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Measuring the efficiency effect of integration in the South African Development Community

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Measuring the Efficiency Effect of Integration in the South African Development Community

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Abstract

This paper concerns the exploration of the efficiency effects of regional economic integration at the level of each member country. In specific, the question addressed is: does regional economic integration improve the economic efficiency of member countries? This broad question is narrowed down by focusing on the Southern African Development Community (SADC) and by focusing on the integration index created recently by the three continental institutions of Africa: the AU, AfDB and UNECA. Efficiency will be measured using stochastic frontier, a parametric methodology that allows the estimation of a country's production possibility frontier. Efficiency is thus estimated according to how close to its production possibility frontier an economy produces its output. The program used will be FRONTIER Version 4.1: http://www.uq.edu.au/economics/cepa/frontier.php.

Keywords: Regional Integration, Stochastic Frontier, Growth Accounting

JELs: F02

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Section 1: Integration in Africa

The purpose of this paper is to assess whether integration of the Southern African Development Community (SADC) is economically efficient. The regional economic community (REC) is on a path of deepening regional integration as part of a wider plan for an economic union of the African continent (see next section). As such, it is important to have as comprehensive a view as possible of the economic implications of regional integration.

This research contributes to the understanding of regional economic integration in the SADC by applying a methodological framework (stochastic frontier analysis) which, to the best of the author's knowledge, has yet to be applied to the question of regional economic integration, and almost certainly has not been applied to the question of regional economic integration in the SADC. This paper finds that, regional economic integration in the SADC is associated with efficiency gains in economic growth comparable in magnitude to the efficiency effects of government debt and basic infrastructure development.

1.1 Background to African integration

In 1991, 51 African countries signed the Treaty Establishing the African Economic Community – more commonly known as the Abuja Treaty (1992). In it, a 34-year, 6-stage plan of total economic integration was set forth (see table 1 below). Given that "the cumulative transitional

period [towards fully integrating the African Economic Community] shall not exceed forty (40) years from the date of entry into force of this Treaty" (Article 6 Abuja Treaty, 1992*),*

Table 1: The six-stage formation of the African Economic Community

	Objective	Time frame (*achieved no later than*)
1	Strengthen and consolidate Regional Economic Communities (RECs)	5 years *(2002)*
2	Stabilise trade tariffs and customs duty	8 years *(2010)*
3	Establish free trade areas and Customs Union for each REC	10 years *(2020)*
4	Coordinate tariff and non-tariff systems between RECs	2 years *(2022)*
5	Establish African Common Market and adopt common policies	4 years *(2026)*
6	Establish: Central Bank, Single Currency, economic and monetary union, pan-African parliament	5 years *(2031)*

Source: Treaty Establishing the African Economic Community (1991)

Africa is on course for full economic and political union which will include: an African central bank, a single African currency, an African economic and monetary union and a pan-African parliament. For such a consequential transformation of the African continent, the trajectory towards full economic and political integration is remarkably under-discussed in Africa's public discourse.

Encouragingly, 44 out of 55 African Union (AU) members have recently signed the African Continental Free Trade Area (AfCFTA) agreement, which will bring about the removal of 90% of tariffs of goods and liberalise services across the continent. This points to the fact that African states are taking the matter of integration seriously, and with good reason: recent calculations from UNCTAD suggest that this could increase intra-African trade by as much as 52% by 2020. (Saygli et al., 2018).

1.2 Background to Economic Integration and the SADC

The SADC is comprised of 15 countries with a population comprising 333 million people of Africa's total 1.2 billion people and contains Africa's richest country, South Africa, which makes up 51% of regional GDP.[2]

The history of the SADC has at least two independent strands. To the south of the region, the Southern African Customs Union (SACU) was formed in 1910 and was comprised of four states which were then known as the Union of South Africa (Republic of South Africa), Basutoland (Lesotho), Bechuanaland (Botswana) and Swaziland. In 1921, South Africa formed its own Reserve Bank with its own currency - the Rand. At the time, the monetary arrangement between these states was somewhat informal yet economically significant.

Perhaps the most relevant document for understanding the economic trajectory of the region, is the Regional Indicative Strategic Development Plan (RISDP), initiated in 2003 and subject to periodic review. The RISDP outlines the economic intentions of the region, setting out a 15 year plan for socioeconomic development and economic integration. More tangible goals include: the eradication of poverty, trade liberalisation, market integration and development of infrastructure (Muntschick, 2017). In terms of economic integration, the original economic plan in the RISDP included the creation of a monetary union by 2016 and the use of a single currency in the region by 2018 (RISDP). Needless to say neither of these has come to fruition, nor are they likely to in the near future.

[2] This data is based on 2016 figures from the World Bank Development (WDI) database.

