<2.2e –16***
SIGNIF CODES:	**0 '***'**	**0.001 '**'**	**0.01 '*'**	**0.05 '.' 0.1 ' '**

Table A3: Regression Estimates for the Production Function with Individual Country, regressed with Trade Open, and Trade Open Short-run Risks for Sub-Saharan African Countries, 1970-2009

Parameter	Estimate	Std.error	z-value	Probt
	Production Function Equation			
Intercept	-3.703	0.290	-12.774	<2.2e –16***
Land	0.246	0.025	9.784	<2.2e –16***
Labor	0.295	0.034	8.562	<2.2e –16***
Capital	0.321	0.028	11.500	<2.2e –16***
Fertilizer	0.012	0.003	3.874	0.000***
trend	0.012	0.001	17.238	<2.2e –16***
Burundi	1.047	0.131	8.017	1.082e-15***
Benin	1.059	0.065	16.422	<2.2e –16***
Burkina Faso	0.199	0.059	3.362	0.000***
Cote d'Ivoire	0.464	0.060	7.733	1.048e –14***
Cameroon	10.150	45.900	0.221	0.825
Congo	1.970	0.081	24.336	<2.2e –16***
Gabon	2.666	0.099	26.817	<2.2e –16***
Ghana	0.277	0.060	4.590	4.432e-06***
Guinea	0.528	0.621	8.504	<2.2e –16***
Gambia	2.702	0.103	26.243	<2.2e –16***
Kenya	-0.446	0.065	-6.856	7.083e-12***
Madagascar	-0.027	0.073	-3.735	0.000***
Mali	0.233	0.069	3.359	0.000***
Mozambique	0.108	0.100	1.075	0.282
Mauritius	2.727	0.119	22.987	<2.2e –16***
Malawi	0.690	0.067	10.311	<2.2e –16***
Namibia	2.330	0.147	15.838	<2.2e –16***
Niger	0.287	0.081	3.550	0.000***
Nigeria	-1.165	0.088	-13.252	<2.2e –16***
Rwanda	12.770	56.510	0.226	0.821
Sudan (former)	-0.812	0.075	-10.881	<2.2e –16***
Senegal	0.285	0.056	5.056	4.277e-07***
Seychelles	4.809	0.171	28.179	<2.2e –16***
Togo	0.970	0.069	13.969	<2.2e –16***
Tanzania	-0.825	0.065	-12.796	<2.2e –16***
Uganda	-0.998	0.064	-15.486	<2.2e –16***
South Africa	-1.030	0.088	-12.073	<2.2e –16***
DRC	9.628	52.630	0.183	0.855
Zambia	9.102	34.210	0.266	0.790
Zimbabwe	0.597	0.058	10.225	<2.2e –16***

Table A3: Regression Estimates for the Production Function with Individual Country, regressed with Trade Open, and Trade Open Short-run Risks for Sub-Saharan African Countries, 1970-2009 (continued)

Parameter	**Estimate**	**Std.error**	**z-value**	**Probt**
	Technical efficiency Equation			
Intercept	0.529	0.080	6.585	4.546e –11***
Topen	-0.010	0.002	-3.932	8.409e – 05***
TopenSR	0.009	0.005	1.976	0.048*
Trend	0.001	0.001	0.620	0.535
Burundi	0.071	0.137	0.519	0.604
Benin	-71.410	349.300	-0.204	0.838
Burkina Faso	-1.905	0.704	-2.707	0.007**
Cote d'Ivoire	-109.300	555.300	-0.197	0.844
Cameroon	9.258	45.900	0.202	0.840
Congo	-1.378	0.436	-3.163	0.002**
Gabon	-0.585	0.103	-5.672	1.413e –08***
Ghana	-0.684	0.146	-4.695	2.670e-06***
Guinea	-0.638	0.118	-5.434	5.503e-08***
Gambia	-0.155	0.109	-1.426	0.154
Kenya	-1.305	0.356	-3.662	0.000***
Madagascar	-0.690	0.210	-3.292	0.000***
Mali	-0.440	0.140	-3.144	0.002**
Mozambique	-0.006	0.120	-0.052	0.958
Mauritius	0.047	0.110	0.426	0.670
Malawi	-1.045	0.280	-3.729	0.000***
Namibia	-0.292	0.226	-1.292	0.196
Niger	-0.341	0.116	-2.940	0.003**
Nigeria	-0.230	0.102	-2.256	0.024*
Rwanda	11.080	56.500	0.196	0.845
Sudan (former)	-0.357	0.121	-2.961	0.003**
Senegal	-1.600	0.566	-2.836	0.005**
Seychelles	-0.520	0.132	-3.950	7.826e-05**
Togo	-1.170	0.415	-2.819	0.005**
Tanzania	-113.900	583.000	-0.195	0.845
Uganda	-0.734	0.161	-4.559	5.150e-06***
South Africa	-87.140	445.100	-0.196	0.845
DRC	10.220	52.620	0.194	0.846
Zambia	7.501	34.210	0.219	0.826
Zimbabwe	-1.128	0.315	-3.582	0.000***
SIGMASQ	0.057	0.004	13.351	<2.2e –16***
GAMMA	0.941	0.008	111.741	<2.2e –16***

