MEASURING TRADE POTENTIALS BETWEEN WEST AFRICAN MONETARY ZONE COUNTRIES USING THE STOCHASTIC FRONTIER GRAVITY MODEL

INNOCENT S. KUMAH
Bachelor of Arts, University of Ghana, 2011

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Department of Economics
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Dr. Kien C. Tran Supervisor	Professor	Ph.D.
Dr. Kamar Ali Thesis Examination Committee Member	Associate Professor	Ph.D.
Dr. Stavroula Malla Thesis Examination Committee Member	Associate Professor	Ph.D.
Dr. Duane Rockerbie Chair, Thesis Examination Committee	Professor	Ph.D.

Abstract

The countries of the West African Monetary Zone (WAMZ) have set on course processes to become a currency union. Among other conditions, the optimal currency theory proposes high trade integrations between the candidate countries of a currency union because it facilitates the synchronization of the business cycles of the countries which is needed for an effective currency union. To assess the levels of trade integrations between the countries of the WAMZ, this study constructs an export frontier for each of the countries of the WAMZ using each country's aggregated export data for at least 45 countries over the period 2000-2014. The study applies the Battese and Coelli (1992) model as well as the Kumbhakar (1990) model. The trade efficiency estimates between the countries of the WAMZ indicate various degrees of trade integrations. Overall, the results suggest a poorly integrated region from a trade standpoint.

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CHAPTER ONE

1.1 INTRODUCTION

Trade is the engine of economic growth. Therefore, countries keep on searching for ways and means to optimise their trade flows with other countries and regions of the world. This has resulted in the formation of different forms of trade agreements including monetary unions in all parts of the world.

There is a growing number of monetary unions in the various parts of Africa (UNCTAD, 2014).[1 2] The major reason for the formation of these monetary unions is to boost intraregional trade and investment (UNCTAD, 2014). It is expected that the costs of trade would be substantially reduced through the formation of these monetary unions which will result in increased intraregional trade on the continent.

The West African Monetary Zone (WAMZ) is one of the two monetary unions in the West African sub-region. It is comprised of Ghana, The Gambia, Sierra Leone, Nigeria, Guinea and Liberia. The initiative to form the WAZM was launched in April 2000 by the Accra Declaration (Harvey and Cushing, 2015). In December 2000, the WAMZ was established through the Bamako Accord by Ghana, Nigeria, The Gambia, Sierra Leone and Guinea. Liberia joined the WAMZ in February, 2010. The vision at the time of the formation of the WAMZ was for it to be unified with the West African Economic and Monetary Zone (WAEMZ) to form one monetary zone in 2004 to fulfil the dream of the founding fathers of the Economic Community of West African States (ECOWAS). The

[1] "In the East African Community, the leaders of the five member countries signed a protocol in November 2013 laying the groundwork for a monetary union within 10years. In the Southern African Development Community, the plan is to establish a monetary union by 2016 and have a single currency by 2018. Regarding the Common Market for Eastern and Southern Africa, members are working towards establishing a monetary union with a common currency by 2018" (UNCTAD, 2014, p. 2).

[2] UNCTAD stands for United Nations Conference on Trade and Development.

Bamako Accord also established the West African Monetary Institute (WAMI) as an administrative body of the WAMZ to work towards the creation of a central bank to be followed by the adoption of a common currency: the Eco. Four deadlines set for the adoption of the Eco have not been met. The latest deadline that was not met was the first of January, 2015. Failure on the part of member countries to meet the primary and secondary convergence criteria is cited as the reason for the unmet deadlines for the adoption of the Eco (Harvey and Cushing, 2015).

Several fiscal and monetary reviews have been carried out to assess the progress made by the member countries of the WAMZ in meeting the primary and secondary convergence criteria. There is also the need for an assessment of the region in terms of the levels of trade integrations between the countries, particularly considering the efforts being made principally through the ECOWAS Trade Liberalisation Scheme (ETLS) to ease barriers to trade between the countries in the quest to optimise trade flows between them.[3] This assessment requires the estimations of some kind of benchmark trade flows between the countries of the WAMZ to compare with the actual trade flows between them. Such estimated benchmark trade flows are called trade potentials in the literature.

The Trade Gravity Model (TGM) has been used to answer several questions including estimating trade potentials. The initial studies in this area called the predicted trade flow from the TGM estimated with the Ordinary Least Square (OLS) estimating technique or other variants of it as trade potential. This meant their predicted trade flows were made

[3] "The ETLS is a tool to facilitate the working of the Free Trade Area. It ensures that goods can be circulated freely without the payment of customs duties and taxes with similar effects on imports. Aside from this, it also includes putting in place measures aimed at facilitating trade by reducing red tape and paper work at the borders" (ECOWAS Trade Liberalisation Scheme Rules for Traders, 2012, p. 7).

using the average determinants of trade. Hence, their predicted trade flows were average trade flows. To reconcile the theory of trade potential with the empirical estimation has led to the borrowing of the concept of frontier analysis as in production into trade. This has resulted in the development of the Stochastic Frontier Gravity Model (SFGM). Proponents of the SFGM also argue that it controls sufficiently for trade resistances.

This study constructs an export frontier for each of the countries of the WAMZ using data for at least forty-five of the top importers from each of the countries of the WAMZ over the period 2000-2014. The study applies the Battese and Coelli (1992) model as well as the Kumbhakar (1990) model. The empirical results suggest various degrees of trade integrations between the individual countries of the WAMZ. Overall, the study finds the region not properly integrated from the standpoint of trade.

1.2 BACKGROUND TO THE STUDY

The main underlying theory which forms the basis for this study is the optimal currency area proposition as related to trade and synchronisation of business cycles of countries intending to form a currency union. The optimal currency area theory as propounded by Mundell (1961), McKinnon (1963) and Kenen (1969) is predicated on the idea that given the existence of certain conditions, it would be more useful and cost effective for a group of countries to adopt a single currency instead of having individual national currencies. Frankel and Rose (1998) categorised four conditions that must be considered to determine if a region qualifies as an optimal currency area. These are the extent of trade; the similarities of the shocks and cycles; the degree of labour mobility; and the system of risk sharing.

The theory espouses that high trade integrations between the countries intending to form a currency union facilitate the synchronisation of the business cycles of the countries and increase the chance of exposure of the region to symmetric external shocks. This is needed for the effective working of any currency union in that individual countries cede their monetary policy tools to a centralised body which assumes the responsibility of smoothing the business cycles of the entire region. Thus, a highly-integrated region enables the centralised body to deploy its monetary policy tools in countering business cycles in an effective way.

There is also empirical evidence to the effect that a highly-integrated region from a trade standpoint synchronises the business cycles of the countries and make them susceptible to symmetric shocks (Frankel and Rose, 1998). However, Frankel and Rose (1998) have also found that high trade intensity and synchronised business cycle factors are endogenous. In summary, their findings suggested that countries intending to form a currency union that do not have high trade linkages ex ante develop high trade linkages post ante. The findings of Frankel and Rose (2000) also pointed to this direction.

A sense of the trade potentials between countries intending to form a currency union would be useful no matter which view one holds: that is, whether countries intending to form a currency union should be highly integrated trade-wise ex ante or that high trade linkages should be developed after the formation of the currency union. In relation to the latter view, estimates of the trade potentials between the countries intending to join a currency union will provide an empirical guide to determine if it is worthwhile. That is, in terms of the expected trade growths together with the other benefits vis-à-vis the numerous costs that are associated with joining a currency union.[4]

There are also ambiguities regarding the trade potentials between the countries of WAMZ based on the predictions of standard trade theories. For example, the Heckscher-Ohlin (H-O) trade theory predicts that countries with different relative factor endowments tend to trade more. All the countries of the WAMZ are relatively endowed with natural resources. Thus, based on the H-O trade theory prediction, substantial trade cannot be expected between the countries of the WAMZ. On the contrary, based on the Linder (1961) trade hypothesis, a huge trade potential would be expected between the countries of the WAMZ as it predicts that countries of similar levels of development normally have identical consumption preferences, and they tend to trade more. Given the contrasting predictions, estimates of the trade potentials between the countries of the WAMZ will give an idea of which of the predictions is highly likely to hold.

1.3 OJBECTIVES OF THE STUDY

Among other conditions, the optimal currency theory espouses that a currency union is best implemented under close trade linkages between candidate countries. Thus, the countries of the WAMZ have been making efforts to deepen the levels of trade integrations between themselves. The objectives of this study are broadly two. The first main objective of this study is to estimate an export frontier for each of the countries of the WAMZ. This would involve the specification and estimation of a SFGM for each of the countries of the WAMZ using the export data for each of the countries to at least forty-five of their top importers

[4] See Okafor (2013) for the costs and benefits of joining a currency union.

over the period 2000-2014. A maximum likelihood estimation technique would be used for the estimation of the specified SFGM for each of the countries of the WAMZ. The in-sample approach would be used. For example, in the estimation of the specified SFGM for Ghana, the other five members of the WAMZ would be included in the sample for the estimation. The core variables of the TGM would be included in the specified SFGM in line with the suggestion of Armstrong (2007) to produce the frontier estimates. The frontier estimates of each of the countries will define their trade relation over the period. They will explain the export relation of each of the countries of the WAMZ over the fifteen years' period considered in the study.

The second main objective of this study is closely tied to the first. It involves the estimation of the trade efficiencies between the countries of the WAMZ. To do this, the frontier parameter estimates would be used to calculate the trade efficiencies for each of the observations used in the estimation of the empirical model for each of the countries of the WAMZ. The main interest of this study is to find out the levels of trade integrations between the countries of the WAMZ, hence the study will focus on the trade efficiencies between the countries of the WAMZ.

1.4 CONTRIBUTIONS TO LITERATURE

This study makes several contributions to the existing literature. To begin with, it augments the burgeoning literature in the use of the SFGM to estimate trade potentials. The use of the concept of frontier analysis in trade is relatively new. Thus, the SFGM has not yet been widely applied and this has been lamented by Armstrong (2007). By estimating the SFGM for six different countries, this study significantly augments the literature in the use of

SFGM to estimate trade potentials. Moreover, it will be one of the first studies that applies the SFGM to estimate the trade potential of a country in West Africa.

Additionally, this study contributes to the growing literature on the WAMZ by assessing the degrees of trade integrations between the countries of the WAMZ and the level of trade integration of the region in totality. The WAMZ has been the subject of several empirical works (cf. Tsangarides and Qureshi, 2008; Salisu and Ademuyiwa, 2012; Okarfor, 2013; Harvey and Cushing, 2015). Several reviews relating to the fiscal and monetary convergence criteria have been carried out. This study in a way complements the previous reviews in the area related to trade between the countries of the WAMZ. This is key in light of the efforts that have been made over the years to remove the barriers to trade between the countries to optimise trade flows between them and integrate the region properly from a trade standpoint.

The TGM has been the subject of extensive empirical application to explain the trade flow of several countries directly and indirectly. Indirectly, this study adds to the existing literature in the use of the TGM to explain the bilateral trade flows of countries. This is particularly important in the cases of The Gambia, Guinea, Liberia and Sierra Leone because the literature to date does not use the TGM directly or indirectly to explain these countries' trade flows. The estimates of the frontier variables of the empirical model for each of the countries will show how well the TGM explains their bilateral trade flows. Related to the significance of testing indirectly the TGM for each of the six countries of the WAMZ is that this study will also show the key determinants of the bilateral trade flows of each of the countries of the WAMZ. Several studies (cf. Baxter and Kouparitsas, 2005) have been carried out to find out the key determinants of the trade flows of countries with findings showing the basic elements of the TGM as the key explanatory factors of the bilateral trade flows of countries. This study will indicate if these variables are the key determinants of the trade flows of each of the countries of the WAMZ.

In the application of the SFGM to estimate trade potentials and trade efficiency, most of the studies have used the Battese and Coelli (1992) model which assumes that the non-negative error term has a truncated normal distribution. Battese and Coelli (1992) also model the inefficiency term differently from others like Kumbhakar (1990). Kumbhakar (1990) models the inefficiency term as a quadratic function of time and assumes that the one-sided error term has a half-normal distribution. This study applies the Battese and Coelli (1992) and Kumbhakar (1990) models to find out how the estimates of the frontier parameters and the trade efficiency estimates fare for each of the models. This will be one of the initial studies that applies two different models in the same study in the application of the SFGM to estimate trade potentials.

This study also contributes to the literature by providing a comprehensive review of the use of the TGM in the estimation of trade potentials. The literature review details the various major studies relating to the estimation of trade potentials and the evolving approaches leading to the development and application of the SFGM.

1.5 STRUCTURE OF THE THESIS

In the chapter two of the thesis, a comprehensive review of the literature in the use of the TGM to estimate trade potentials is provided. The first half of the chapter reviews the literature regarding the initial approach in the use of the TGM to estimate trade potentials, where the predicted trade flow from the estimated TGM using the OLS estimating technique or other variants of it is called the trade potential. The other half of the chapter reviews the literature on the use of the SFGM approach to estimating trade potentials.

The methodology and the empirical model for the study are discussed in the third chapter of the thesis. The data for the empirical estimations and their sources are discussed in chapter four. The empirical results are also presented and discussed in this chapter. The shortcomings of the results are also briefly discussed. In chapter five which is the final chapter of the thesis, the conclusions based on the empirical results are discussed. The policy recommendations of the study are also presented in this chapter of the thesis as well as a recommended area for further studies. The chapter ends with the concluding remarks of the study.

CHAPTER TWO: REVIEW OF LITERATURE

The concept of trade potential refers to the maximum trade flow for a given set of determinants of trade under minimum trade frictions (Miankhel et al., 2009). Bhattacharya and Das (2014) define potential trade as "the maximum possible bilateral trade, given the 'natural' constraints, 'but without' the influence of any 'policy-induced' constraints to trade, that is, 'in the absence of' 'behind the border' and 'beyond the border' constraints" (p. 260). "Behind the border" constraints are factors that are within the control of the exporter, whereas "beyond the border" constraints are factors that are within the control of the importer.

Potential trade between country pairs can only occur under the least trade resisting factors. In other words, potential trade occurs under the least trade frictions. It is, however, the case that several restraining factors are at play which limit trade between countries from reaching potential levels. Countries therefore want to know their trade potentials with other countries and regions so that they can work to eliminate the potential trade-resisting factors. This has led to a growing body of literature on the measurement of trade potentials between countries and regions. The main quantitative tool used in the measurement of trade potentials between countries and regions is the Trade Gravity Model (TGM).

The TGM has been used to answer numerous research questions since its introduction by Tinbergen (1962). However, it was only in the 1990s that the gravity model was applied in measuring the trade potentials of countries and regions.[5] Wang and Winters (1991), Hamilton and Winters (1992), Baldwin (1994), Gros and Gonciarz (1996), and Nilson (2000) were some of the pioneering studies. They all focused on countries of the European

[5] Trade gravity model, gravity equation and gravity model are used interchangeably.