Figure 1: Population and GDP in the SADC

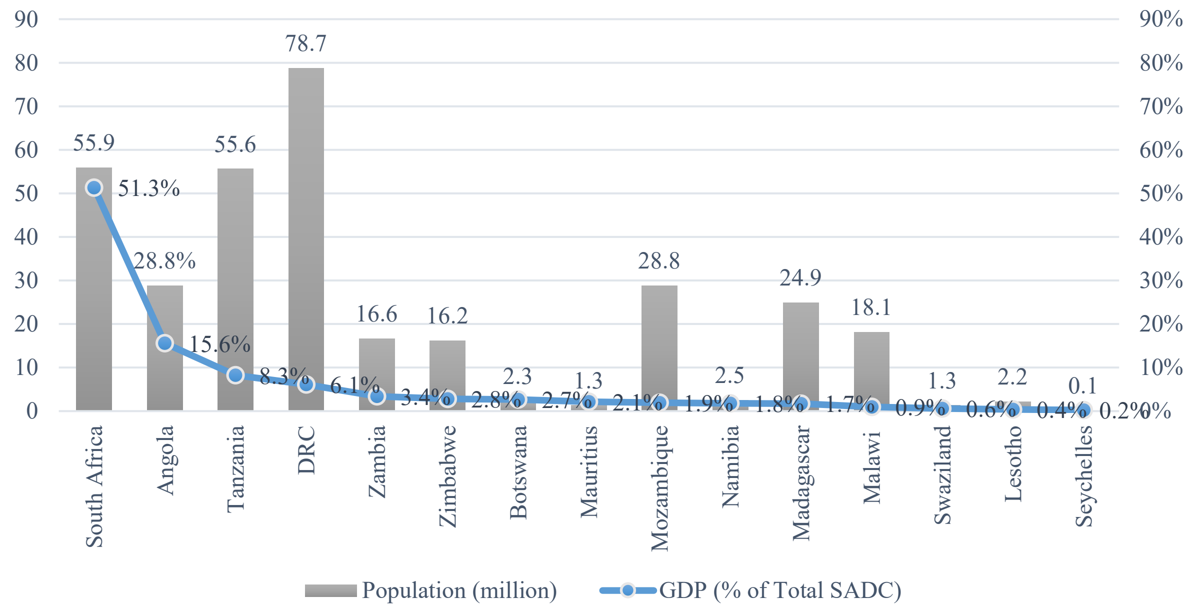


Figure 1 source: World Bank Development Indicators

The SADC is comprised of a medium sized economy (South Africa) and 14 small economies. In 2005 the governors of reserve banks committed to adopting a common monetary policy by 2018 (this year). As Jefferis (2007, pg. 92) notes: "the political momentum in Africa… appears to have run ahead of the economic reality and the commitments that have been made to monetary union are not based on any detailed analysis of whether monetary union is suitable in an African context".

There have been a variety of factors which have complicated the SADC's road towards integration. On the whole, members have enormous domestic political and economic issues with which to deal. To name but a few: Madagascar's membership was suspended from 2009-2014 following a military coup, the Seychelles temporarily dropped its membership from 2004-2008, and the DRC has been periodically embroiled in external and civil wars. As shown below in figure 2, the region is generally characterised by poor institutional outcomes. In terms of political freedoms and civil rights, most countries are considered "partly free" or "not free" by Freedom House, with the DRC a notable example scoring the 9th lowest (worst) score in the world for political freedom, primarily due to ongoing conflict. In terms of corruption, where a low score indicates a high level of corruption, most SADC countries score below the global average, as shown in Figure 2 below.

Figure 2: Political Freedom and Corruption Scores 2017-2018

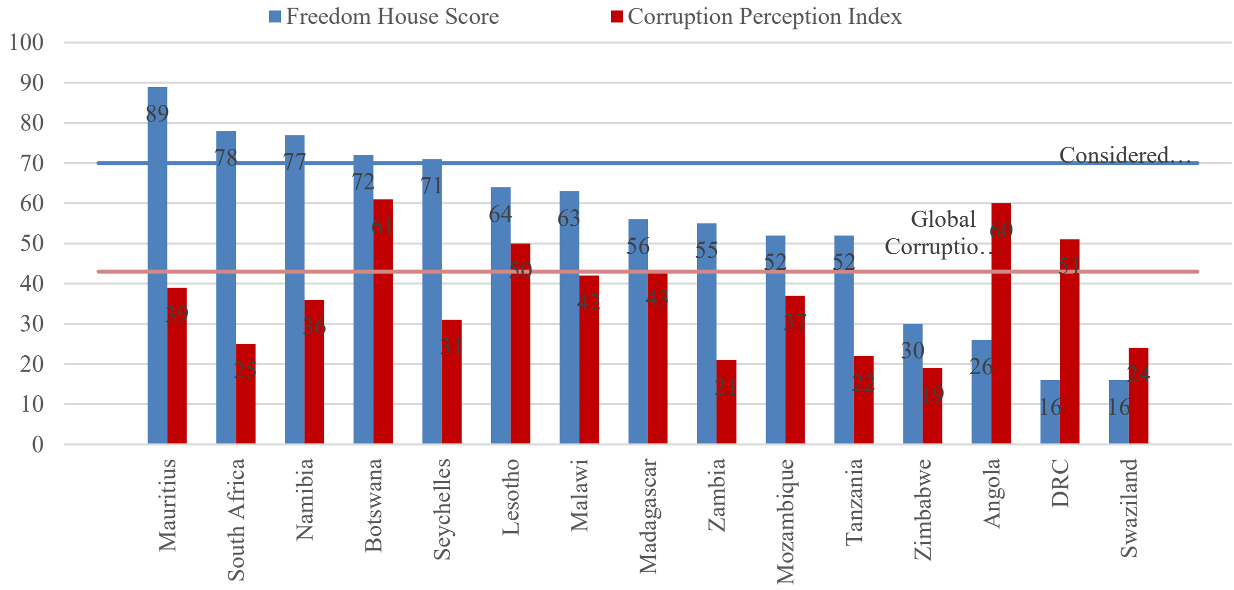


Figure 2 source: Freedom House (2018); Transparency International

In Africa fiscal discipline is among the key concerns, impeding further integration. The tale of government debt has been twofold: on the one hand smaller or poorer countries like Botswana and the DRC have kept their debt admirably contained in the last 15 years, aided in part, by the IMF and African Development Bank's debt forgiveness in the 1990s. On the basis of many of the SADCs smaller countries containing their government debt, one might be tempted to conclude that there is a positive outlook for fiscal discipline on the whole in the region.

However, figure 3 below shows that while many smaller countries have been reducing government debt, this has been significantly outweighed by increasing debt in larger economies. In particular