SIGNIF CODES: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '**

Table A4: Regression Estimates for the Production Function with Individual Country regressed with Trade Open, Trade Open Short-run and Trade Open Long-run Risks for Sub-Saharan African Countries, 1970-2009

Parameter	Estimate	Std.error	z-value	Probt
	Production	**Function Equation**		
Intercept	-3.689	0.293	-12.592	<2.2e –16***
Land	0.243	0.025	9.760	<2.2e –16***
Labor	0.297	0.035	8.450	<2.2e –16***
Capital	0.322	0.028	11.419	<2.2e –16***
Fertilizer	0.012	0.003	3.885	0.000***
trend	0.012	0.001	16.726	<2.2e –16***
Burundi	1.048	0.130	8.043	8.751e – 16***
Benin	1.063	0.073	14. 523	<2.2e – 16***
Burkina Faso	0.202	0.067	3.023	0.003***
Cote d'Ivoire	0.469	0.068	6.934	4.085e – 12***
Cameroon	0.855	0.086	9.985	<2.2e – 16***
Congo	1.971	0.089	22.152	5.053e –13***
Gabon	2.671	0.109	24.422	<2.2e –16***
Ghana	0.281	0.069	4.056	4.998e-05***
Guinea	0.530	0.072	7.400	1.361e-13***
Gambia	2.701	0.109	24.783	<2.2e –16***
Kenya	-0.446	0.072	-6.219	4.992e-10***
Madagascar	-0.273	0.076	-3.564	0.000***
Mali	0.241	0.078	3.107	0.002**
Mozambique	86.600	48.630	0.178	0.859
Mauritius	2.730	0.126	21.695	<2.2e –16***
Malawi	0.693	0.075	9.275	<2.2e –16***
Namibia	2.331	0.143	16.318	<2.2e –16***
Niger	0.294	0.869	3.377	0.000***
Nigeria	-1.158	0.092	-12.521	<2.2e –16***
Rwanda	18.690	97.000	0.193	0.847
Sudan (former)	-0.809	0.080	-10.087	<2.2e –16***
Senegal	0.288	0.064	4.488	7.192e-06***
Seychelles	4.809	0.018	27.051	<2.2e –16***
Togo	0.972	0.077	12.623	<2.2e –16***
Tanzania	-0.825	0.071	-11.562	<2.2e –16***
Uganda	-0.996	0.072	-13.791	<2.2e –16***
South Africa	-1.024	0.090	-11.418	<2.2e –16***
DRC	14.110	83.790	0.168	0.866
Zambia	22.550	112.000	0.201	0.840
Zimbabwe	0.600	0.067	8.957	<2.2e –16***

Table A4: Regression Estimates for the Production Function with Individual Country regressed with Trade Open, Trade Open Short-run and Trade Open Long-run Risks for Sub-Saharan African Countries, 1970-2009 (Continued)