Union (EU) and countries of Central and Eastern Europe (CEECs). Generally, these studies sought to project the expected trade growth between CEECs and EU countries on the backdrop of the breakdown of the "Iron Curtain" which resulted in the liberalisation of the economies of the CEECs for trade with the EU countries.

Peter Egger (2002) identified two approaches that were used by the pioneering studies in their use of the gravity model to calculate trade potentials. He called one of the approaches out of sample projection, and the other approach as in-sample projection. The out of sample approach involved the estimation of the gravity equation for EU countries or OECD countries and the use of the estimated parameters to project the trade volumes between the countries of the EU and CEECs.[6] The underlying assumption of this approach was that the EU countries were already trading at their potential levels so that the estimated parameters from the gravity equation represented potential trade estimates. Under the in-sample approach, the countries of Central and Eastern Europe were included in the estimation of the gravity equation. The residuals of the estimated gravity equation were interpreted as the difference between potential and actual trade (Egger, 2002). A negative residual was interpreted as representing an unexhausted trade gap, whereas a positive residual was indicative of overexploited trade potential. Wang and Winters (1991), Hamilton and Winters, (1992), and Nilson (2000) used cross-section data and an OLS estimator, whereas Balwin (1994) and Gros and Gonciarz (1996) used a panel data framework and random effect estimator in their estimation of the gravity equation.

Nilson (2000) sought to estimate the degree of trade integration of the CEECs and Cyprus with EU countries in his quest to assess the readiness of the CEECs and Cyprus in

[6] OECD represents Organisation for Economic Cooperation and Development.

meeting the economic criteria for their admission into the EU. The economic criteria stipulated that CEECs and Cyprus needed to have the ability to cope with the competitive pressure and market forces within the EU in the medium term before they were admitted into the EU. Nilson (2000) estimated the trade potentials between the candidate countries and EU countries, which he then compared with the actual trade flows to determine their levels of trade integration. Clearly, what Nilson (2000) sought to do was to find a benchmark in terms of trade flows with which to compare the actual trade flows in determining the levels of integration of the countries of CEEC and Cyprus with the EU countries. He found that the CEECs and Cyprus were ready for admission into the EU based on the empirical results, which showed their actual trade flows were close to the potential trade flows.

Egger (2002) highlighted the importance of the proper specification and choice of estimator in relation to parameter consistency and efficiency of the gravity equation, in his critique of the pioneering studies in their use of the gravity equation to calculate trade potentials, particularly the in-sample approach. He noted that the cross-section specification framework and the use of an OLS estimator were likely to result in inconsistent and inefficient estimates due to the lack of control for bilateral unobserved effects. He also made the point that the random effect estimator used by Baldwin (1994) and Gros and Gonciarz (1996) had a high possibility to produce inefficient and inconsistent estimates, because the orthogonality assumption between the explanatory variables and the unobserved effects was highly unlikely to hold. He thus concluded that the so called large unexploited trade potentials derived by some of the studies on EU countries and CEECs using the in-sample approach were due to model misspecifications and estimation problems. He applied six different panel estimators in his study and used the in-sample trade projection approach to calculate trade potentials of the countries used in his study to find out the consistent and efficient estimator. His yardstick in determining the consistent and efficient estimator(s) was based on the estimator producing white noise residuals (i.e., residuals that do not follow a systematic pattern). He concluded that in his application, the consistent and efficient estimator was the Hausman and Taylor AR (1) estimator because it produced in-sample trade projections that were not significantly different from the observed trade flows.

The World Trade Centre (WTC) of the UNCTAD/WTO has developed what it calls the TradeSim (2003) which is used to calculate the trade potentials of developing and transition countries with their trading partners. The gravity equation was estimated using 36 exporting countries from the developing world and 58 importing countries. An average of the 1999-2000 trade data for selected countries were used with an OLS estimating technique. Batra (2006) also calculated what he calls the global trade potentials of India using the gravity equation. His approach involved estimating the gravity equation using a cross section of 149 countries with bilateral trade flows for the year 2000. He used the estimated parameters to project India's trade potentials with specific regions and countries. WTC (2003) and Batra (2006) failed to control for exporter and importer unobserved effects, despite pooling a large cross section of different countries. This calls into question the consistency and efficiency of their parameter estimates which they used in the calculation of trade potentials of their countries of interest.

De Benedictis and Vicarelli (2005) estimated in-sample trade potentials for each of the 11 founding countries of the European Union with 32 trading partners using the gravity model. The gravity equation was estimated for each of the 11 countries separately using 32 importer countries (each EU country serving as an exporter country). They used three specifications of the gravity equation in their study. These included static linear specification, static linear with fixed effects specification, and dynamic specification with fixed effects. The three different specifications were estimated using OLS, within fixed effects and systems General Method of Moments (GMM) estimators respectively. The main interest of their study was to find out the robustness of the in-sample approach of calculating trade potentials due to the use of different estimators. They found that different estimators produced different trade potential results. The dynamic specification with fixed effects estimated using systems GMM produced fitted trade flows that were close to observed trade flows. Thus, they ranked it to be the best performing estimator in their application. They noted that because the in-sample trade potential projections were highly sensitive to the choice of estimator, caution must be exercised in drawing policy conclusions based on the empirical results of such studies.

Ferrarini (2013) estimated the trade potentials (export potentials) of Myanmar using the out of sample gravity projection and panel data framework. The gravity equation used in the projection of the trade potentials of Myanmar was estimated using the bilateral export flows of six countries of the Association of Southeast Asian Nations (ASEAN) for the period 2000-2010. His approach was driven mainly by the lack of trade data for Myanmar. He used a pseudo-fixed effect (PSEUDOFE) estimator in his estimation of the gravity equation. Unlike the proper fixed estimator which makes estimation of time-invariant determinants of trade such as the distance factor in gravity estimation infeasible, the PSEUDOFE permits the estimation of the time-invariant determinants of trade in gravity estimation. He asserted that in the use of the gravity equation to estimate trade potentials, the parameter estimates of time-invariant factors are key, and that their omission produces wrong trade potential estimates. The robustness of his gravity regression results was checked using three other estimators: generalised least squares random effects estimator, feasible generalised least square estimator, and unconditional fixed effects Tobit estimator. His results were robust to different estimators. He found Myanmar to be trading at fifteen percent of her trade potentials.

A common feature of many studies in the use of the gravity equation to answer research questions that are not primarily related to the calculation of trade potentials is the use of the parameter estimates from the regression analysis to project trade flows between countries of interest (De Benedictis and Vicarelli, 2005). For example, Sohn (2005) in a study in which he sought to find out the extent to which the TGM explains the bilateral trade flows of South Korea used the estimates of the gravity equation to project the trade flows between South Korea and thirty of her trading partners.[7] He interpreted the projected trade flows as trade potentials. He asserted that “the gravity model is supposed to provide a long-run view of trade flows. Thus, if there is any sort of market intervention that prevents a new equilibrium, the gravity equation engenders a gap between the actual trade flow and the long-run value, the trade potential” (Sohn, 2005, p. 426).

A relatively new and improved gravity methodology used in the calculation of trade potentials is the Stochastic Frontier Gravity Model (SFGM). The SFGM draws heavily on the Stochastic Frontier Production Function framework developed by Aigner et al. (1977) and Meeusen and van den Broeck (1977). One of the main reasons for the search for an improved gravity methodology in calculating trade potentials is the weakness of the traditional model to sufficiently control for trade resistances. The distance variable and categorical variables, such as common language and adjacency included in the traditional

[7] See also Adam and Tweneboah (2009).

gravity equations to control for trade resistance factors, do not sufficiently control for trade resistances as most of them are unobservable. In other words, the usual variables included in the traditional gravity equation to control for trade resistances do not control for what Anderson (1979) calls "economic distance" (i.e., all the other trade resistances between a bilateral trading partners). Related to the concept of "economic distance" are the multilateral trade resistance factors formally introduced into gravity modelling by Anderson (1979) and made popular through the work of Anderson and van Wincoop (2003).

By multilateral trade resistance, Anderson and van Wincoop (2003) suggested that trade flow between a pair of countries is not only dependent on the trade resistances between the two countries, but also dependent on trade resistances between the two countries and all their respective trading partners. For example, the volume of trade between Canada and the United States of America (USA) is not only dependent on trade resistances (economic distance) between the two countries alone, but also dependent on the trade resistances of each country with all their respective trading partners. If the trade resistances between Canada and Mexico or any other trading partners of Canada apart from the USA reduces, due to, say, the fostering of a successful bilateral trade agreement, Canada's multilateral resistance will reduce, and this will increase trade between Canada and Mexico and reduce trade between the USA and Canada. The multilateral resistance factor introduces an element of substitutability into trade between countries (Starck, 2012). This term has gained such acceptance in the literature that failure to control for it in any estimation of the gravity model is seen by Baldwin and Taglioni (2006) as committing a gold medal error in their ranking of the severity of the often-committed errors in gravity estimation.

The multilateral resistance term is largely unobservable and difficult to measure. Failure to properly control for "economic distance", and by extension multilateral resistance in gravity estimating, results in inconsistent and inefficient parameter estimates. This is because its improper control or omission results in the violation of the normality assumption of the error term in the traditional gravity model estimated with OLS, and causes heteroscedasticity in the error term whose structure is often unknown. The traditional gravity model is estimated in log linear form and according to Silva and Tenreyro (2006), log linearization in the presence of heteroscedasticity produces inconsistent estimates. "This is because the expected value of the logarithm of a random variable depends on higher-order moments of its distribution" (p. 653).

Several approaches have been put forward and applied in the literature in the bid to control for multilateral resistance terms in gravity estimation. Anderson and van Wincoop (2003) solved for the multilateral trade resistance factors in terms of the observable determinants of trade cost and applied a customised non-linear least square estimator to obtain consistent parameter estimates. The major drawback with their approach is that it is very elaborate (Baier and Bergstrand, 2009). It also results in the reduction in efficiency.

A less taxing and frequently used approach is to control for multilateral resistance terms with country-specific fixed effects (Rose and van Wincoop, 2001; Feenstra, 2004). This approach does generate consistent parameter estimates but it makes the direct estimation of partial effects of numerous potentially important explanatory variables infeasible, due to their perfect collinearity with the country-specific effects (Baier and Bergstrand, 2009). Kalirajan (2008) also argues that the fixed effects approach is not based on economic theory.

Baier and Bergstrand (2009) proposed the use of first-order log-linear Taylor-series expansion to generate linear approximation of the multilateral trade resistance terms and the use of OLS estimation to obtain consistent estimates. They did, however, note in the application of their approach that it led to some reduction in efficiency, relative to the Anderson and van Wincoop (2003) approach. Other studies also used what are generally referred to as remoteness indexes as proxies for the multilateral trade resistance terms (cf. Head and Mayer, 2013). Head and Mayer (2013), however, observed that proxy variables for the multilateral resistance terms do not take the theory seriously.

Proponents of the SFGM argue that it adequately controls for the multilateral trade resistance terms (Kalirajan, 2008; Miankhel et al., 2009; Ravishankar and Stack, 2014). This is because the SFGM permits the direct estimation of the degree of relevancy of unobservable trade hindrances that prevent the trade flow between a pair of countries from reaching its frontier given the determinants of trade. Armstrong (2007), however, points out that an element of faith is at play in assuming that the non-negative disturbance term that controls for unobservable trade hindrances controls for all unobservable trade hindrances.

The SFGM approach to estimating trade potentials is more consistent with the theory of trade potential (Kalirajan, 2008; Ravishankar and Stack, 2014; Bhattacharya and Das, 2014). This is one of the other major reasons for its development as an alternate and improved method to the traditional gravity method in the estimation of trade potential. The traditional gravity approach to calculating trade potential uses the average effect of the determinants of trade in the estimation of trade potential. Theoretically, trade potential is supposed to be the maximum possible level of trade flow given the determinants of trade and the least resistance to trade. This requires the estimation of the upper limits of the data set representing the most liberalised economies, but not the centered limit of the data, as is the case in the application of the traditional gravity method using OLS. The SFGM is estimated using maximum likelihood methods, and this permits the estimation of the upper limits of the data. Thus, it makes the theory of trade potential more consistent with empirical estimation.

Kalirajan (2008) identifies the following advantages of the SFGM of estimating trade potentials. Firstly, it does not suffer from loss of estimation efficiency. Secondly, it estimates the combined effects of the “economic distance” bias term (“behind the border” factors), which is creating heteroscedasticity and non-normality, isolating it from the statistical error term. This enables researchers to analyse the determinants of this bias term. Thirdly, it provides potential trade estimates that are close to free trade estimates, since it represents the upper limits of data, which come from those economies that have liberalised trade restrictions the most. Finally, it bears strong theoretical and trade policy implications. That is, it provides theoretical and policy recommendations for finding ways of improving the socio-political-institutional factors for frictionless trade (Bhattacharya and Das, 2014).

Though relatively new, the SFGM has been applied in several studies to calculate the trade potentials of countries. Kang and Fratianni (2006) used the SFGM approach to estimate trade efficiencies for several countries, ten geographical regions, and eleven regional trade agreements. Their trade efficiency estimates were low for the countries. They argued that “when the trade gravity equation is viewed as the outcome of cost minimisation, then the use of the stochastic frontier estimation is justified” (p. 5).

Armstrong et al. (2008) estimated a world export frontier to compare the trade performance of East Asia with South Asia. They found that East Asian countries performed better in terms of realised trade potential than South Asian countries and the rest of the world. Their findings showed that South Asian countries had vast unrealized trade potential.

Miankhel et al. (2009) applied the SFGM to estimate the trade potentials of Australia with 65 of her trading partners for the period 2007-2008. Various product classifications were used in their study instead of aggregate trade flows. The parameter estimates from their regression results for the various product classifications had the usual signs as would be expected in the standard gravity analysis. They found the parameter estimates of the non-negative disturbance term, which gives indication of the significance of “behind the border” factors in hindering trade flow from reaching its potential levels, to be statistically significant for all the product groups except one. They argued that given the statistical significance of this error term, the traditional gravity model would have produced inconsistent parameter estimates because of its deficiency to control for unobservable trade hindrances. Their calculation of trade potentials of various product groups of Australia with specific countries and regions indicated gaps of different proportions compared to the actual trade flows. Largely, Australia is far from reaching its trade potentials with various countries and regions as per their results.

Trade efficiency scores were calculated by Ravishankar and Stack (2014) for ten Eastern European Countries (new members of the European Union) with seventeen Western European Countries (established members of the European Union) using the SFGM. The model was estimated using the export flows of the seventeen established members of the European Union with the ten new members from Eastern Europe as the importer countries. A panel framework covering the period 1994-2007 was used. The efficiency scores from their study were generally high, suggesting a high degree of trade integration of the ten Eastern European Countries with their counterparts of Western Europe over the 1994-2007 period.