Figure 4: SADC Development Indicators

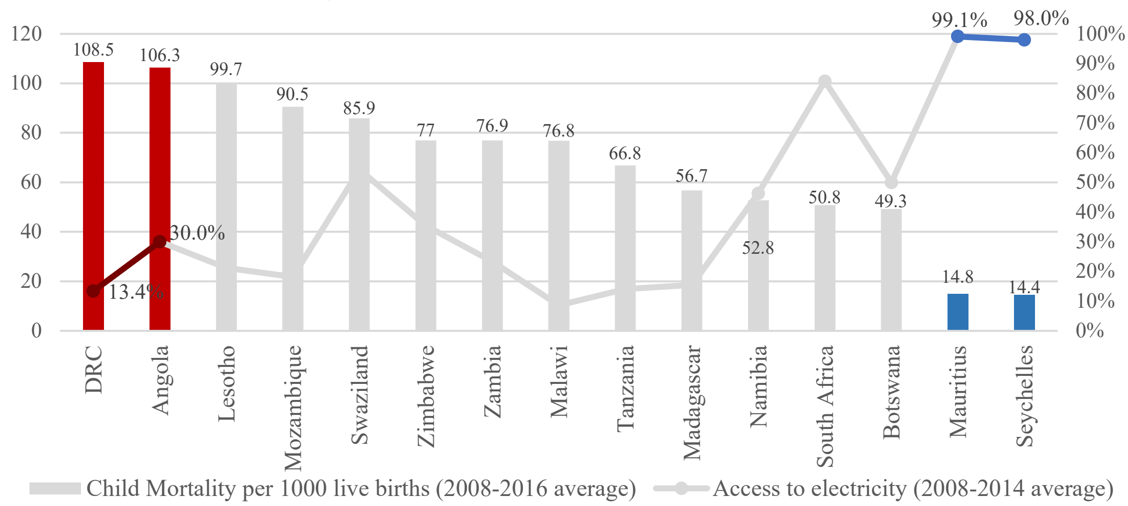


Figure 4 source: World Bank Development Indicators

South Africa has experienced rapidly rising levels of debt and increased borrowing costs associated with higher risk premiums. This has been reinforced in the SADC's other two largest economies: Angola and Tanzania. Hence, when taking into account the weight of GDP in the region, government debt is in fact rising to worryingly high levels. Figure 3 also demonstrates a broader point about summarising macroeconomic outcomes in the SADC: not taking into account GDP weightings can drastically affect the overall picture of the region.

This important matter is discussed in more detail in the next section when weightings with regard to creating measurements of integration are considered. Given that fiscal discipline would be a prerequisite for a monetary union, this creates rigidities in both monetary and fiscal policies. Perhaps one of the most relevant arguments for the case of the SADC is Kenen's (1969) argument that more diversified economies are better candidates for integration because it means that idiosyncratic commodity shocks (for example to oil) do not have a disproportionate effect on any member.

For several reasons it should not to be taken for granted that integration will lead to improved efficiency and growth effects as experienced elsewhere in the world: political institutions are weak, fiscal discipline is lax in the face of rising government debt, SADC economies are not well-diversified, very little trade exists within the region and members are at different levels of development.

A rich variety of methodologies have been used to investigate African integration and integration in the SADC, among them: VAR, cointegration and VECM techniques (Buigut & Valev 2006; Zehirun et al. 2015), welfare gain analysis (Masson 2006; Masson 2008; Debrun & Masson, 2013), cost-benefit analysis (Karras 2007; Debrun et al 2010), cluster analysis (Buigut 2006), a Tobit model (Tsangarides et al 2006) and a gravity model (Qureshi & Tsangarides 2015). While this points to a rich source of literature from which to extrapolate, the existing literature is also inconclusive in terms of the effects of integration – perhaps as much a symptom of the subject under consideration as methodological shortcomings.

To the author's best knowledge, this paper represents the first attempt to use stochastic frontier analysis to address the question of African integration and will add to the literature in several ways. Firstly, it will include integration as a variable in a stochastic frontier model and the effects of integration (which is a specific goal of the SADC and the African continent) will be specifically linked to the consequences of economic output in the SADC. This is especially relevant because it is a stated goal of the region (SADC, 2003). Secondly, the statistical validity of the model is tested by running unit root tests, checking for simultaneity effects and the presence of cointegration. These procedures are often overlooked in the literature which may lead to invalid or spurious findings, especially given that stochastic frontier analysis single-equation model. Thirdly, the study covers a range of other important determinants of inefficiency specifically in the SADC which have not yet been identified in the literature.

1.3 Constructing the Integration Index

The African Regional Integration Index (ARII) includes 5 dimensions to quantify the degree of regional integration: trade, infrastructure, financial-macroeconomic integration, productive integration, as well as labour mobility. Each component is divided into sub-components as detailed below.

In its 2016 report (UNECA et al., 2016) the composite index for each Regional Economic Community (REC) is calculated as a simple average of the dimensions. In the report (UNECA et al., 2016), it is suggested that forthcoming iterations should consider weighting the labour mobility and regional infrastructure scores by population sizes of members and weighting the other three (trade, productive integration, and financial and macroeconomic convergence) by GDP. One can measure integration at two levels: the integration of the Regional Economic Community as a whole, or the integration of each member into its Regional Economic Community – this study is concerned with the latter.

It should be immediately noted that several of the proposed measures of integration do not have any significant precedent in the integration literature – especially regional infrastructure. While no doubt a worthwhile development outcome, improving infrastructure has no apparent economic connection to regional integration, and as such Infrastructure Development Index should be regarded as inappropriate to its measurement.

The importance of development goals towards growth does not necessitate its inclusion in an integration index, and as such, this score is separated from the integration index calculation. The remaining three variables in the regional infrastructure dimension are included because they align with the three sub-dimensions included in the Programme for Infrastructure Development in Africa (PIDA) rather than because of any precedence in the literature. Air connections, cost of roaming and net electricity trade are supposed to capture transport, communications and energy integration respectively. Only one of these variables (net electricity trade) contains more than one time period.

The other problematic dimension is labour mobility. Comprised of three variables, each measures the potential for migration. In the literature, labour mobility is typically measured by actual net migration inflows.[3] Similar to the regional infrastructure dimension, the labour mobility dimension is further constrained by a lack of panel data. Where cross-sectional data are available, these cross-sections in time are often not the same for each SADC member. Hence, any meaningful statistical inferences based on this data are not possible.

The remaining three dimensions cover trade integration and financial integration, for which the data extends over 4 years (2010-2013) for the majority of SADC members. On the whole, empirical examination of integration in terms of the ARII is severely constrained by the lack of data availability: of the 16 variables put forward in the ARII, only 9 are available for more than 1 year. For the remaining 7 cross-sectional variables, analysis is complicated by the low number of observations per time period and by the fact that the single data points for each member are scattered across different time periods. One should therefore be cautious even in drawing descriptive conclusions from this database.

The ARII is constructed in three steps:

1. Each variable, i, is given an index score at time t for country j as follows:

$$Variable_{ij}^{t} = \frac{Country\ Result_{ij}^{t} - Minimum\ Result_{i}}{Maximum\ Result_{i} - Minmium\ Result_{i}} \tag{8.1.1}$$

Or in the case where a score is inversely related to integration:

$$Variable_{ij}^{t} = 1 - \frac{Country\ Result_{ij}^{t} - Minimum\ Result_{i}}{Maximum\ Result_{i} - Minmium\ Result_{i}} \tag{8.1.2}$$

2. The score for each dimension, k, at time t is calculated as the average of the (m) variables in dimension k:

$$Dimension_{kj}^{t} = \frac{1}{m}\sum_{i=1}^{m_k} Variable_{ij}^{t} \tag{8.2}$$

3. The composite ARII score is then calculated as the average across the 5 dimensions:

$$ARII_{j}^{t} = \frac{1}{5}\sum_{k=1}^{5} y_{ij}^{t} \tag{8.3}$$

This can then be further aggregated to create an integration score for SADC for each year:

$$SADCINT^{t} = \frac{1}{j}\sum_{j=1}^{15} ARII_{j}^{t} \qquad for\ t = 1, \ldots, T \tag{8.4}$$

[3] See, for example see Peri (2012) for measures of immigration used in a growth accounting framework.