Parameter	**Estimate**	**Std.error**	**Z-Value**	**Probt**
	Technical efficiency Equation			
Intercept	0.511	0.083	6.178	6.504e –10***
Topen	-0.010	0.002	-4.100	4.127e – 05***
TopenSR	0.006	0.005	1.276	0.202
TopenLR	0.013	0.005	2.741	0.006**
trend	0.000	0.001	-0.001	0.999
Burundi	0.073	0.136	0.535	0.593
Benin	-87.400	485.400	-0.181	0.857
Burkina Faso	-1.845	0.649	-2.844	0.004**
Cote d'Ivoire	-140.900	799.000	-0.176	0.860
Cameroon	-0.070	0.110	-0.641	0.522
Congo	-1.385	0.144	-3.053	0.002**
Gabon	-0.564	0.121	-4.646	3.381e-06***
Ghana	-0.691	0.142	-4.885	1.036e-06***
Guinea	-0.613	0.143	-4.283	1.848e-05***
Gambia	-0.240	0.113	-2.115	0.034*
Kenya	-1.297	0.364	-3.513	0.000***
Madagascar	-0.661	0.211	-3.138	0.002**
Mali	-0.440	0.146	-3.020	0.003**
Mozambique	8.571	48.640	0.176	0.860
Mauritius	-0.047	0.122	-0.387	0.699
Malawi	-1.023	0.298	-3.437	0.000***
Namibia	-0.275	0.220	-1.250	0.211
Niger	-0.317	0.119	-2.673	0.008**
Nigeria	-0.216	0.106	-2.039	0.041**
Rwanda	17.000	97.010	0.175	0.861
Sudan (former)	-0.376	0.124	-3.039	0.002**
Senegal	-1.584	0.534	-2.964	0.003**
Seychelles	-0.563	0.141	-3.997	6.414e –05***
Togo	-1.193	0.421	-2.832	0.005**
Tanzania	-116.500	659.900	-0.177	0.860
Uganda	-0.777	0.168	-4.621	3.817e-06***
South Africa	-99.950	566.400	-1.177	0.860
DRC	14.720	83.800	0.176	0.861
Zambia	20.970	112.000	0.187	0.851
Zimbabwe	-1.114	0.338	-3.294	0.000
SIGMASQ	0.057	0.004	12.932	<2.2e –16***
GAMMA	0.942	0.008	114.081	< 2.2e –16***
SIGNIF CODES:	**0 '***'**	**0.001 '**'**	**0.01 '*'**	**0.05 '.' 0.1 ' '**

APPENDIX B: PRINTOUT RESULTS FOR R-CODE USED IN THE ANALYSIS

```
ss <- read.csv("H:/Saleem.Shaik/WorldAG/analysis/New/SSA/SSAdata(3) 20Aug2013.csv")

#View(ss)
names(ss)
summary(ss)

# POOLED Cobb-Douglas production frontier
CDsfa  <- sfa( log( Output ) ~ log( Land ) + log( Labor ) + log( Capital) + log( Fertilizer ) +
trend, data = ss )
summary( CDsfa )

# POOLED Cobb-Douglas production frontier
ECDsfa  <- sfa( log( Output ) ~ log( Land) + log( Labor) + log( Capital ) + log( Fertilizer ) +
trend + LlandT + LlaborT + LcapitalT + LfertilizerT, data = ss )
summary( ECDsfa )

# Technical Efficiency Effects Frontier (Battese & Coelli 1995)
# (efficiency effects model with intercept)
CDsfaZ   <- sfa( log( Output ) ~ log( Land ) + log( Labor ) + log( Capital ) + log( Fertilizer ) +
trend + Country Code | Trade Openness + trend + Country Code, data = ss )
summary( CDsfaZ )

# Technical Efficiency Effects Frontier (Battese & Coelli 1995)
# (efficiency effects model with intercept)
CDsfaZA   <- sfa( log( Output ) ~ log( Land ) + log( Labor ) + log( Capital ) + log( Fertilizer ) +
trend + LlandT + LlaborT + LcapitalT + LfertilizerT + Country Code | Trade Openness + trend +
Country Code, data = ss )
summary( CDsfaZA )

# Technical Efficiency Effects Frontier (Battese & Coelli 1995)
# (efficiency effects model with intercept)
CDsfaZ1   <- sfa( log( Output ) ~ log( Land ) + log( Labor ) + log( Capital ) + log( Fertilizer ) +
trend + Country Code | Trade Openness + Trade Openness Short-run + Country Code, data = ss )
summary( CDsfaZ1 )

# Technical Efficiency Effects Frontier (Battese & Coelli 1995)
# (efficiency effects model with intercept)
CDsfaZ2  <- sfa( log( Output ) ~ log( Land ) + log( Labor ) + log( Capital ) + log( Fertilizer ) +
trend + Country Code | Trade Openness + Trade Openness Short-run + Trade Openness Long-
run + trend + Country Code, data = ss )
summary ( CDsfaZ2 )
```