The trade potentials and trade efficiency levels between country pairs of six countries of the South Asian Association for Regional Cooperation (SAARC) were estimated by Bhattacharya and Das (2014) using the SFGM. The countries included Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka. The stochastic frontier gravity equation was estimated for each of the six countries using panel data spanning 1995-2008. Trade efficiency levels between the countries were calculated for the period 1995-2000 and 2001-2008. Pakistan achieved the highest trade efficiency level with other members for the period 1995-2000, followed by Sri Lanka. Bhutan achieved the lowest efficiency level with other members for the same period. Relatively, India performed poorly in the exploitation of her trade potentials with the other countries.

Kalirajan and Paudel (2015) employed the SFGM framework to perform counterfactual analysis of a free trade agreement or preferential trade arrangement of India with China to find out the extent to which such trade arrangements will help India reduce her trade deficit with China. They used a panel data framework over 1995-2010 export data in fitting the stochastic frontier gravity equation for India and China. They found that under the prevailing tariff structures and exchange rate, India achieved 68 percent of her export potential with China, while China achieved 86 percent of her export potential with India. They performed a simulative exercise of a hypothetical 50 percent reduction in the simple average tariff, which was about 7.7 percent for China and 11.5 percent for India in 2010. The counterfactual analysis showed that the trade potential of India with China will roughly increase by 12 percent, and that of China with India will increase by 18 percent approximately. Under the scenario of a free trade arrangement of India with China, the counterfactual analysis showed that India will increase her export potential 20 percent, whereas China will increase her export potential to India by 28 percent. Given the results of the simulative exercises, they cautioned that India must first achieve her export potentials with China by working to reduce her “behind the border” trade resisting factors before making any attempt at forging either a preferential trade agreement or free trade arrangement with China.

Application of the gravity model to estimate the trade potentials of any of the countries of the WAMZ, either with other member countries of the WAMZ or with other trading partners in general is scarce in the literature. Adam and Tweneboah (2009) did, however, use the estimated parameters of the gravity equation in a study which focused on Ghana to project the bilateral trade flows of Ghana with her major trading partners, including the other five members of the WAMZ. Their results revealed the potential for trade growth of Ghana with Nigeria and Guinea, but exhausted trade flows of Ghana with the other members of the WAMZ. Adam and Tweneboah, (2009) cautioned that the success of the proposed single currency hinges on the proper intraregional integration of the countries. It must be noted, however, that their study suffers from the inherent weaknesses of the traditional gravity model estimated with OLS, particularly in its use to calculate trade potentials. Their potential trade flows were calculated using the mean effects of the determinants of trade included in their gravity equation. Therefore, their calculated trade flows were average trade flows, but not frictionless or optimum trade flows. Again, the failure to control for unobserved trade resistances and multilateral trade resistances between Ghana and her trading partners used in the estimation casts doubts on the consistency and efficiency of their regression results of the gravity model.

It is clear from the literature review that the SFGM has numerous strengths over the other methods of estimating trade potential. One of such major strengths of the SFGM is that it makes the empirical estimation of trade potential more consistent with the theoretical conceptualisation of trade potential. This is the main reason for the application of the SFGM in this study.

CHAPTER THREE: METHODOLOGY AND MODEL SPECIFICATION

In this chapter, we first describe the general stochastic frontier production function (SFPF) models which form the basis for the derivation of the SFGM. In particular, two specific stochastic frontier models are discussed, namely, the Battese and Coelli (1992) and the Kumbhakar (1990) models. Next, we introduce the general SFGM as well as the empirical model that will be used for the remainder of this thesis.

3.1 STOCHASTIC FRONTIER MODELS (SFM)

The Stochastic Frontier Production Function (SFPF) developed separately by Aigner et al. (1977) and Meeusen and van den Broeck (1977) has been a workhorse in the productivity and efficiency literature. The SFPF relates the maximum amount of output obtained from a given input level and technology to a structural part of the production function and to a decomposed disturbance term which can be written as:

$$y_{it} = f(x_{it};\beta) + v_{it} - u_{it}, \quad i = 1,2,\dots,n; t = 1,\dots,T_i \tag{1}$$

where in equation (1), y_{it} represents logarithm of output of firm i at time t; x_{it} is vector logarithm of inputs of firm i at time t; β is a vector of unknown parameters; $f(.)$ is a known production frontier function (e.g., Cobb-Douglas or Translog); v_{it} is a two-sided symmetric random disturbance representing factors that are beyond the firm's control such as weather, topography, machine performance, etc.; and $u_{it} \geq 0$ is a one-sided disturbance representing technical inefficiency. Following standard practice, it is assumed that $v_{it} \sim i.i.d\ N(0,\sigma_v^2)$, $u_{it} \sim i.i.d\ N^+(0,\sigma_u^2)$ where $N^+(\dots)$ denotes a half-normal (truncated at zero) distribution. For illustration and discussion purposes, half-normal distribution of u_{it} is used, albeit other distributions such as exponential, gamma, and truncated normal can also be used. Finally, it is assumed that the v_{it} and u_{it} are independent and both errors are independent of x_{it}.

Note that in equation (1), if the one-sided error term, u_{it} assumes a value of zero (i.e., if there are no productive inefficiencies), for a given input and technology, then the firm operates on the frontier of the production, implying that the firm is fully efficient, provided there are no statistical and measurement errors. On the other hand, any positive value of u_{it} indicates that the firm is operating below the frontier, implying that there exists productive inefficiency within the production process of the firm.

Under the distributional assumptions of v_{it} and u_{it}, the density function of $\varepsilon_{it} = v_{it} - u_{it}$ can be written as (e.g., Aigner et al. (1977)):

$$f(\varepsilon_{it}) = \frac{2}{\sigma}\phi\left(\frac{\varepsilon_{it}}{\sigma}\right)\left[1 - \Phi(\frac{\lambda\varepsilon_{it}}{\sigma})\right], \qquad -\infty \leqq \varepsilon_{it} \leqq +\infty; \tag{2}$$

where $\sigma^2 = \sigma_u^2 + \sigma_v^2$, $\lambda = \sigma_u/\sigma_v$, $\phi(.)$ and $\Phi(.)$ are standard normal density and standard cumulative distribution functions, respectively. The mean and the variance of the composite error ε_{it} are:

$$E(\varepsilon_{it}) = -\frac{\sqrt{2}}{\sqrt{\Pi}}\sigma_u, \tag{3}$$

$$V(\varepsilon_{it}) = V(u_{it}) + V(v_{it}) = \left(\frac{\Pi-2}{\Pi}\right)\sigma_u^2 + \sigma_v^2. \tag{4}$$

Based on equation (2), the log-likelihood function for y_{it} is then given by:

$$L(\theta|y,x) = \frac{1}{2}\sum_{i=1}^{N} T_i(ln2 - ln\pi - ln\sigma^2) - \frac{1}{2\sigma^2}\sum_{i=1}^{N}\sum_{t=1}^{T_i}[(y_{it} - f(x_{it},\beta))]^2 +$$

$$\sum_{i=1}^{N}\sum_{t=1}^{T_i}\ln\left\{1 - \Phi\left[\frac{\lambda(y_{it} - f(x_{it},\beta))}{\sigma}\right]\right\}, \tag{5}$$

where $\theta = (\beta, \lambda, \sigma^2)'$. Note that, it is clear from equation (5) when $\lambda = 0$ which implies $\sigma_u = 0$ (i.e., firms are fully efficient), the above log-likelihood function reduces to the log-likelihood function of a standard multiple regression with normal error.

The unknown parameter vector θ can be estimated by maximising the log-likelihood function in equation (5), that is,

$$\hat{\theta} = arg\max_{\theta} L(\theta|y, x). \tag{6}$$

Under certain regularity conditions, the maximum likelihood estimator (MLE) $\hat{\theta}$ is known to be consistent for large N and either large T or fixed T.

Note that, the SFPF and its estimation with maximum likelihood method lends itself to the calculation of the levels of productive or technical inefficiencies or efficiencies within a given firm over time or across firms at a given time. Thus, given the estimate of θ, the *technical inefficiency* of firm i at time t can be predicted based on Jondrow et al.'s (1982) prediction formula:

$$E(u_{it}|\varepsilon_{it}) = \left[\frac{\sigma\lambda}{1+\lambda^2}\right]\left[\tilde{\mu}_{it} + \frac{\phi(\tilde{\mu}_{it})}{\Phi(\tilde{\mu}_{it})}\right], \tag{7}$$

where $\tilde{\mu} = \frac{\lambda\varepsilon_{it}}{\sigma}$. Alternatively, the *technical efficiency* of firm i at time t can be predicted as $E[\exp(-u_{it})|\varepsilon_{it}]$.

3.2 THE KUMBHAKAR (1990) MODEL.

The general stochastic production frontier models presented in equation (1) leave the firm's specific technical inefficiency in an unrestricted form. Kumbhakar (1990) proposed a specific model for the technical inefficiency by allowing for it to vary according to a specific pattern: that is, he assumed $u_{it} = \gamma(t)u_i$. Kumbhakar's model can be generally written as:

$$y_{it} = f(x_{it}; \beta) + v_{it} - u_{it}, \tag{8}$$

$$u_{it} = \gamma(t)u_i = (1 + \exp(bt + ct^2))^{-1}u_i, \tag{9}$$

where it is apparent that $\gamma(t)$ is a well-defined function of time, b and c are unknown parameters to be estimated along with the unknown parameters of the frontier β, and u_i is assumed to $i.i.d.N(0, \sigma_u^2)$ and truncated at zero. From equation (9), it can be shown that $\gamma(t)$ has values between zero and one, and it can be monotonically increasing (decreasing) or concave (convex) depending on the signs and magnitudes of b and c. As Kumbhakar (1990) noted, if $(b + ct)$ was negative (or positive), the simpler function $(1 + \exp(bt))^{-1}$ may be appropriate.

Under the distributional assumptions on v_{it} and u_{it}, the log-likelihood function for y_{it} and the predicted firm specific technical inefficiency are obtained by setting $\xi_{it} = 1$ in equation (6) and equation (8) of Kumbhakar (1990), respectively.

3.3 THE BATTESE AND COELLI (1992) MODEL

In contrast to Kumbhakar's (1990) model for time specific pattern technical inefficiency, Battese and Coelli (1992) suggest an alternative model for firm specific technical inefficiency by allowing it to depend on a simple exponential function of time. Their model can be written as:

$$y_{it} = f(x_{it}; \beta) + v_{it} - u_{it}, \tag{10}$$

$$u_{it} = \eta_{it} u_i = \{exp[-\eta(t - T)]\} u_i, \qquad t \in g(i); i = 1, 2, \ldots, N \tag{11}$$

where η is an unknown scale parameter and $g(i)$ represents the set of T_i time periods among which the T periods involved for which observations for the ith firm are obtained. In their model, the u_i's are assumed to be independent and identically distributed non-negative truncations of the $N(\mu, \sigma^2)$ distribution. In equation (11), it is apparent that technical inefficiency decreases, remains constant, or increases if $\eta > 0$, $\eta = 0$ and $\eta < 0$ respectively. Note that, the case in which $\eta > 0$ is likely to be more appropriate when firms tend to improve their level of technical efficiency overtime. In addition, the specification of time-varying technical inefficiency in (11) is a ridged parameterization in the sense that the technical efficiency must either increase at an increasing rate ($\eta > 0$), decrease at an increasing rate ($\eta < 0$), or remain constant ($\eta = 0$). This restriction can be relaxed if one desires by allowing η_{it} to have a quadratic form as in the Kumbhakar (1990) model. That is, a more flexible model is:

$$\eta_{it} = 1 + \eta_1 (t - T) + \eta_2 (t - T)^2$$

where η_1 and η_2 are unknown parameters. Similar to Kumbhakar (1990), this model allows firm specific effects to be convex or concave but the time invariant model is a special case when $\eta_1 = \eta_2 = 0$.

Based on the distributional assumptions of normal and truncated normal for the v_{it}'s and u_i's, respectively, the density function for $\varepsilon_{it} = y_{it} - f(x_{it}; \beta) = v_{it} - \eta_{it} u_i$, then can be obtained as:

$$f(\varepsilon_{it}) = \frac{\left[1 - \Phi\left(-\frac{\mu_i^*}{\sigma_i^*}\right)\right] exp\left\{-\frac{1}{2}\left(\frac{\varepsilon_{it}^{'}\varepsilon_{it}}{\sigma_v^2}\right) + \left(\frac{\mu}{\sigma}\right)^2 - \left(\frac{\mu_i^*}{\sigma_i^*}\right)^2\right\}}{(2\pi)^{\frac{T_i}{2}} \sigma_v^{(T_i - 1)} \left\{\sigma_v^2 + \eta_i^{'}\eta_i \sigma^2\right]^{\frac{1}{2}} \left[1 - \Phi\left(-\frac{\mu}{\sigma}\right)\right]\right\}}, \tag{12}$$

where

$$\mu_i^* \equiv \frac{\mu\sigma_v^2 - \eta_i^{'}\varepsilon_{it}\sigma^2}{\sigma_v^2 + \eta_i^{'}\eta_i\sigma^2},$$

$$\sigma_i^{*2} \equiv \frac{\sigma^2\sigma_v^2}{\sigma_v^2 + \eta_i^{'}\eta_i\sigma^2},$$

where η_i is a $(T_i \times 1)$ vector of $\eta_{it}'s$ associated with the time periods observed for the i^{th} firm and $\Phi(.)$ represents the cumulative distribution function for the standard normal random variable. Given (12), the logarithm of the likelihood function for the sample observations, (y_{it}, x_{it}) is:

$$L^*(\theta; y) = \frac{1}{2}\left(\sum_{i=1}^{N} T_i\right)\{ln(2\pi) + ln(\sigma_s^2)\} - \frac{1}{2}\sum_{i=1}^{N}(T_i - 1)ln(1-\gamma) - \frac{1}{2}\sum_{i=1}^{N}\sum_{t=1}^{T_i} ln\left[1 + \left(\eta_{it}^{'}\eta_{it} - 1\right)\gamma\right] - Nln[1 - \Phi(-z)] - \frac{1}{2}Nz^2 + \sum_{i=1}^{N}\sum_{t=1}^{T_i} ln[1 - \Phi(-z_{it}^*)] + \frac{1}{2}\sum_{i=1}^{N}\sum_{t=1}^{T_i} z_{it}^{*2} - \frac{1}{2}\sum_{i=1}^{N}\sum_{t=1}^{T_i}\left(y_{it} - f(x_{it};\beta)\right)'(y_{it} - f(x_{it};\beta))/(1-\gamma)\sigma_s^2 \quad (13)$$

where $\theta \equiv (\beta^{'}, \sigma_s^2, \gamma, \mu, \eta)^{'}$, $\sigma_v^2 + \sigma^2 = \sigma_s^2$, $\gamma = \sigma^2/\sigma_s^2$, $z \equiv \mu/(\gamma\sigma_s^2)^{1/2}$, and $z_{it}^* = \frac{\mu(1-\gamma) - \gamma\eta_{it}^{'}(y_{it} - f(x_{it};\beta))}{\{\gamma(1-\gamma)\sigma_s^2\left[1 + \left(\eta_{it}^{'}\eta_{it} - 1\right)\gamma\right]\}^{1/2}}$.