A few aspects of this methodology are worth noting. First of all the ARII, as it stands in equation 8.3 is a measure of relative integration for each time period, t. This means that, while comparison across countries for a given time period is meaningful, comparing scores across time periods is not necessarily meaningful. For example, given a set of integration scores at time t, if all SADC countries' level of integration decrease in equal measure at time t+1 except for one member, whose score also decreases but by a smaller amount, this member's integration score will rise (provided it is not the lowest scoring member in the group). Thus, a country's score may increase even when, in absolute terms, its economic integration in a region has declined.

Modifications are therefore necessary in order to apply the ARII for use in a panel dataset. The following suggestions are provided in the 2016 methodology report itself for further development of the index (UNECA et al., 2016):

1. Highly correlated variables within each dimension will essentially result in double counting without adding extra information to the dimension's score, excluding the share of total intra-regional goods trade as a percent of total SADC intra-trade is necessary.
2. The regional integration score in equation 8.4 is based on a simple average which does not take into account the weightings of population sizes or GDP. Population weightings would be relevant for regional infrastructure dimension (especially the transport sub-dimension) and labour mobility dimension while GDP weighting is appropriate for the Trade, Productive and Financial-Macroeconomic dimensions.

In addition to these insights, it is also worth noting:

3. The financial-macroeconomic dimension is underspecified: it contains no information on fiscal policy convergence (an important consideration recognised in OCA literature) or interest rate convergence (relatively higher interest rates create negative spill-over effects for the region).
4. No consideration is given to convergence of institutional quality. Institutional convergence is, by definition, a necessary condition for integration. It is also an important determinant for income levels (Rodrik et al., 2004).

In order to fix the issue of non-comparability of scores across time, the index score is amended to:

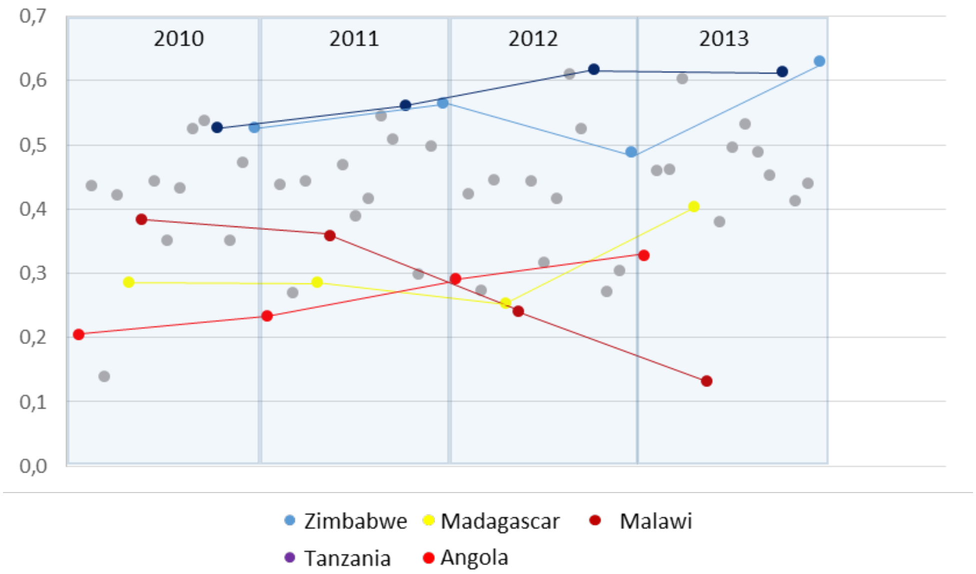
$$Variable_{ij}^{t} = \frac{Country\ Result_{ij}^{t} - Minimum\ Result_{i}^{t}}{Maximum\ Result_{i}^{t} - Minmium\ Result_{i}^{t}} \qquad for\ all\ t = 1, \ldots, \mathrm{T} \qquad (8.1.3)$$

Table 2: Construction of the ARII

Integration type	Trade	Productive	Labour	Financial and Macroeconomic	Regional infrastructure
Cross-sectional variables	Tariff liberalisation	N/A	Proportion of free-movement protocols ratified Proportion of REC member countries whose nationals are issued with a visa on arrival	Convertibility of national currencies	Average Cost of Roaming Proportion of flight connections in REC
Panel variables	Share of intra-regional imports (% GDP) Share of intra-regional exports (% GDP) Share of total intra-regional trade	Share of intra-regional intermediate imports Share of intra-regional intermediate exports Merchandise Trade Complementarity	N/A	Inflation rate differential	Total regional electricity trade (net imports) Infrastructure Development Index
Total Components	4	3	3	2	4

This means that each index score has a meaningful interpretation both spatially for each country, j, and across time, t. Some highlights from the resulting index are displayed below in Figure 6.

Figure 5: SADC ARII (high and low performers in colour)



Section 2: Stochastic Frontier Analysis

2.1(a) Theoretical Background to Stochastic Frontier Analysis Methodology

Initial models of Stochastic Frontier Methodology (SFM) literature developed three kinds of production frontier models. The first two, deterministic functions and stochastic functions, are cross-sectional models – whereas the final model which has been developed is concerned with panel data estimation techniques, and has several advantages over the first two kinds. The deterministic, cross-sectional production function first proposed in Afriat (1972) is defined as:

$$Y_i = f(x_i; \beta)\exp(-U_i) \qquad i = 1,2 \ldots, N \tag{1}$$

Where Y_i represents the possible production level for the ith observation; $f(x_i; \beta)$ is a production function (Cobb-Douglas or translog) of the x_i vector of inputs, and β its corresponding coefficients; U_i is a non-negative random variable which captures the observation-specific technical inefficiency of the production process. The frontier of production is deterministic in this model in the sense that output, Y_i, is bounded above by a deterministic quantity, namely $Y_i = f(x_i; \beta)$, where Y_i is the posited, maximum *frontier* output implied by the available inputs. In this model, technical inefficiency (TE_i) is measured by the ratio of observed output to its frontier output:

$$TE_i = \frac{Y_i}{Y_i^*}$$

$$= \frac{f(x_i;\beta)\exp(-U_i)}{f(x_i;\beta)}$$

$$= \exp(-U_i) \qquad (2)$$

The technical efficiency term is estimated in practice by taking the ratio of the observed output to an estimated level of frontier output based on maximum-likelihood or corrected ordinary least-squares of the coefficients. This simple estimation was then extended into the stochastic frontier production function in two independent papers by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) and is defined:

$$Y_i = f(x_i;\beta)\exp(V_i - U_i) \qquad i = 1,2 \ldots, N \qquad (3)$$

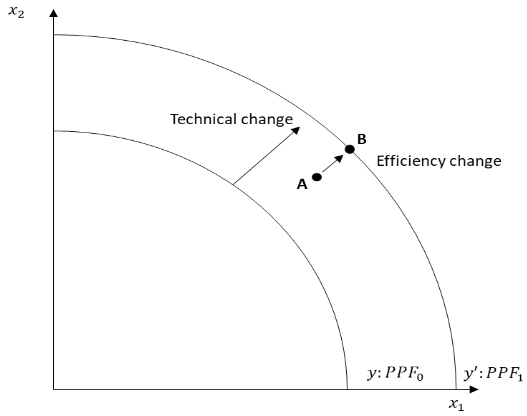
Where V_i is a random error with zero-mean associated with random factors which affect production but are not under the control of the firm such as: measurement errors, strike action and weather conditions. In this model, output is bounded above by a stochastic quantity rather than a deterministic value. Thus the frontier output is given as:

$$Y_i^* = f(x_i;\beta)\exp(V_i) \qquad (4)$$

The addition of the random error term V_i has the effect of adjusting the posited frontier output according to whether the random shocks of V_i are positive or negative. Technical efficiency in this model is defined as in (2), however, the actual values of inefficiency given by the two models will be different according to whether the random error component is positive or negative: when the shock to (deterministic) production is positive, the frontier output is larger than a simple deterministic frontier and thus, other things equal, the observed level of output will be judged to be less efficient (compared to the deterministic frontier) when the shock is positive and more efficient when the shock is negative.

The difference between technical and efficiency changes (shown stylistically in figure 6 below) should be understood as the difference between movements of the frontier (PPF_0 to PPF_1) and movements away or towards (inefficiency or efficiency) the frontier (point A to B), respectively.

Figure 6: Technical change versus Efficiency change



In reality, the prediction of equation (2) was not considered viable until Jondrow et al. (1982) who suggested that technical efficiency be estimated according to the expression: $1 - E(U_i|V_i - U_i)$. It is also worth noting Stevenson's (1980) proposal for the U_i term: a non-negative truncation of the distribution $N(\mu, \sigma^2)$. Finally, panel data models were first outlined in Pitt and Lee (1981) and are broadly defined by:

$$Y_{it} = f(x_{it}; \beta) \exp(V_{it} - U_{it}) \qquad i = 1,2, \dots, N \qquad t = 1,2, \dots, T \qquad (5)$$

Where the subscript 't' indicates the availability of time series data for the ith observation. Pitt and Lee (1981) consider three models which vary according to the assumptions made about the non-negative U_{it} term, the assumptions were: 1) time-invariance of the U_{it} term i.e. $U_{it} = U_i$ for all observed time periods; 2) uncorrelated $U_{it}'s$ and 3) correlated $U_{it}'s$. In addition, various time-varying effects have been proposed: Cornwell, Schmidt and Sickles (1990) estimate a quadratic function of time using instrumental variable methods and Battese and Coelli (1992) put forward a methodology for time-varying effects for unbalanced data. The methodology in Battese and Coelli (1995) further provides a framework for explanatory variables of the inefficiency term in the context of panel data. More specifically, the production function is defined as:

$$Y_{it} = \exp(\mathrm{x_{it}}\beta + V_{it} - U_{it}) \qquad (6)$$

Where Y_{it} stands for observed output and the indices i and t are as before in (5). x_{it} is a (1 x k) vector for the functions of inputs of production and other explanatory variables of output. β is a (k x 1) vector of the coefficients to be estimated. V_{it} is assumed to be iid $N(0, \sigma_v^2)$ and is assumed to be independently distributed of U_{it}. As before, U_{it} is a non-negative random variable of technical inefficiency specified according to:

$$U_{it} = \delta Z_{it} + w_{it} \qquad (7)$$

The U_{it} term is, thus, assumed to be a function of a (1 x m) vector of explanatory variables associated with technical inefficiency of production of firms over time, δ is the (m x 1) vector of coefficients to be estimated and w_{it} is a random variable defined by the truncation of the normal distribution with zero mean and homoscedastic variance, σ^2, such that $w_{it} \geq -z_{it}\delta$. Which, as mentioned above, is consistent with the non-negative truncation of the U_{it} term of the distribution $N(z_{it}\delta, \sigma^2)$. The explanation of the technical inefficiency as in (7) is first due to Reifschneider and Stevenson (1991) who note that the mean, $z_{it}\delta$, of the normally distributed U_{it} term is not required to be positive for each observation. This model is estimated by means of maximum likelihood such that equations (6) and (7) are estimated simultaneously – as will be the case in this paper.

1.3(b) Empirical Background to Stochastic Frontier Analysis Methodology

SFA has only come in to use at the macroeconomic level more recently. The output and productivity at hand in macroeconomic analysis is economic growth, and therefore a Stochastic Frontier Model (SFM) used at the macroeconomic level must take into account the growth literature (Ghosh and Mastromacro, 2009). At its core, Stochastic Frontier Analysis provides a more nuanced view of productivity on the macroeconomic level. As Iyer et al. (2008) put it: The stochastic frontier model "decomposes total factor productivity growth into two mutually exclusive and exhaustive components: one relating to technological progress and the other to efficiency utilizing factor inputs." (pg. 751).