The MLE of θ then can be obtained by maximizing the log-likelihood function given in (13). Battese and Coelli (1992) showed that the specific technical efficiency of the ith firm at time t, $TE_{it} = \exp(-u_{it})$ can be predicted using minimum-mean-squared-error predictor, and it is given by:

$$E[\exp(-u_{it})|\varepsilon_{it}] = \left\{\frac{1 - \Phi\left[\eta_{it}\sigma_{it}^* - \left(\frac{\mu_{it}^*}{\sigma_{it}^*}\right)\right]}{1 - \Phi\left(-\frac{\mu_{it}^*}{\sigma_{it}^*}\right)}\right\} \exp\left[-\eta_{it}\mu_{it}^* + \frac{1}{2}\eta_{it}^2\sigma_{it}^{*2}\right]. \quad (14)$$

3.4 THE STOCHASTIC FRONTIER GRAVITY MODEL (SFGM)

The TGM is one of the most applied frameworks for empirical work in international economics. The TGM is based on the Newtonian Universal Law of Gravitation which states that the gravitational force between objects is proportional to the masses of the objects and inversely related to the squared of the distance between the objects (Newton, 1687). The TGM was introduced into empirical economic literature by Tinbergen (1962). In its basic form, the model predicts that the volume of trade flow between two countries is proportionally related to the scales of the two countries, which is mostly represented with the gross domestic products of the two countries and inversely related to the geographical distance between the pair of countries, which is a proxy mainly for the transportation costs involved in the movement of the goods.

The theoretical foundation of the TGM was called into question in the 1970s and was later provided through the works of Anderson (1979), Bergstrand (1985, 1989), Deardorff (1998), and Easton and Kortum (2002). Anderson's (1979) derivation of the TGM was based on Armington's (1969) assumption of differentiation of goods by their place of production. Bergstrand (1985, 1989) derived the TGM from Helpman and Krugman's (1985) trade theory of monopolistic competition with differentiated products and economies of scale and the factor proportions trade theory. Deardorff (1998) based his derivation of the TGM on the Heckscher-Ohlin trade theory of relative differences in factor endowments of countries. Easton and Kortum (2002) applied the Ricardian trade theory of differences in production technologies across countries in their derivation of the TGM.

Given the inherent weaknesses of the traditional gravity model which have been discussed in the literature review in chapter two, the SFGM has emerged as an improved alternate framework for the estimation of the trade potentials. Generally, the SFGM version of the TGM draws mainly on the concept of SFPM and it can be stated as follows:

$$x_{ijt} = f(z_{ijt}; \beta) + v_{ijt} - u_{ijt}, \tag{15}$$

where x_{ijt} represents actual export from country i to country j at time t. $f\left(z_{ijt};\beta\right)$ is a function of a vector, z_{ijt}, of determinants of potential export of country i to j at time t, and β is a vector of unknown parameters; u_{ijt} is a one-sided error term which represents country specific factors of the exporting country at time t that constrain its exports from reaching potential level given the determinants of its export. They are referred to in the literature as "behind the border" factors. When this error term assumes a value of zero, it implies that "behind the border" factors are insignificant and that actual export is the same as potential export provided there are no statistical errors. When it takes a value other than zero, it means that country specific factors are important and they constrain actual export from reaching the potential export. Finally, v_{ijt} is the conventional error term which controls for statistical errors and omitted variables. However, in the context of the SFGM, this error term also controls for "beyond the border" trade resisting factors. These are factors that are under the control of the importer. These trade resisting factors can be removed by the exporter through trade agreements with the importer.

3.5 THE EMPIRICAL MODEL

Various specifications of the gravity equation have been put forward and applied depending on the underlying assumptions for their derivation and the research question of a given study. In the context of the SFGM estimation, Armstrong (2007) has put forward a suggested model specification and it is his suggested specification that motivates the model specification used for this study.

The model specification suggested by Armstrong (2007) is comprised of two stages of estimation. The first stage involves the estimation of a trade frontier and the second stage involves the estimation of the determinants that explain the variation in the one-sided error term. Armstrong (2007) proposes that the basic elements of the TGM such as gross domestic products (GDPs), relative distance, border effects and other determinants which cannot be altered in the medium to long term (such as language) are included in the estimation of the trade frontier. He calls these factors the natural determinants of trade.

$$t_{ij} = f\left(dist_{ij}, other\ stuff\right) \tag{16}$$

He defines the trade resistances between country i and j per equation (16). This is further broken down into man-made and natural resistances in (17): Natural resistances are barriers to trade that are not policy related whereas man-made trade barriers are policy induced.

$$t_{ij} = f\left(resist_{ij}\right) = f\left(natural_{ij}, manmade_{ij}\right) = b\left(natural_{ij}\right)g(manmade_{ij}) \tag{17}$$

$$b\left(natural_{ij}\right) = rDist_{ij}^{\alpha_1} \exp\left(border_{ij}^{\alpha_2} + landlocked_i^{\alpha_3} + landlocked_j^{\alpha_4} + lang_{ij}^{\alpha_5}\right) \tag{18}$$

$$g\left(manmade_{ij}\right) =$$

$$g\left(trade\ agreements_{ij}, political\ dist_{ij}, regional\ blocs, tarriff, institution \ldots\right) \tag{19}$$

In equation (18), $rDist_{ij}$ is the relative distance between country i and j; $border_{ij}$ is a dummy variable which takes the value of one if i and j share a border or zero if otherwise. $Landlocked$ is a dummy variable which takes the value of one if a country is landlocked and $lang_{ij}$ is dummy variable if i and j share a similar language. In equation (19), $Trade\ agreements_{ij}$ is a dummy variable which represent a trade agreement between i and j; $political\ dist_{ij}$ is a measure of the political proximity between i and j;

$regional\ blocs$ is a dummy variable for regional trading groups; and $tarriff$ represents various tariff measures and $institution$ captures institutional settings.

$$lnt_{ij} = lnb(natural) + g(manmade) \qquad (20)$$

Equation (20) captures all the trade resistances between i and j. The standard gravity equation proposed by Armstrong (2007) is given below:

$$Inx_{ijt} = In\beta_0 + \beta_1 lny_{it} + \beta_2 Iny_{jt} + \beta_3 ln\, b(natural) + \sum_m \beta_m\, lnZ_m + v_{ijt} - u_{ij}, \qquad (21)$$

where $u_{ij} = \lambda(manmade_{ij}) \geq 0$.

x_{ijt} is the value of the trade flow from i to j at time t and $y_{it}(y_{jt})$ are the GDPs for i and j at time t. They control for the economic masses of country i and j. The Z's are the other determinants of trade. ε_{ijt} is the conventional double-sided error term and u_{ij} is the one-sided error term.

Given the focus of this study which is to estimate a trade frontier for each of the countries of the WAMZ as well as the trade efficiencies between each pair of countries, the empirical model used includes mainly the core elements of the TGM. One policy variable in the form of a dummy for preferential trade agreements (PTAs) is, however, included in the empirical model. The main reason for its inclusion is explained in the detailed explanations of the elements of the empirical model. Equation (22) is the stochastic frontier gravity equation to be estimated for each of the six countries of the WAMZ.

$$InEXP_{ijt} = \beta_0 + \beta_1 InGDPX_{it} + \beta_2 InGDPM_{jt} + \beta_3 InDIST_{ij} + \beta_4 LANG_{ij} + \beta_5 ECOWAS_{ijt} + \beta_6 PTA_{ijt} + v_{ijt} - u_{ijt}. \quad (22)$$

$InEXP_{ijt}$ is the logarithm of the value of the export flows from each of the six countries of the WAMZ to their top importing countries from the year 2000 through 2014. $InGDPX_{it}$ is the logarithm of the value of the gross national product of the exporting country at time t. It controls for the economic size of the exporting country concerning its production capacity. Larger countries have large production abilities and can export more based on the areas in which they have comparative advantages. All other things being equal, an increase in $InGDPX_{it}$ will increase the volume of exports. Thus, β_1 is expected to be positive, all other things being equal.

$InGDPM_{jt}$ is the logarithm of the value of the gross national product of the importing country at time t. It serves as an indicator of the economic size of the importing country concerning its market size. Larger countries have huge domestic markets; thus, they can absorb more imports. All other things being equal, an increase in $InGDPM_{jt}$ will increase import absorption of country j. Thus, β_2 is expected to be positive.

$InDIST_{ij}$ represents the logarithm of the absolute distance between the capital cities of bilateral trading partners i and j. It proxies mainly for the transportation costs between trading partners. Longer distance between trading partners serves as a barrier to trade. It makes the exports uncompetitive in the market of the importing country due to higher transportation costs incurred in the movement of goods which are transferred to consumers in the form of higher prices. According to Head (2003), the distance variable also captures other costs and barriers to trade. He identified cultural distance, communication costs, transaction costs, synchronization costs, and time elapsed during shipment as the other factors for which the distance factor proxies.[8] β_3 is expected to be negative.

$LANG_{ij}$ is an indicator variable that represents common language between the exporter and importer. Baxter and Kouparitsas (2005) described the language factor as the most commonly used measure of "cultural distance" in gravity modelling. It will take the value of 1 if the trading partners i and j share the same official language and zero otherwise. Generally, the common language factor between trading partners is assumed to reduce transaction costs and increase trade flows. Baxter and Kouparitsas (2005) categorised the language variable under universally included variables in gravity estimation because they claimed several studies have found it to be a robust determinant of bilateral trade flow. β_4 is expected to be positive.

$ECOWAS_{ijt}$ represents the membership of the exporter and importer of the Economic Community of West African States (ECOWAS) at time t. The Ecowas is a regional trading bloc of which all six countries of the WAMZ are members. It is a free trade area, at least on paper. Besides the variable's inclusion to capture the effects of the regional trading bloc on the trade flows of the countries of the WAMZ, it is also included to capture the effects of several other factors included in many gravity estimations such as adjacency or contiguity and the border effect. The other members of the ECOWAS are the immediate neighbours of the countries of the WAMZ, some of which share borders with them. Hence, the inclusion of this variable takes care of the adjacency effect and the border effect on the trade flows of the countries of the WAMZ. These factors are expected to have positive effects on the export flows of the countries of the WAMZ since it been demonstrated

[8] See Head (2003) for explanation of the other factors distance proxies for in gravity estimation.

empirically (cf. Baxter and Kouparitsas, 2005) that countries that share a common border or are geographically close tend to trade more given reductions in the costs of trade in the form of lower transportation costs. Again, some studies have been done in investigating the effects of regional trading blocs on the trade flows of member countries. For example, Frankel and Rose (2000) found that trade between a pair of countries triples if they belong to the same regional trading bloc.[9] They did admit that their result is slightly above the results of other studies. β_5 is expected to be positive.

PTA_{ijt} represents preferential trade agreements between the exporter and the importer at time t. The World Trade Organisation (WTO) defines PTA as unilateral trade preferences. European Union (EU) countries compose majority of the countries with which each of the six countries of the WAMZ has PTAs. Much uneasiness has been generated in the countries of WAMZ and in West Africa in general by the decision of the EU to replace the PTAs of its members with what it calls Economic Partnership Agreements (EPAs), which will allow the countries of the EU more access to the West African market. This policy variable is included primarily to test the general effects of PTAs on the trade flows of the countries of the WAMZ. Each of the six countries of the WAMZ also have PTAs with the following countries: Australia, Canada, Ireland, Japan, New Zealand, Switzerland, Turkey and, the USA. The theory predicts a positive relationship between PTA and trade flow, in that a PTA reduces "beyond the border" trade resistances. There is some empirical evidence in support of the prediction of the theory (cf. Bergstrand, 1989). PTA_{ijt} is an indicator variable that will take the value of 1 if the trading partners have a preferential trade agreement at time t. We expect β_6 to be positive.

[9] See also Baxter and Kouparitsas (2005).

u_{ijt} is an error term that controls for the combined effects of country specific "behind the border" implicit trade resisting factors: that is, unobservable trade resisting factors in the exporting country at time t. Broadly, this error term captures inefficiencies under the control of the exporter that limit trade flow from reaching its potential. Infrastructural rigidities, inefficiencies at the ports, bad economic policies, and institutional inefficiencies are a few of the specific "behind the border" resistances that this error term captures. The degrees of importance of "behind the border" resistances to the trade flows of each of the countries of the WAMZ over the periods under consideration would be generated together with β_0 to β_6 through the estimation of equation (22) for each of the countries of the WAMZ.

Several studies have found the estimated parameter of "behind the border" resistances to trade to be very significant in restraining the trade of countries from reaching potential levels. For example, Kalirajan and Paudel (2015) found it to be very significant in restraining the trade flows of China and India from reaching their potentials with their trading partners. Miankhel et al. (2009) and Sayavong (2015) found it to very significant in limiting trade flows of Australia and Laos respectively from reaching their frontier with their trading partners. Its estimated value is expected to be positive and statistically significant for each of the countries of the WAMZ. v_{ijt} represents the conventional error term that takes care of statistical errors and omitted variables. It also controls for "beyond the border" trade resistances.

Equation (22) would be estimated using maximum likelihood methods in line with the literature applying the Battese and Coelli (1992) model and the Kumbhakar (1990) model with their underlying assumptions.

CHAPTER FOUR: DATA AND THE EMPIRICAL RESULTS

In this chapter, the main sources of the data used, and the empirical results relating to the frontier and trade efficiency estimates of both the Battese and Coelli (1992) and Kumbhakar (1990) models, are reported and discussed. Also, the limitations of the empirical results are discussed in this chapter.

4.1 DATA AND THEIR SOURCES

The data for the export flows of the countries are obtained primarily from COMTRADE (online version). The Standard Trade International Classification Revision 3 (STIC REV. 3) data are used in the estimations. The reported trade values by the importing trading partners included in the samples for each of the six countries of the WAMZ are used because of their reliability and availability. The COMTRADE data is supplemented with trade data from the Direction of Trade (DOT) data. The lists catalogued by "globalEDGE" serve as a guide in the selection for the main trading partners of each of the countries of the WAMZ.[10]

The lists of the countries selected for the estimation of the empirical model for each country of the WAMZ are provided in the Appendices A through F. Except for The Gambia, balanced panels are used in the estimations of the models for each of the countries. The GDP data are obtained from World Development Indicators of the World Bank. The Purchasing Power Parity (PPP) converted values with 2011 as the base year are used. The data for the distance covariate is obtained from the CEPII.[11] The simple distances between

[10] "globaEDGE" is a knowledge web-portal created by the International Business Center at Michigan State University.
[11] CEPII refers to the French Centre d'Etudes Prospective et d'Informations Internationales.

capital cities in kilometers are used. CEPII also serves as a source in the creation of the language dummy variable. The list of the countries with which WAMZ members have preferential trade agreements are obtained from the World Trade Organisation's website. The list of the members of the ECOWAS is obtained from the worldwide web.