From the perspective of a neoclassical model, production is implicitly assumed to be maximised such that economies always produce on the frontier. Stochastic Frontier Analysis makes no such assumption and, as will be demonstrated, likelihood ratio tests are used to test whether production inefficiencies (inputs not producing on the posited frontier) exist. Unsurprisingly, the general consensus in the literature appears to be that inefficiency models always provide a better description of the data than models which exclude inefficiency. This includes analysis for both developed and developing countries (Ghosh and Mastromarco, 2009; 2013).

In Iyer et al. (2008) and Wijeweera et al. (2010), human capital is included as an input in the production function (which are translog equivalents of equation 6 above) while FDI and human capital are both included in the efficiency model (equation 7 above). In Wijeweera et al. (2010), human capital is found to be a significant factor in both the production model and the efficiency model. Interestingly, FDI is not found to be individually significant in the efficiency model, but when included with a highly skilled labour force, the effects of FDI are significant.

These findings are supported by Ghosh and Mastromarco (2009) for developing countries and Ghosh and Mastromarco (2013) for OECD countries. The interpretation for this is that a country will not realise the growth benefits of FDI unless it invests in human capital as well. In a similar vein, Iyer et al. (2008) find that FDI efficiency gains increase in countries with better developed financial markets. However, for the specific case of sub-Saharan Africa, Danquah and Ouattara (2015) find that human capital does not exert a significant effect on efficiency, which they attribute to the low endowment of human capital in the region generally.

Aguiar et al. (2017) extend the efficiency analysis to build on work which suggests there may be other factors important to determine growth such as institutional quality. Institutional factors are included in their efficiency model (equation 7 above) in terms of business environment (World Bank Doing Business Index) and the regulatory environment (Worldwide Governance Indicators) – both of which are found to produce inefficiencies for poor quality institutions. They also find that government debt, high tariffs and resource abundance all are associated with productive inefficiencies. These are highly relevant findings for SADC countries and integration in the region.

For example reducing the high levels of government debt in the SADC could bring about higher productive efficiency and (recalling the requirement of fiscal discipline as a prerequisite to monetary union) simultaneously create conditions conducive for further integration. In terms of tariffs, creating free trade areas in the SADC could likewise could bring about efficiency windfalls. Resource abundance is also highly relevant to the SADC which is rich in oil, diamonds, gold and many other resources which, if Aguiar et al. (2017) are to be believed, reduces productive efficiency because it creates a direct path to wealth which may result in complacency when it comes to providing value-added services.

2. 2 Stochastic Frontier Methodology

The stochastic frontier approach relies on the growth-accounting framework. In this framework, growth in output is explained by two changes: changes in inputs (capital and labour) and technical change which is taken from the residual. Stochastic frontier models have the advantage of being able to decompose this residual into technical change, inefficiency and statistical noise.

Traditionally, in neoclassical models, technological progress is defined as the residual portion of growth which cannot be explained by changes in input factors. This technical residual, the Solow residual (Solow, 1957), has several limiting assumptions: monopolistic markets, non-constant returns to scale, and variable factor utilisation are all assumed away under this measure. The lack of nuance in the Solow residual led Abramovitz (1956) to remark that it is a measure of the ignorance about the causes of economic growth. This is because the residual fails to distinguish between shifts of the technical frontier and movements towards, or away from, this frontier. This is precisely the distinction which stochastic frontier aims to measure (see figure 6 above).

The Model

Using panel data, the general specification for a production frontier can be modelled as:

$$Y_{it} = f(x_{it})\, \tau_{it}\, \epsilon_{it} \qquad i = 1,2 \dots, N; \quad t = 1, \dots, T$$

Where output, Y_{it}, is modelled by a set of inputs x_{it} which always includes labour and physical capital and increasingly, human capital is also included in this specification[4]. τ_{it} is the efficiency measure $(0 < \tau_{it} < 1)$ and ϵ_{it} is the stochastic portion of the frontier. Taking the simpler case of the first two inputs, in a parametric framework one is left to decide between one of two linearised specifications of $f(x_{it})$: A linearised Cobb-Douglas production function of the form:

$$y_{it} = \beta_1 l_{it} + \beta_2 k_{it} + v_{it} - u_{it} \qquad (9.1)$$

Where the lower case letters denote the natural logarithmic counterpart of a variable, and where, (similar to equation 6 in section 1) v_{it} is the linearised counterpart of the error term $(= ln\epsilon_{it})$. Alternative one can specify a translog production function of the form:

$$y_{it} = \beta_1 l_{it} + \beta_2 k_{it} + \beta_3 0.5 l_{it}^2 + \beta_4 0.5 k_{it}^2 + \beta_5 l_{it} k_{it} + v_{it} - u_{it} \qquad (9.2)$$

Which is a second order Taylor approximation of a CES production function (Christen et al., 1973). In several studies (for example, Iyer et al., 2008; Ghosh and Mastromacro, 2009, 2013; Wijeweera, 2010; Aguiar et al. 2017), the translog form is preferred to the Cobb-Douglas specification because it does not impose the constraining assumption of constant substitution elasticities across countries. The theoretical question of which model is a better representation of the data can be circumvented by testing the assumption empirically as is done in the next section.

u_{it}, the linearised inefficiency variable, is the variable of interest in this paper and, (similar to equation 7 in section 1) is given as:

$$u_{it} = \delta Z_{it} + \omega_{it} \qquad (10)$$

[4] In this study, human capital is omitted to mitigate the endogeneity effects of output and educational attainment. This issue is discussed in more detail in section 5 (Danquah and Ouattara, 2015)

Where, as in equation 7, δ is the vector of estimated coefficients for the vector of explanatory variables, Z_{it} (which may or may not include an intercept term, δ_0). Several explanatory variables have been proposed to explain the inefficiency term, those considered in this study are listed below:

List of inefficiency variables[5]:

1. Trade Openness
2. Government finance
3. Resource abundance
4. FDI
5. Ease of doing business/ Regulatory environment
6. Value added of primary sector
7. Financial Development
8. Basic Infrastructure

Table 3: Summary of factors for and against the case of African integration

Factors for integration	Factors against the case for integration
1. Gains from trade	1. High and divergent levels of government debt
2. Labour and capital mobility	2. Unstable institutions
3. Stabilisation of several small economies into a single economic bloc	3. Widely varying stages of development
	4. Divergence of key macroeconomic variables such as inflation and real interest rates

The aim of this paper, then, is to include a measurement of regional economic integration in the explanatory vector Z_{it} for the SADC region. The implicit hypothesis is that integration increases (decreases) output through reductions (increases) in economic inefficiency. As was noted in section 2, in the case of the SADC there are several factors for and against the case of regional economic integration some of which are summarised below.