4.2 THE FRONTIER AND OTHER PARAMETER ESTIMATES OF THE BATTESE AND COELLI (1992) MODEL

The estimations were performed using Stata 13.1.[12] The frontier and other parameter estimates of the BC 92 model are reported in Table 1. We tested for the hypothesis that $\sigma_u^2 = 0$ against the alternative that $\sigma_u^2 \neq 0$ using the likelihood ratio test, and the test results are in favour of stochastic frontier estimation for each of the countries of the WAMZ. The test results are reported in Appendix G. Generally, most of the estimates of the frontier variables have the expected signs and are statistically significant. The sizes of the estimates of the variables are different for the various countries, suggesting that the individual countries have unique export relations. This provides some justification for the choice of the methodology applied in this study estimating individual trade frontiers for each of the countries, instead of estimating a trade frontier for the region.

Except for Liberia, the estimates of the $InGDPs$ of the exporter are all positive and statistically significant. This suggests that the countries of the WAMZ export more when the scales of their economies expand. The sizes of the estimates, however, are different for each of the countries. The $InGDPX$ estimates of Ghana and Nigeria are inelastic, whereas they are elastic for The Gambia, Guinea and Sierra Leone.

[12] Battese and Coelli (1992) model is hereafter referred to as BC 92 model.

Table 1: Maximum likelihood estimates for the countries of the WAMZ using Battese and Coelli (1992) model.

Variables	The Gambia	Ghana	Guinea	Liberia	Nigeria	Sierra Leone
InGDPX	4.54***	0.97***	6.80***	-0.28	0.97**	3.60***
	(1.25)	(0.28)	(1.80)	(0.45)	(0.34)	(0.70)
InGDPM	0 .46**	0.81***	1.64***	0.77***	1.28***	0.73***
	(0.16)	(0.08)	(0.22)	(0.16)	(0.21)	(0.14)
InDIST	-0.61	-0.66*	-3.85***	-1.14*	-0.95**	-2.06***
	(0.36)	(0.29)	(0.64)	(0.52)	(0.36)	(0.54)
LANG	0.14	-1.07***	0.38	0.03	0.25	1.23**
	(0.42)	(0.3)	(0.69)	(0.59)	(0.56)	(0.45)
PTA	0.4	-0.14	-1.25***	0.98*	0.30	0.83**
	(0.45)	(0.25)	(0.32)	(0.38)	(0.33)	(0.28)
ECOWAS	0.23	-0.84	-4.04**	-1.03	2.35**	-2.75
	(0.86)	(0.76)	(1.379)	(1.513)	(0.813)	(1.423)
Constant	-91.31***	-20.60**	-147.64***	11.63	-31.87***	-66.98***
	(26.17)	(7.40)	(38.99)	(10.91)	(8.17)	(13.90)
Sigma_2	2.12***	0.76***	2.13***	2.31***	2.08***	1.84***
	(0.23)	(0.19)	(0.19)	(0.41)	(0.28)	(0.2)
Gamma	0.25	0.38	0.89**	0.35	0.82*	0.12
	(0.43)	(0.33)	(0.28)	(0.69)	(0.41)	(0.39)
Mu	3.42***	1.93***	6.62***	0.48	2.72**	5.19***
	(0.79)	(0.39)	(1.19)	(2.25)	(0.85)	(0.68)
Eta	-0.04**	0.02***	-0.02**	0.48	0.01*	-0.04**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Log likelihood function	-1470.03	-1117.11	-1511.19	-1615.43	-1905.17	-1456.27
Number of Obs.	684	765	763	728	964	712

Note: The figures in parenthesis are standard errors.
Note: ***,** and * signify statistically significant at 1%, 5% and 10% respectively.

The estimates of the $InGDPs$ for the importer, which control for the scales of the trading partners of the countries of the WAMZ, are positive and statistically significant for all the six countries of the WAMZ. This is in line with our a priori expectation. The offshoot of this is that the trading partners of the countries of the WAMZ import more from the countries of the WAMZ as their economies expand. The $InGDPM$ estimates of Guinea and Nigeria are elastic whereas the estimates for the countries are inelastic.

Consistent with the a priori expectation based on the prediction of the theory which is discussed in chapter three, the estimates of the distance variable are negative for each of the six countries and are statistically significant except the estimate for The Gambia. The distance variable proxies mainly for transportation costs where a country trades less with far distanced countries due to higher transportation costs involved in the movement of the goods. The negatively signed estimates suggest that the countries of the WAMZ trade less with countries that are geographically distanced from them. It implies that distance is a major barrier to the export flows of the countries of the WAMZ. The distance estimates of Guinea, Sierra Leone, and Liberia are elastic, suggesting a more severe restraining force of distance on their exports. The distance estimates of the other three countries are inelastic.

The estimates for the language dummy variable are positive for all the countries except Ghana. However, it is only the estimate of Sierra Leone that is statistically significant. English is the official language of Sierra Leone. The sign of the estimate suggests that Sierra Leone exports more to English speaking countries. The negative and statistically significant estimate of Ghana is contrary to the prediction of the theory that language reduces transaction costs between bilateral trading partners and thereby increases bilateral trade flows.

The estimates of the PTA dyadic variable are positive for the following countries: The Gambia, Liberia, Nigeria, and Sierra Leone. However, it is only statistically significant for Liberia and Sierra Leone. Also, the sizes of the estimates of these two countries are significant. These results suggest that the PTAs of the two countries had real positive impact on the export flows of the two countries over the periods examined. The PTA estimates for Ghana and Guinea are negative. The estimate for Guinea is statistically significant. This suggests that the PTAs of Guinea did not have positive effect on her trade flows over the period.

The sign of the estimates of the ECOWAS categorical variable of The Gambia and Nigeria are in line with our a priori expectation: they are positive. However, it is only the estimate of Nigeria that is statistically significant. The positive and statistically significant estimate suggests Nigeria exports more to the ECOWAS region. The estimates of Ghana, Guinea, Liberia, and Sierra Leone are negative, but only statistically significant for Guinea. This is contrary to the expected sign informed by economic theory. This implies that the ECOWAS sub-region is not a significant export destination for Guinea.

4.2.1 THE GAMMA (γ) COEFFICIENT

$$\gamma = \frac{\sigma_u^2}{\sigma_u^2+\sigma_v^2} \tag{23}$$

The γ coefficient is defined per equation (23). σ_u^2 is the variance of the inefficiency error term. σ_v^2 is the variance of the double-sided random error term. The gamma coefficient ranges between zero and one in terms of its value. It explains the variation in the composite error term that is due to "behind the border" trade constraints for which the one-sided error term controls. A positive and statistically significant gamma coefficient confirms that trade constraints under the control of the exporter, which in this case is the six countries of the WAMZ, were effective in limiting the export flows of the countries from their potential levels. It is one of the diagnostic statistics that gives validity to the decomposition of the error term in equation (22).

The estimates of the gamma coefficient are positive for each of the six countries, but only the estimates of Guinea and Nigeria are statistically significant. This implies that for Guinea and Nigeria, "behind the border" factors significantly restrained their exports from reaching their frontiers. For the other four countries, the statistically insignificant estimates suggest that most of the variations in the composite error term were due to variation in the double-sided error term, which possibly could be coming from "beyond the border" trade resisting factors.

4.2.2 THE ETA (η) COEFFICIENT

The η coefficient gives indication to the behaviour of the gamma coefficient over time. A positive and statistically significant η coefficient shows that trade potential limiting factors under the control of the exporter decreased over time. A negative and statistically significant η indicates otherwise. The estimates of the η coefficient are positive for Ghana, Nigeria, and Liberia, but are only statistically significant for Ghana and Nigeria. These estimates suggest Ghana and Nigeria generally reduced the trade inefficiencies under their control over the period considered in the study. The opposite situation occurred in the cases of The Gambia, Guinea, and Sierra Leone, going by the negative and statistically significant η estimates.

4.2.3 THE MU ESTIMATE

This is an estimate of the mean of the one-sided error term. A statistically significant estimate indicates that the folded normal distribution (folded at the mean) fits the given data. Except for Liberia, the estimates are statistically significant for each of the countries. This implies the truncated normal distributional assumption for the one-sided error term fits the data used in the estimations.

4.3 THE FRONTIER AND OTHER PARAMETER ESTIMATES OF THE KUMBHAKAR (1990) MODEL

The frontier parameter estimates together with the other essential parameter estimates of the Kumbhakar (1990) model are reported in Table 2 below.[13] The estimates of the basic elements (i.e., GDPs for the exporter and importer and the distance variables) have the expected signs and are statistically significant in most cases for each of the six countries. The sizes of the estimates of the $InGDP$ for the exporter are significantly different from the estimates of the BC 90 model. The $InGDPX$ estimates of the KUMB 90 model for Ghana and Nigeria are elastic, whereas the estimates of the BC 92 model are inelastic. The estimates of the KUMB 90 model of The Gambia, Guinea, and Sierra Leone are smaller vis-à-vis the estimates of the BC 92 model. The estimate for Liberia, which is negative and statistically insignificant for the BC 92 model, is positive for KUMB 90 model but also statistically insignificant.

The sizes of KUMB 90 model estimates of the $InGDP$ of the importer are marginally different compared with the estimates of the BC 92 model. Like the results of the BC 92

[13] The Kumbhakar (1990) model is hereafter called KUMB 90 model.

Table 2: Maximum likelihood estimates for the countries of the WAMZ using Kumbhakar (1990) model.

Variables	The Gambia	Ghana	Guinea	Liberia	Nigeria	Sierra Leone
InGDPX	1.43*	2.04***	2.45***	0.60	1.71***	1.40***
	(0.57)	(0.13)	(0.69)	(0.38)	(0.17)	(0.22)
InGDPM	0.87***	0.74***	1.03**	0.85***	1.16***	0.78***
	(0.18)	(0.09)	(0.34)	(0.17)	(0.16)	(0.16)
InDIST	-1.23***	-0.93*	-1.81*	-1.13*	-1.08**	-1.08*
	(0.37)	(0.39)	(0.82)	(0.53)	(0.35)	(0.52)
LANG	-0.05	-0.99**	-0.18	-0.49	-0.19	-0.65
	(0.43)	(0.31)	(0.66)	(0.58)	(0.43)	(0.51)
PTA	-0.30	0.52*	-1.02**	1.10**	0.18	1.06***
	(0.45)	(0.23)	(0.33)	(0.38)	(0.31)	(0.31)
ECOWAS	0.08	-0.80	-3.16**	-0.02	1.98**	-0.55
	(1.05)	(0.96)	(1.20)	(1.67)	(0.63)	(1.25)
Constant	-29.69*	-43.90***	-49.93***	-9.99	-48.11***	-28.3***
	(12.03)	(4.99)	(15.02)	(9.55)	(5.18)	(6.49)
b	5.24	-9.57	-5.89	-10.77	-0.29	-1.49
	(70.88)	(-)[14]	(-)	(-)	(-)	(-)
c	-5.74	0.52***	-6.02	0.65***	-2.43*	0.06
	(70.87)	(0.02)	(251.38)	(0.07)	(0.96)	(0.05)
Usigma_2	8.06***	5.03***	17.89***	9.75***	15.73***	7.94***
	(2.08)	(1.20)	(4.40)	(2.38)	(3.16)	(2.33)
Vsigma_2	3.68***	0.90***	2.56***	4.27***	2.45***	3.11***
	(0.20)	(0.04)	(0.13)	(0.23)	(0.11)	(0.17)
Lambda	1.47***	2.36***	2.63***	1.51***	2.53***	1.59***
	(0.36)	(0.26)	(0.51)	(0.38)	(0.39)	(0.40)
Log likelihood function	-1470.89	-1127.87	-1529.09	-1621.2	-1909.01	-1473.16
Number of Obs.	684	765	763	728	964	712

Note: The figures in parenthesis are standard errors.
Note: ***,** and * signify statistically significant at 1%, 5% and 10% respectively.

[14] The estimates did not converge.

model, the $InGDPM$ estimates for Guinea and Nigeria are elastic, whereas the estimates for the other four countries are inelastic.

The KUMB 90 model estimate of the distance variable of The Gambia is statistically significant and twice the size of the estimate of the BC 92 model. The estimate of the BC 92 model is not significant, statistically. The estimates for Guinea and Sierra Leone from the KUMB 90 model are significantly lower, compared with the BC 92 model estimates.

The estimate of the language dummy variable of Ghana is negative and statistically significant like the result of the BC 92 model. This reinforces the earlier mentioned point that the estimates for Ghana did not live up to the prediction of the theory. The theory predicts otherwise. The BC 92 model estimate of Sierra Leone is consistent with the predicted sign of the language dummy variable and is statistically significant. Although the sign of the estimate of the KUMB 90 model flipped, it is statistically insignificant.

The estimates of the PTA dummy variable have the expected signs and are statistically significant for Ghana, Liberia and Sierra Leone. A similar result was obtained for only Liberia, and Sierra Leone in the case of the BC 92 model. Given the similarity in the results for Liberia and Sierra Leone, it can be inferred with a high degree of certainty that the PTAs of both countries significantly facilitated their trade flows over the period. The estimate for Guinea has an unexpected sign and is statistically significant. A similar result was obtained in the case of the BC 90 model. This cements the inconsistency of the results per the prediction of the theory.

The estimates for the ECOWAS dyadic variable are similar to the results obtained for the BC 92 model. The estimate of Nigeria has the expected sign and is statistically significant. The opposite is the case for Guinea. Given the similarity of the results, it goes to reinforce the importance of the ECOWAS market for Nigeria and the failure of the estimate of Guinea to live up to the prediction of the theory.

4.3.1 THE LAMBDA (λ) ESTIMATE

The lambda parameter is defined as:

$$\lambda = \frac{\sigma_u}{\sigma_v}, \tag{24}$$

where σ_u is the standard error of the one-sided error term and σ_v is the standard error of the double-sided error component. The lambda parameter measures of the proportion of the composite error term that is due to the one-sided error term. In other words, it gives an indication of how significant the inefficiency error term is in restraining trade flow from the frontier. The estimates for the lambda parameter are statistically significant for each of the six countries. The inefficiency levels are 1.479, 2.363, 2.639, 1.510, 2.531 and 1.596 more than the random error for The Gambia, Ghana, Guinea, Liberia, Nigeria, and Sierra Leone respectively. This implies that "behind the border" trade barriers significantly restrained the trade flows of the six countries from reaching their potentials over the period. The estimates for the six countries validate the decomposed modelling of the error term. They show that the empirical model is a good fit for the data.