Section 3. Model Identification and Results

Due to the short period for which meaningful integration data are available (2010-2013), the empirical investigation proceeds in two steps: the author first excludes integration from the analysis

[5]This list is drawn from Evans et al. (2002), Iyer et al. (2008), Ghosh and Mastromacro (2009, 2013), Wijeweera (2010) and Aguiar et al. (2016) and is specifically chosen for developing countries. See appendix B for a summary of the data.

which allows economic inefficiency in the SADC to be examined since its inception in 1992; based on this analysis, the author then selects the control variables to be included with the integration variable in control in the inefficiency equation (equation 10) above. While not ideal, this process is necessary and useful. The integration variable imposes significant data restrictions (available only from 2010-2013) implying limited degrees of freedom for statistical inference and hence statistical sensitivity to the choice of inefficiency control variables; by obtaining a view from a longer panel which excludes integration over the 1992-2014 period, it is possible to narrow down the set of inefficiency control variables to include over the shorter period of time for which integration data is available. This analysis also provides unique insights for economic inefficiency in the SADC, which is in itself a novel empirical exercise for the region.

3.1 Inefficiency in the SADC (1992-2014)

The beginning of the SADC provides a natural starting point to investigate economic inefficiency for the region. Appendix B discusses in more detail the necessary tests to ensure valid statistical inference including test for unit roots, cointegration and Granger-causality (Granger, 1988). These tests rule out the possibility of spurious regression as well as endogeneity bias resulting from simultaneity. From a panel cointegration analysis, it is also found that a long-run relationship exists between output and the two inputs of the production model.

Given the statistical validity, one can now evaluate the optimal parametric specification for inefficiency in the SADC. Three variations are considered: 1) models with and without inefficiency 2) the Cobb-Douglas specification versus the translog specification and 3) models with and without time trends. All of these factors can be evaluated empirically (Kumbhakar and Lovell, 2003). The presence of inefficiency in the production process of the economies can be tested explicitly in the stochastic frontier approach. This is achieved by testing the joint significance of the estimated parameters in the inefficiency.

These will include the coefficients, $\delta_0, \delta_1, \dots, \delta_m$ from equation 10 above as well as the variance term γ, which measures the proportion of total variation ($\bar{\sigma}^2$) in the disturbance terms (v_{it} and u_{it}) attributable to the variation in the inefficiency term u_{it}.

In mathematical form this is written:

$$\gamma = \frac{\sigma_u^2}{\bar{\sigma}^2}, \qquad \bar{\sigma}^2 = \sigma_u^2 + \sigma_v^2 \qquad (11)$$

where the choice of production function is tested by means of a likelihood-ratio test using a mixed chi-squared distribution (Coelli, 1995). The test of no inefficiency amounts to the test of joint significance that:

$$H_0: \gamma = \delta_0 = \delta_1 = \cdots = \delta_m = 0$$

Finally, the question of time trends is chosen from the statistical significance of the coefficient when included in the model. This includes time trends in the production function and the inefficiency model. In the case of the Translog production function this would involve comparing the original form from above:

$$y_{it} = \beta_1 l_{it} + \beta_2 k_{it} + \beta_3 0.5 l_{it}^2 + \beta_4 0.5 k_{it}^2 + \beta_5 l_{it} k_{it} + v_{it} - u_{it} \quad (9.2)$$

with the form:

$$y_{it} = \beta_1 l_{it} + \beta_2 k_{it} + \beta_3 0.5 l_{it}^2 + \beta_4 0.5 k_{it}^2 + \beta_5 l_{it} k_{it} + \beta_t t + \beta_{tt} t^2 + v_{it} - u_{it} \quad (9.3)$$

And where equation 10 above:

$$u_{it} = \delta Z_{it} + \omega_{it} \quad (10.1)$$

Would be modified to:

$$u_{it} = \delta Z_{it} + \delta_t t + \omega_{it} \quad (10.2)$$

As shown below, the presence of inefficiency effects is highly significant. This means that it is necessary to include a specification for the inefficiency model. The translog production function is superior to the Cobb-Douglas production function. This is to be expected given the restrictive nature of the Cobb-Douglas function which does not allow for input and substitution elasticities to vary across countries. Its rejection in favour of the translog production form implies that allowing the elasticities to vary offers a better description of the data. This finding is also supported by consistently similar findings in the literature especially for the case of developing countries (Evans, 2002; Kneller and Stevens, 2003). It is also found that the inclusion of a time trend in both the production function and the inefficiency model is preferable, which accounts for technical progress over time.

Table 4: Hypothesis testing for production function[6]

Hypothesis Test, H_0	LR-test Statistic	p-value	Decision
No inefficiency effects: $\gamma = \delta_1 = \cdots = \delta_m = 0$	89.5	< 0.001	Reject model with no inefficiency effects, in favour of stochastic frontier model
Cobb-Douglas function is an adequate model: $\beta_3 = \beta_4 = \beta_5 = 0$	101.32	< 0.001	Reject Cobb-Douglas model in favour of translog specification
No Technical change: $\beta_t = \beta_{tt} = 0$	17.106	0.0067	Reject the null, in favour of the alternative that technical changes are significant

The specification for this first model is then the production function in (9.3):

$$y_{it} = \beta_1 l_{it} + \beta_2 k_{it} + \beta_3 0.5 l_{it}^2 + \beta_4 0.5 k_{it}^2 + \beta_5 l_{it} k_{it} + \beta_t t + \beta_{tt} t^2 + v_{it} - u_{it} \quad (9.3)$$

And the inefficiency model in 10.2

$$u_{it} = \delta Z_{it} + \omega_{it} \quad (10.2)$$

More particularly, we have:

Inefficiency Model 1

$$u_{it} = \delta_0 + \delta_1 FDI_{it} + \delta_2 ElectricityAccess_{it} + \delta_3 AgriValueAdded_{it} + \delta_4 M2_{it} s + \delta_5 ResourceRents_{it} + \delta_6 TradeOpenness_{it} + \delta_7 t + \omega_{it}$$

The results for the preferred model are shown below. In the production function, all variables are highly significant except the time trend which is significant at the 10% level and the quadratic variables for labour and time are not statistically significant. Turning to the inefficiency model, it should be noted that because the model measures inefficiency, a negative coefficient implies reduced inefficiency (or gains in output as shown above in figure). Hence FDI, access to electricity, agricultural value added and financial development are all significant factors explaining