4.4 TRADE EFFICIENCY ESTIMATES

$$TE = E[\exp(-u_{it})|\varepsilon_{it}] \tag{25}$$

The trade efficiency estimates of the BC 92 and KUMB 90 models were calculated using equation (25), which is a formulation by Battese and Coelli (1988). Trade efficiency refers to the tapped trade potential. Two important points are worth highlighting here for the proper perspective and better appreciation of the trade efficiency estimates between the countries of the WAMZ. Firstly, trade potential in the context of the SFGM is conceptualised differently from the initial studies that interpreted the predicted trade flow from the estimated TGM using OLS or other variants of it as potential trade. In the words of Armstrong et al. (2008) "trade potential is the trade achieved at a frontier that estimates a level of trade that might be achieved in the case of the most opened and frictionless trade possible given the current trade, transport and institutional technologies or practices" (p. 3). With this conceptualization of trade potential, no country can exceed the potential level of trade which is the opposite of the results of some of the earlier studies that found the predicted trade flow to exceed the actual trade flow. The benchmark trade flow (the potential trade) is set relatively higher here.

Secondly, the trade efficiency estimates in the case of Ghana for instance for the other member countries of the WAMZ are better appreciated if viewed relative to the performance of the other countries included in the sample used to estimate Ghana's trade frontier. We have therefore provided the average trade efficiency estimates of each of the countries included in the samples in the Appendices for the BC 92 model to enable the reader appreciate how the efficiency estimates of the countries of the WAMZ fare, relative to the other sample members of each of the six countries of the WAMZ.

It is also worth stating that given the divergent modelling of the non-negative error term by BC 92 and KUMB 90 models, no direct comparisons can be made between the efficiency estimates.

Generally, and on an average basis, the efficiency estimates between the countries of the WAMZ are mixed. Some are as high as over sixty percent and others are as low as zero percent. The trade efficiency estimates of The Gambia for the other members of the WAMZ

Table 3: The Trade efficiency estimates of The Gambia for the other countries of the WAMZ over 2000-2014.

Year	Ghana BC 92	Ghana KUMB 90	Guinea BC 92	Guinea KUMB 90	Liberia BC 92	Liberia KUMB 90	Nigeria BC 92	Nigeria KUMB 90	Sierra Leone BC 92	Sierra Leone KUMB 90
2000	0.202	0.43	0.719	0.784	-	-	0.081	0.092	0.187	0.424
2001	0.19	0.269	0.71	0.687	-	-	0.073	0.022	0.175	0.264
2002	0.178	0.269	0.701	0.687	-	-	0.065	0.022	0.163	0.264
2003	0.166	0.269	0.691	0.687	0.057	0.215	0.058	0.022	0.152	0.264
2004	0.154	0.269	0.682	0.687	0.051	0.215	0.052	0.022	0.141	0.264
2005	0.143	0.269	0.672	0.687	0.045	0.215	0.046	0.022	0.131	0.264
2006	0.133	0.269	0.662	0.687	0.04	0.215	0.041	0.022	0.12	0.264
2007	0.123	0.269	0.652	0.687	0.035	0.215	0.036	0.022	0.111	0.264
2008	0.113	0.269	0.642	0.687	0.03	0.215	0.031	0.022	0.101	0.264
2009	0.104	0.269	0.631	0.687	0.026	0.215	0.027	0.022	0.093	0.264
2010	0.095	0.269	0.621	0.687	0.023	0.215	0.023	0.022	0.084	0.264
2011	0.086	0.269	0.61	0.687	0.019	0.215	0.02	0.022	0.077	0.264
2012	0.079	0.269	0.599	0.687	0.017	0.215	0.017	0.022	0.069	0.264
2013	0.071	0.269	0.588	0.687	0.014	0.215	0.015	0.022	0.062	0.264
2014	0.064	0.269	0.577	0.687	0.012	0.215	0.012	0.022	0.056	0.264

Source: calculated by the researchers.

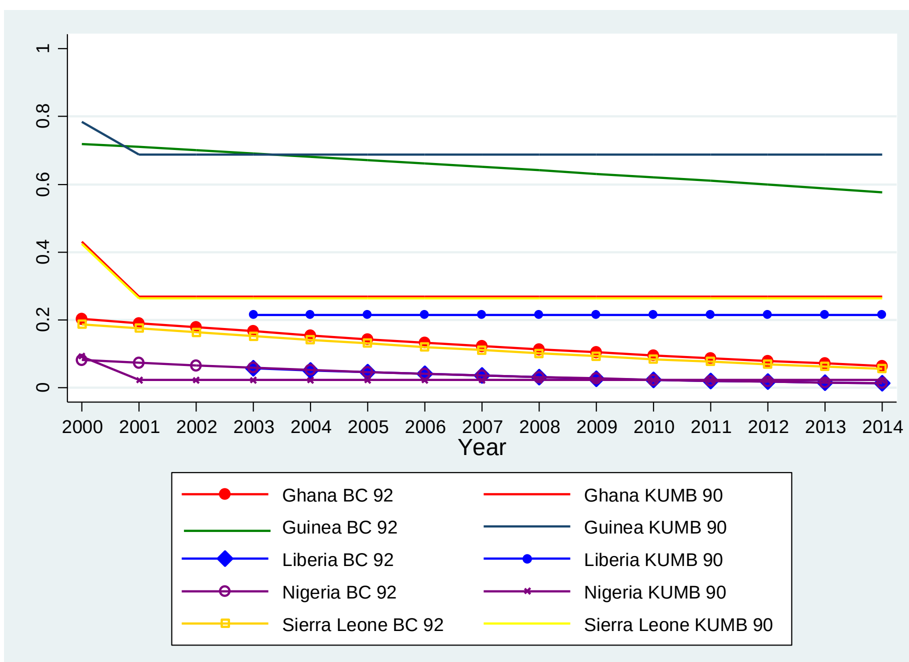

Figure 1: The trade efficiency estimates of The Gambia for the other countries of the WAMZ over 2000-2014.

are reported in Table 3 and plotted in Figure 1. The estimates for both models exhibit declining trends over the period, as indicated in Figure 1. On average, the trade efficiency levels of The Gambia for Guinea and Nigeria using the BC 92 and the KUMB 90 models are similar. The Gambia's estimates for Guinea rank the highest. They are close to the export frontier. This is followed by Ghana and Sierra Leone. The trade efficiency estimates of The Gambia for Ghana and Sierra Leone on the average lie below the half way mark of the frontier. The estimates for Nigeria are closer to the lower boundary of the export frontier. For Liberia, on average, the efficiency estimates of the BC 92 model are close to the lower boundary of the export frontier, whereas the average estimate for KUMB 90 model is 21 percent.

The trade efficiency estimates of Ghana for the other countries of the WAMZ are reported in Table 4 and shown graphically in Figure 2. On the average, there are remarkable similarities between the estimates of the BC 92 and KUMB 90 models. The estimates of the BC 90 model show an increasing trend over the period. The estimates of the KUMB 90 model demonstrate a decreasing trend over the period.[15] Overall, the trade efficiency estimates on the average are below the 50 percent mark of the export frontier. The trade efficiencies of Ghana are highest for The Gambia and followed closely by Nigeria. Sierra Leone and Liberia follow with average efficiency scores that are a little below the 10 percent mark of the export frontier. The average estimates for Guinea are marginally below the average estimates for Sierra Leone.

[15] The trade efficiency estimates of Ghana; Guinea; and Liberia declined monotonically over the 2000-2014 period for the KUMB 90 model. However, the differences between the estimates are negligible, thus, in rounding off the decimals, the differences are lost both in the tables and on the graphs.

Table 4: The trade efficiency estimates of Ghana for the other members of the WAMZ over 2000-2014.

Year	The Gambia BC 92	The Gambia KUMB 90	Guinea BC 92	Guinea KUMB 90	Liberia BC 92	Liberia KUMB 90	Nigeria BC 92	Nigeria KUMB 90	Sierra Leone BC 92	Sierra Leone KUMB 90
2000	0.177	0.316	0.023	0.07	0.045	0.087	0.101	0.237	0.042	0.093
2001	0.186	0.316	0.026	0.07	0.049	0.087	0.108	0.237	0.046	0.093
2002	0.195	0.316	0.029	0.07	0.053	0.087	0.115	0.237	0.05	0.093
2003	0.204	0.316	0.032	0.07	0.058	0.087	0.122	0.237	0.055	0.093
2004	0.214	0.316	0.035	0.07	0.063	0.087	0.129	0.237	0.06	0.093
2005	0.223	0.316	0.039	0.07	0.068	0.087	0.137	0.237	0.065	0.093
2006	0.233	0.316	0.042	0.07	0.073	0.087	0.145	0.237	0.07	0.093
2007	0.243	0.316	0.046	0.07	0.079	0.087	0.153	0.237	0.075	0.093
2008	0.252	0.316	0.051	0.07	0.085	0.087	0.162	0.237	0.081	0.093
2009	0.262	0.316	0.055	0.07	0.091	0.087	0.17	0.237	0.087	0.093
2010	0.273	0.316	0.06	0.07	0.097	0.087	0.179	0.237	0.094	0.093
2011	0.283	0.316	0.065	0.07	0.104	0.087	0.188	0.237	0.1	0.093
2012	0.293	0.316	0.07	0.07	0.111	0.087	0.197	0.237	0.107	0.093
2013	0.303	0.316	0.076	0.07	0.118	0.087	0.207	0.237	0.114	0.093
2014	0.314	0.316	0.082	0.07	0.126	0.087	0.216	0.237	0.121	0.093

Source: calculated by the researchers.

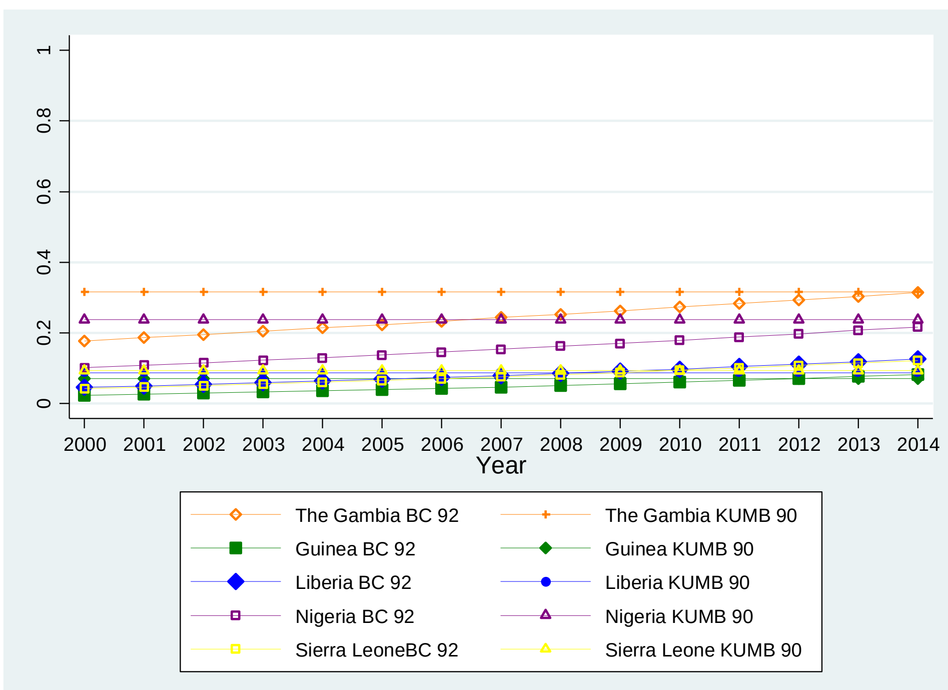

Figure 2: The trade efficiency estimates of Ghana for the other countries of the WAMZ over 2000-2014.

Table 5: The trade efficiency estimates of Guinea for the other members of the WAMZ over 2000-2014.

Year	The Gambia BC 92	The Gambia KUMB 90	Ghana BC 92	Ghana KUMB 90	Liberia BC 92	Liberia KUMB 90	Nigeria BC 92	Nigeria KUMB 90	Sierra Leone BC 92	Sierra Leone KUMB 90
2000	0.005	0.046	0.024	0.126	0.07	0.478	0	0.002	0.003	0.104
2001	0.005	0.046	0.022	0.126	0.06	0.478	0	0.002	0.002	0.104
2002	0.004	0.046	0.02	0.126	0.062	0.478	0	0.002	0.002	0.104
2003	0.003	0.046	0.019	0.126	0.058	0.478	0	0.002	0.002	0.104
2004	0.003	0.046	0.017	0.126	0.055	0.478	0	0.002	0.001	0.104
2005	0.003	0.046	0.015	0.126	0.051	0.478	0	0.002	0.001	0.104
2006	0.002	0.046	0.014	0.126	0.048	0.478	0	0.002	0.001	0.104
2007	0.002	0.046	0.013	0.126	0.044	0.478	0	0.002	0.001	0.104
2008	0.002	0.046	0.011	0.126	0.041	0.478	0	0.002	0	0.104
2009	0.001	0.046	0.01	0.126	0.039	0.478	0	0.002	0	0.104
2010	0.001	0.046	0.009	0.126	0.036	0.478	0	0.002	0	0.104
2011	0.001	0.046	0.008	0.126	0.033	0.478	0	0.002	0	0.104
2012	0.001	0.046	0.007	0.126	0.031	0.478	0	0.002	0	0.104
2013	0	0.046	0.007	0.126	0.028	0.478	0	0.002	0	0.104
2014	0	0.046	0.006	0.126	0.026	0.478	0	0.002	0	0.104

Source: calculated by the researchers.

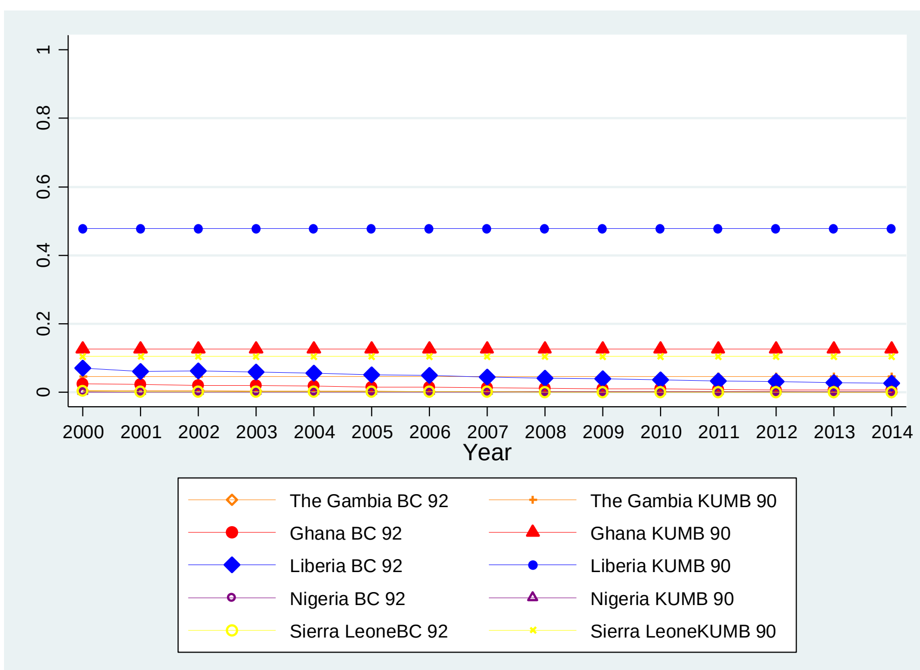

Figure 3: The trade efficiency estimates of Guinea for the other countries of the WAMZ over 2000-2014.

Table 6: The trade efficiency estimates of Liberia for the other countries of the WAMZ over 2000-2014.

Year	The Gambia BC 92	The Gambia KUMB 90	Ghana BC 92	Ghana KUMB 90	Guinea BC 92	Guinea KUMB 90	Nigeria BC 92	Nigeria KUMB 90	Sierra Leone BC 92	Sierra Leone KUMB 90
2000	0.557	0.638	0.204	0.215	0.016	0.017	0.046	0.054	0.582	0.639
2001	0.564	0.638	0.212	0.215	0.017	0.017	0.05	0.054	0.589	0.639
2002	0.571	0.638	0.22	0.215	0.019	0.017	0.054	0.054	0.596	0.639
2003	0.579	0.638	0.227	0.215	0.021	0.017	0.058	0.054	0.603	0.639
2004	0.586	0.638	0.235	0.215	0.023	0.017	0.062	0.054	0.61	0.639
2005	0.593	0.638	0.243	0.215	0.026	0.017	0.066	0.054	0.617	0.639
2006	0.6	0.638	0.251	0.215	0.028	0.017	0.071	0.054	0.623	0.639
2007	0.607	0.638	0.26	0.215	0.031	0.017	0.076	0.054	0.63	0.639
2008	0.614	0.638	0.268	0.215	0.033	0.017	0.081	0.054	0.637	0.639
2009	0.621	0.638	0.276	0.215	0.036	0.017	0.086	0.054	0.643	0.639
2010	0.627	0.638	0.285	0.215	0.04	0.017	0.091	0.054	0.65	0.639
2011	0.634	0.638	0.293	0.215	0.043	0.017	0.097	0.054	0.656	0.639
2012	0.641	0.638	0.302	0.215	0.046	0.017	0.102	0.054	0.663	0.639
2013	0.648	0.638	0.311	0.215	0.05	0.017	0.108	0.054	0.669	0.639
2014	0.654	0.638	0.319	0.215	0.054	0.017	0.114	0.054	0.675	0.639

Source: calculated by the researchers.

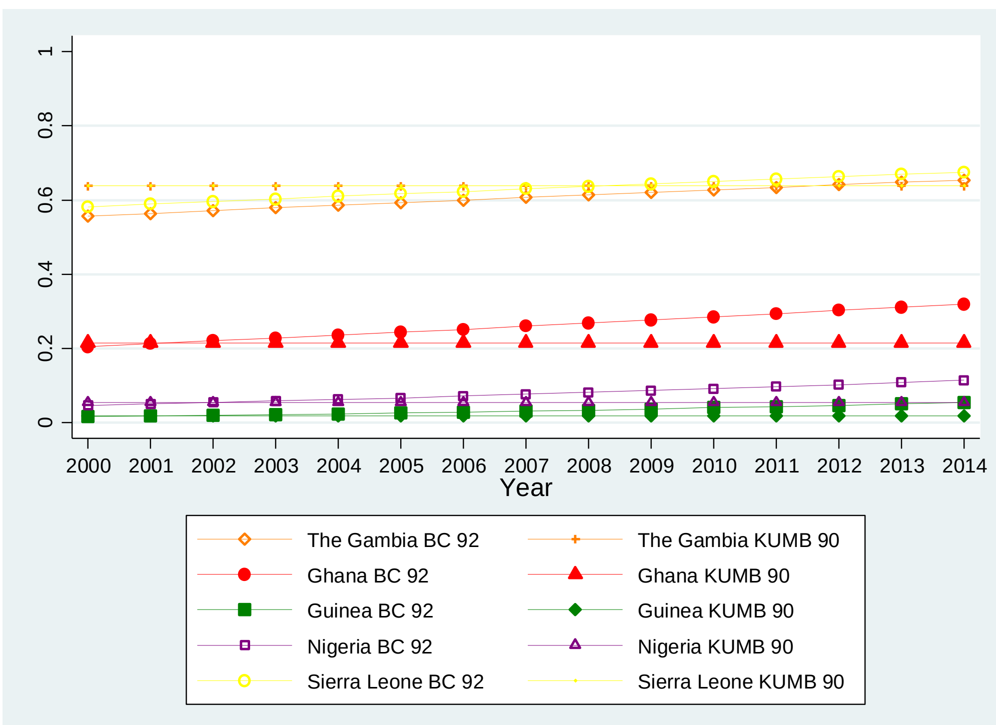

Figure 4: The trade efficiency estimates of Liberia for the other countries of the WAMZ over 2000-2014.

The estimates of the trade efficiencies of Guinea for the other countries of the WAMZ are generally very low. The estimates are presented in Table 5 and are graphically displayed in Figure 3. The estimates of the BC 92 model as well as the KUMB 90 model declined over the period under consideration. The estimates for Nigeria lie on the lower boundary of the export frontier for both models. The estimates for the other countries on the average differ for both models. The disparities are pronounced for Liberia where the average efficiency estimate for the KUMB 90 model is close to the fifty percent mark of the frontier, whereas the estimates on the average for the BC 92 model are below the ten percent mark of the frontier. The differences in the results for The Gambia, Ghana, and Sierra Leone are less pronounced.

On the average, the trade efficiency estimates of Liberia for the other countries of the WAMZ are similar for BC 92 and KUMB 90 models. The results are reported in Table 6 and plotted in Figure 4. The BC 92 model estimates have an increasing trend over the period. The estimates for the KUMB 90 model decreased over the period. On the average, the estimates for The Gambia are above the fifty percent mark of the export frontier. The estimates for Ghana on the average lie above the twenty percent mark of the frontier. In the cases of Guinea and Liberia, the estimates on the average are below the ten percent mark of the frontier. The estimates for Nigeria are closer to frontier’s lower level.

The trade efficiency estimates of Nigeria for the other countries of the WAMZ exhibit an increasing trend over the period for the BC 92 model, but a declining trend for the KUMB 90 model. However, the estimates are in most cases similar on the average for both models. The highest trade efficiency estimates of Nigeria are for Liberia. There are substantial disparities in the average estimates for the two models. The estimates for the BC 92 model are on the average below the twenty percent mark of the frontier but above

Table 7: The trade efficiency estimates of Nigeria for the other countries of the WAMZ over 2000-2014.

Year	The Gambia BC 92	The Gambia KUMB 90	Ghana BC 92	Ghana KUMB 90	Guinea BC 92	Guinea KUMB 90	Liberia BC 92	Liberia KUMB 90	Sierra Leone BC 92	Sierra Leone KUMB 90
2000	0.014	0.034	0.046	0.12	0.008	0.018	0.154	0.422	0.012	0.083
2001	0.014	0.027	0.048	0.105	0.009	0.014	-	-	-	-
2002	0.015	0.027	0.05	0.105	0.009	0.014	-	-	0.013	0.071
2003	0.016	0.027	0.052	0.105	0.01	0.014	-	-	-	-
2004	0.017	0.027	0.054	0.105	0.011	0.014	-	-	-	-
2005	0.018	0.027	0.056	0.105	0.011	0.014	-	-	-	-
2006	0.019	0.027	0.058	0.105	0.012	0.014	0.177	0.401	0.017	0.071
2007	0.02	0.027	0.061	0.105	0.013	0.014	0.181	0.401	0.018	0.071
2008	0.022	0.027	0.063	0.105	0.014	0.014	0.185	0.401	0.019	0.071
2009	0.023	0.027	0.066	0.105	0.015	0.014	0.19	0.401	0.02	0.071
2010	0.024	0.027	0.068	0.105	0.016	0.014	0.194	0.401	0.021	0.071
2011	0.025	0.027	0.071	0.105	0.016	0.014	0.198	0.401	0.022	0.071
2012	0.027	0.027	0.073	0.105	0.017	0.014	0.202	0.401	0.023	0.071
2013	0.028	0.027	0.076	0.105	0.018	0.014	0.206	0.401	0.024	0.071
2014	0.029	0.027	0.079	0.105	0.02	0.014	0.211	0.401	0.026	0.071

Source: calculated by the researchers.

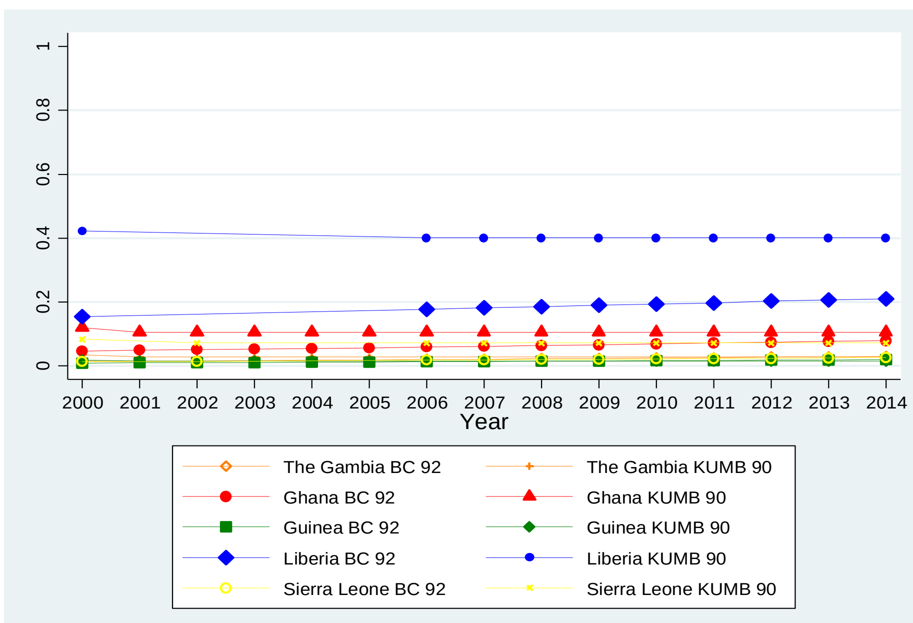

Figure 5: The trade efficiency estimates of Nigeria for the other countries of the WAMZ over 2000-2014.

Table 8: The trade efficiency estimates of Sierra Leone for the other countries of the WAMZ over 2000-2014.

Year	The Gambia BC 92	The Gambia KUMB 90	Ghana BC 92	Ghana KUMB 90	Guinea BC 92	Guinea KUMB 90	Nigeria BC 92	Nigeria KUMB 90
2000	0.054	0.62	0.115	0.659	0.045	0.203	0.056	0.225
2001	0.048	0.57	0.105	0.619	0.039	0.158	0.049	0.179
2002	0.042	0.565	0.096	0.608	0.034	0.146	-	-
2003	0.037	0.562	0.087	0.604	0.03	0.143	0.038	0.163
2004	0.032	0.56	0.078	0.603	0.025	0.142	0.033	0.162
2005	0.028	0.56	0.071	0.603	0.022	0.141	0.028	0.162
2006	0.024	0.56	0.063	0.603	0.018	0.141	0.024	0.161
2007	0.02	0.56	0.056	0.603	0.015	0.141	0.021	0.161
2008	0.017	0.56	0.05	0.602	0.013	0.141	0.018	0.161
2009	0.014	0.56	0.044	0.602	0.011	0.141	0.015	0.161
2010	0.012	0.56	0.039	0.602	0.009	0.141	0.012	0.161
2011	0.01	0.56	0.034	0.602	0.007	0.141	0.01	0.161
2012	0.008	0.56	0.029	0.602	0.006	0.141	0.008	0.161
2013	0.006	0.56	0.025	0.602	0.005	0.141	0.007	0.161
2014	0.005	0.56	-	-	0.004	0.141	0.005	0.161

Source: calculated by the researchers.

the forty percent mark of the frontier in the case of the KUMB 90 model. The trade efficiency estimates of Nigeria for the other countries of the WAMZ are reported in Table 7 and graphically displayed in Figure 5. On the average, the second highest estimates of Nigeria are for Ghana. The average estimate for the BC 92 model lies below the ten percent level of the frontier but marginally above the ten percent mark for the KUMB 90 model. The average estimates for The Gambia, Guinea, and Sierra Leone are below the ten percent mark of the frontier.

The trade efficiency estimates of Sierra Leone for the other countries of the WAMZ apart from Liberia are in Table 8 and plotted in Figure 6. The estimates of Liberia are not provided due to the unavailability of the data on the export flows from Sierra Leone to

Liberia over the period from the sources of the export data. The trade efficiency estimates are substantially different for the BC 92 and KUMB 90 models, particularly for Ghana and The Gambia. In the case of The Gambia, whereas the average efficiency estimate over the period for the BC 92 model is close to the lower boundary of the frontier, the average estimate for the KUMB 90 model is above the fifty percent level of the frontier. For Ghana, the average estimate for the BC 90 is below the ten percent mark of the frontier. The average estimate for the KUMB 90 is above the sixty percent mark. The differences in the estimates for the two models in the cases of Guinea and Nigeria are less pronounced. The efficiency estimates of the BC 90 model for both countries on the average lie close to the lower

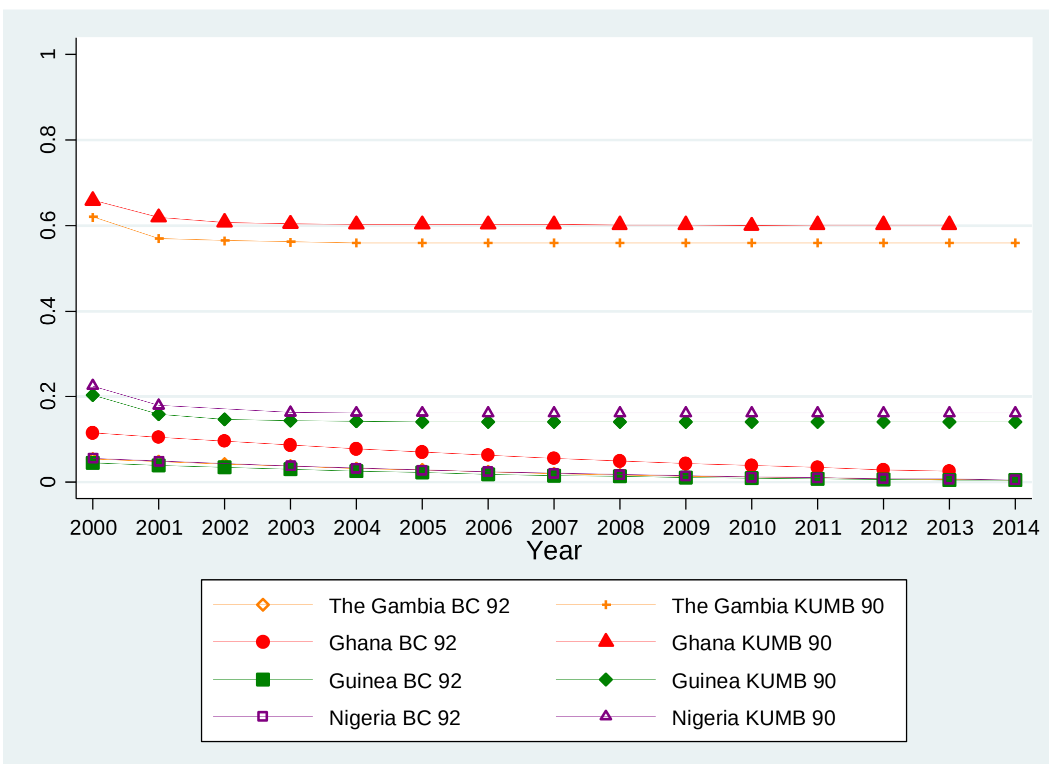

Figure 6: The trade efficiency estimates of Sierra Leone for the other countries of the WAMZ over 2000-2014.

boundary of the frontier. The estimates for the KUMB 90 model are above the fifteen percent mark of the frontier on the average.

4.5 LIMITATIONS OF THE RESULTS

The results are subject to several limitations. To begin with, the frontier estimates, as well as the efficiency estimates, are sensitive to the model used: that is, in the case of this study, whether the data is fitted with the BC 92 or KUMB 90 model. Previous studies failed to point this out. Again, the results are dependent on what specification of the TGM is used. We tried other specifications of the gravity equation such as the Bergstrand's (1987) specification which includes per capita income of the exporter and the importer, and the empirical results were different. We also fitted the data with the specification of the gravity equation which includes the populations of the exporters and the importers as additional control variables for the masses of the exporter and importer which also produced different results. Another limitation relates to the trade efficiency estimates between the countries of the WAMZ. It borders on the quality of their export data. Undocumented trade flows between the countries will mean that the trade efficiency estimates are understated.

CHAPTER FIVE

5.1 SUMMARY AND CONCLUSIONS

Generally, the TGM reasonably explains the trade flows of the countries of the WAMZ. This is evident in the signs and magnitudes of the frontier estimates both for the BC 92 and KUMB 90 models, especially the estimates of the basic elements of the TGM (i.e., GDPX, GDPM and DISTANCE). These variables had the expected signs in most cases as predicted by their underlying theories and the evidence provided by the empirical literature. The outcomes of the estimations regarding the frontier variables of the empirical model add to the empirical literature of the use of the TGM to explain the trade flows of countries and regions. This is particularly important in the cases of The Gambia, Liberia, Guinea and Sierra Leone in that it is hard to come across any empirical work in the use of the TGM to explain their trade flows.

The PTA dummy variable was included in the empirical model to evaluate the effects of the PTAs of the countries of the WAMZ on their trade flows. The estimates of Sierra Leone and Liberia were positive and substantial in terms of their sizes for both the BC 92 and KUMB 90 models. EU countries are in the majority in terms of the composition of the countries with whom Sierra Leone and Liberia have PTAs. Per the results, it is likely that the two countries would have been the most affected in terms of their export flows to the EU market if they did not sign onto the Economic Partnership Agreements (EPAs) which the EU is replacing with the PTAs.

The results demonstrate that the countries of the WAMZ had “behind the border” factors that restrained their exports from reaching their frontiers over the period. This was very clear in the estimates of the lambda coefficients of the KUMB 90 model. The estimates were substantial in terms of their sizes and statistically significant for all the countries of the WAMZ. Similarly, the estimates of the gamma coefficient of the BC 92 model showed that Guinea and Nigeria had their exports restrained significantly by inefficiencies under their control over the period.

Generally, the trade efficiency estimates between the countries were low relative to the trade efficiency estimates of a study like Ravishankar and Stack (2014). However, the results were similar to the findings of Kang and Fratianni (2006). This suggests the existence of large untapped trade potentials between the countries of the WAMZ. There is scope for more trade between the countries of the WAMZ based on the low trade efficiencies between them per the results. On the average, Guinea had the lowest trade efficiencies for the other countries of the WAMZ over the period. This implies that her untapped market potentials with the other countries of the WAMZ are huge. Guinea should see substantial increments in her exports to the other countries of the WAMZ in the future if the appropriate policies are implemented to reduce the inefficiencies. A similar prediction can be made for all the other countries of the WAMZ based on the vast untapped trade potentials they have with other countries of the WAMZ per the low trade efficiency estimates.

5.2 POLICY IMPLICATIONS

The primary issue this study sought to address was to find out empirically the level of trade integration of the WAMZ region due to the proposed adoption of a common currency, which the optimum currency area theory suggests is best implemented in a properly integrated trading region among other conditions. The results suggest a poorly integrated region. This implies that a lot of work needs to be done to ensure the region is properly integrated in terms of trade between the countries before the promulgation of a common legal tender. This study cannot offer specific suggestions on how to deepen the levels of trade integrations between the countries of the WAMZ based on empirical evidence.

Those recommendations would only be possible if the second stage of estimation Armstrong (2007) suggested is undertaken where the factors responsible for the variation in the inefficiency terms are estimated. Due to this limitation of the study, the suggestions made on how the countries of the WAMZ can deepen their trade integrations are general in nature. Individually and collectively, the countries of the WAMZ need to address their infrastructural difficulties to facilitate the transport of goods and services across their borders. Roads, railway lines, ports, and airports are a few of the infrastructure elements that need to be provided and upgraded in each country and between the countries of the WAMZ.

Another issue that needs to be addressed is for each of the countries to iron out the bottlenecks at their ports of entries. The ECOWAS protocols aimed at facilitating the movements of goods and services across the countries of the region need to be followed and implemented to the letter by the countries of the WAMZ.

The countries of the WAMZ also need to undertake comprehensive studies of the markets of all members to identify areas they have comparative advantages relative to the other members. This will enable them to tailor economic policies that will help to develop the industries that will produce goods and services to feed the demands in the other member countries. A practical example relates to Ghana and Nigeria. Ghana has vast salt deposits and Nigeria has a large demand for salt needed to feed her petrochemical industry. Ghana can tailor economic policies aimed at developing her salt industry to feed the large market in Nigeria. Such policies will in the long run enable the countries of the WAMZ to take advantage of the huge untapped trade potentials between them. Generally, improvements in the institutions in each of the countries of the WAMZ will also help to increase trade between them.

5.3 SUGGESTED AREA FOR FURTHER STUDY

One area that requires study to provide the empirical information required for concrete suggestions to address the inefficiencies between the countries of the WAMZ will be to undertake the second stage of estimation as per the suggestion of Armstrong (2007). This will involve the estimation of the determinants responsible for the variation in the inefficiency term for each of the countries. Deluna (2013) did this for the Philippines and his study could serve as a guide in determining the variables to include in the second stage of the estimation.

5.4 CONCLUDING REMARKS

There is empirical evidence that suggests that the volume of trade improves between countries that adopt a common currency ex-post (cf. Frankel and Rose, 1998), partly due to the elimination of currency conversion difficulties. The optimal currency theory, however, proposes that countries intending to form a currency union should be significantly integrated from a trade standpoint ex-ante among several other pre-conditions that must be in existence to safeguard the effective working of the currency union. High trade integrations between the individual countries improves the synchronisation of the business cycles of the countries, which enables the centralised issuer of the legal tender to smooth business cycles with monetary policies.

Generally, the assessments of the region per the empirical results from both BC 92 and KUMB 90 models show low trade efficiencies between the countries of the WAMZ. It is imperative that the individual countries and the region as a unit work to improve the levels of trade integrations between them before they proceed with the adoption of the common currency. One of the ways by which the trade volumes between the countries can improve will be for each country to conduct comprehensive studies to identify the areas it has comparative advantages in relative to the other countries and for each country to design economic policies to develop those industries to feed the demands in the other member countries.

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APPENDIX A.

Table 9: The average trade efficiency estimates of The Gambia for other countries.

Country	Average Efficiency
Australia	0.022
Austria	0.013
Belgium	0.596
Benin	0.082
Brazil	0.013
Cameroon	0.061
Canada	0.032
China	0.549
Cote d'Ivoire	0.023
Finland	0.01
France	0.437
Germany	0.083
Guinea Bissau	0.395
Hong Kong	0.29
India	0.067
Indonesia	0.045
Italy	0.035
Japan	0.042
Kenya	0.075
Lebanon	0.077
Malaysia	0.119
Mali	0.364
Mauritania	0.245
Netherlands	0.351
Norway	0.011
Pakistan	0.048
Senegal	0.07
Slovenia	0.009
South Africa	0.156
South Korea	0.023
Spain	0.171
Sweden	0.011
Switzerland	0.005
Tanzania	0.033
Thailand	0.597
Togo	0.05
Turkey	0.014

United Arab Emirate	0.037
Uganda	0.011
United Kingdom	0.606
United States of America	0.053
Vietnam	0.514

Source: calculated by the researchers.

APPENDIX B.

Table 10: The average trade efficiency estimates of Ghana for other countries.

Country	Average Efficiency
Australia	0.063
Belgium	0.352
Benin	0.352
Brazil	0.004
Burkina Faso	0.704
Cameroon	0.037
Canada	0.114
China	0.04
Cote d'Ivoire	0.142
Denmark	0.035
Egypt	0.009
Estonia	0.778
Germany	0.098
Greece	0.037
Hong Kong	0.06
India	0.142
Indonesia	0.017
Ireland	0.327
Israel	0.021
Italy	0.1
Japan	0.081
Kenya	0.007
Lebanon	0.078
Malaysia	0.174
Mali	0.223
Netherland	0.605
New Zealand	0.08
Norway	0.04
Poland	0.035
Portugal	0.037
Russia	0.031
Senegal	0.342
Singapore	0.27
South Africa	0.095
South Korea	0.027
Spain	0.083
Switzerland	0.208

Thailand	0.044
Togo	0.382
Tunisia	0.009
Turkey	0.11
United Arab Emirates	0.115
United Kingdom	0.729
Ukraine	0.262
United States of America	0.143
Vietnam	0.021

Source: calculated by the researchers.

APPENDIX C.

Table 11: The average trade efficiency estimates of Guinea for other countries.

Country	**Average Efficiency**
Algeria	0
Australia	0
Belgium	0.051
Benin	0.014
Cameroon	0
Canada	0.019
China	0.001
Cote d'Ivoire	0.023
Denmark	0.001
France	0.004
Germany	0.007
Greece	0
Hong Kong	0.12
Hungary	0
India	0.019
Indonesia	0
Ireland	0.415
Israel	0
Italy	0
Japan	0.001
Lebanon	0.01
Malaysia	0.008
Mali	0.013
Mexico	0
Morocco	0.005
Netherlands	0.002
New Zealand	0.027
Poland	0.002
Portugal	0
Romania	0.014
Russia	0.005
Senegal	0
Singapore	0.013
South Africa	0.001
South Korea	0.538
Spain	0.009
Sweden	0.001
Switzerland	0.001
Tanzania	0.001

Thailand	0.005
Turkey	0
United Arab Emirates	0.012
United Kingdom	0
Ukraine	0.106
United States of America	0.002
Vietnam	0.065

Source: calculated by the researchers.

APPENDIX D.

Table 12: The average trade efficiencies estimates of Liberia for other countries.

Country	Average Efficiency
Australia	0.003
Austria	0.002
Belgium	0.511
Benin	0.08
Brazil	0.003
Canada	0.205
China	0.416
Cote d'Ivoire	0.465
Czech Republic	0.182
Denmark	0.037
Egypt	0.03
Finland	0.009
France	0.231
Germany	0.678
Greece	0.551
Hong Kong	0.118
India	0.421
Indonesia	0.195
Ireland	0.005
Italy	0.124
Japan	0.008
Lebanon	0.067
Malaysia	0.716
Mexico	0.021
Morocco	0.005
Netherlands	0.094
Norway	0.444
Poland	0.832
Russia	0.007
Senegal	0.039
Singapore	0.141
Slovenia	0.332
South Africa	0.186
South Korea	0.443
Spain	0.137

Sweden	0.001
Switzerland	0.037
Thailand	0.208
Togo	0.257
Turkey	0.157
Uganda	0.04
United Kingdom	0.188
Ukraine	0.167
United States of America	0.289
Vietnam	0.511

Source: calculated by the researchers.

APPENDIX E.

Table 13: The average trade efficiency estimates of Nigeria for other countries.

Country	Average Efficiency
Australia	0.005
Austria	0.356
Bangladesh	0.026
Belgium	0.021
Benin	0.044
Brazil	0.488
Bulgaria	0.001
Burkina Faso	0.015
Cameroon	0.519
Canada	0.104
Chile	0.047
China	0.025
Cote d'Ivoire	0.503
Croatia	0.005
Denmark	0.005
Egypt	0
France	0.186
Gabon	0.048
Germany	0.087
Greece	0.008
Hong Kong	0.069
India	0.096
Indonesia	0.239
Ireland	0.008
Israel	0.002
Italy	0.07
Japan	0.103
Kenya	0.008
Lithuania	0
Malaysia	0.038
Mali	0.01
Mexico	0.031
Morocco	0.045
Mozambique	0.008
Netherlands	0.387
New Zealand	0.039
Niger	0.093
Norway	0.003
Oman	0

Pakistan	0.004
Peru	0.689
Philippines	0
Portugal	0.74
Russia	0
Saudi Arabia	0
Senegal	0.663
Singapore	0.021
South Africa	0.541
South Korea	0.202
Spain	0.474
Sweden	0.049
Switzerland	0.262
Thailand	0.082
Togo	0.031
Tunisia	0.001
Turkey	0.045
United Kingdom	0.044
Ukraine	0.003
United States of America	0.188
Vietnam	0.085

Source: calculated by the researchers.

APPENDIX F.

Table 14: The average trade efficiency estimates of Sierra Leone for other countries.

Country	Average Efficiency
Australia	0.053
Austria	0.008
Barbados	0.008
Belgium	0.769
Canada	0.017
China	0.101
Cote d'Ivoire	0.029
Croatia	0.006
Czech Republic	0.016
Denmark	0.009
Estonia	0.096
Finland	0.027
France	0.122
Germany	0.088
Greece	0.012
Netherlands	0.012
Hong Kong	0.036
Hungary	0.002
India	0.062
Indonesia	0.03
Ireland	0.01
Italy	0.008
Japan	0.072
Kenya	0.019
Lebanon	0.104
Malaysia	0.112
Mexico	0.023
Morocco	0.011
New Zealand	0.018
Poland	0.059
Portugal	0.004
Russia	0.006
Saudi Arabia	0.004
Slovenia	0.02
South Africa	0.028
South Korea	0.07
Spain	0.03

Sri Lanka	0.014
Sweden	0.003
Switzerland	0.01
United Arab Emirates	0.094
United Kingdom	0.02
United States of America	0.024
Vietnam	0.513

Source: calculated by the researchers.

APPENDIX G.

Table 15: Likelihood ratio test results for the countries of the WAMZ

	The Gambia	Ghana	Guinea	Liberia	Nigeria	Sierra Leone
Likelihood ratio	197.38	504.22	508.64	301.22	730.22	205.17
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Note: The figures in parentheses are probability values.