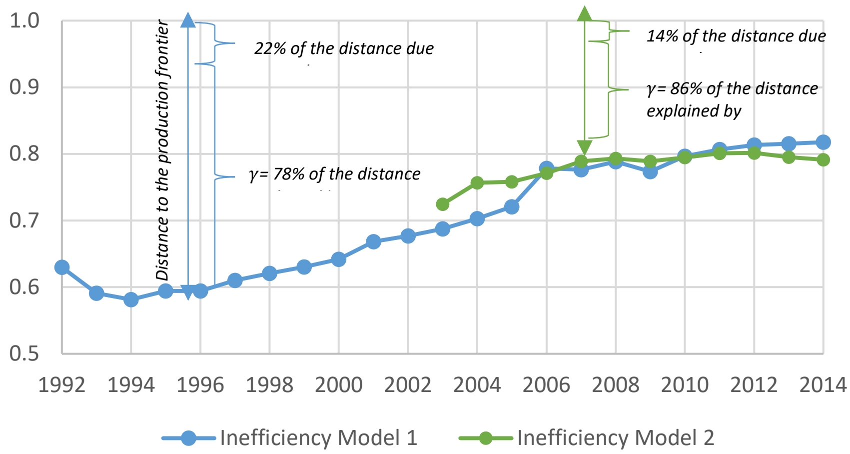
[6] The result reported here reflect the testing of the translog production function with and without inefficiency effects as in equation 9.3

inefficiency. The finding that FDI decreases inefficiency is already well documented in the literature (Iyer et al., 2008; Wijeweera et al., 2010).

Access to electricity also results in efficiency gains, as can be expected from improving basic infrastructure. Agricultural value added as a percent of GDP is also significant but is associated with an increase in inefficiency. Theoretically one channel through which this might operate is an over-reliance on the primary sector for economic growth. Similarly, rents on natural resources as a percent of GDP is associated with increases in inefficiency although it is not statistically significant at a traditionally accepted level (p=0.15). The explanation given for this in Aguiar et al. (2017) is that abundance of natural resources creates a direct path to wealth thus dis-incentivising countries to create value added services.

Financial development, as measured by M2, is found to be an important factor in reducing economic inefficiency – similar results are found when the financial development measure is changed to domestic credit instead of M2. It is worth noting that in Evans et al. (2002), M2 features as part of the Translog production function rather than in an inefficiency model. For the SADC, including financial development as part of the production function does not yield significant results which can be explained by long-run monetary neutrality.

Figure 7: Inefficiency in the SADC (1992-2014)



Trade openness (the sum of exports and imports as a percent of GDP) is found not to have a statistically significant impact on inefficiency in the SADC region. This may in part be explained by the fact that there is a strong overlap between FDI and trade openness which are thus difficult to disentangle (Babatunde, 2011). The gamma parameter, which is highly significant, means that 78% of the variation of the distance from the frontier can be explained by inefficiency variables as is shown impressionistically in figure 8 above. Over the 1992-2014 period, inefficiency declines in the SADC with a low of 58% efficiency in 1994 and a high of 82% efficiency by 2014.

Table 5: Production and Inefficiency Models

Production Function				
Variable	**Estimate**	**Std. Error**	**t-ratio**	**p-value**
Intercept	14.82752	0.97712	15.17	<0.001***
l_{it}	-1.63239	0.30167	-5.41	<0.001***
k_{it}	1.62048	0.18958	8.54	<0.001***
$0.5l_{it}^2$	0.03929	0.04036	0.97	0.330
$0.5k_{it}^2$	0.21703	0.01991	10.89	<0.001***
$l_{it}k_{it}$	0.00029	0.00064	0.46	<0.001***
t	-0.13058	0.03107	-4.20	0.092*
t^2	0.01347	0.00801	1.68	0.644
Inefficiency Model (1)	*1992-2014*			
Intercept	0.79008	0.29983	2.635	**0.008*** **
FDI	-0.04591	0.01610	-2.851	**0.004*** **
Elec.Access	-0.01258	0.00512	-2.456	**0.014** **
Agri.ValueAdded	0.00436	0.00158	2.750	**0.006*****
M2	-0.01605	0.00892	-1.7995	**0.072***
ResourceRents	0.02064	0.01430	1.443	0.148
Trade Openness	0.00415	0.00541	0.766	0.443
Time	-0.01782	0.01303	-1.367	0.171
σ^2	0.18138	0.03379	5.367	**<0.001*** **
γ	0.78272	0.01372	56.019	**<0.001*** **
Log Likelihood Value:	*117.94*	*Mean efficiency:*	*0.70356*	
Inefficiency Model (2)	*2003-2014*			
Intercept	0.33431	0.13084	2.555	**0.011** **
FDI	-0.09981	0.03220	-3.099	**0.002*** **
Elec.Access	-0.07405	0.01077	-6.871	**<0.001*** **
Agri.ValueAdded	0.00831597	0.00370	2.241	**0.024** **
M2	-0.00956	0.00637	-1.500	0.134
Resolving Insolvency	0.04787	0.02515	1.903	**0.057***
Government Debt	0.05312	0.01995	2.661	**0.008*** **
Time	0.05312653	0.01995	2.661	**0.053** **
σ^2	0.08748290	0.02065	4.236	**<0.001*** **
γ	0.86948032	0.01363	71.081	**<0.001*** **
Log Likelihood Value:	*95.92*	*Mean efficiency:*	*0.78038*	

One of the issues with this initial model is that it does not include institutional factors such as government spending and regulatory conditions which are important determinants of long-term growth (Acemoglu and Zilibotti 2001; Acemoglu et al. 2004; Christie, 2014). Incorporating data on these factors requires truncating the period of analysis from 1992-2014 to 2003-2014 for which the relevant data is available. The two variables added to the model are government finances and a measure for the ease of doing business namely, the average time taken to resolve insolvency.

The two insignificant variables in model 1 (rents on natural resources and trade openness) are dropped for this model. Only one variable for the business regulatory environment (among those available in the ease of doing business measures) is used to avoid multicollinearity issues. Because the number of observations across the two models are not the same, comparing the model with and without institutional specification is not possible by means of a classic likelihood ratio test. The resulting model is:

Inefficiency Model 2

$$u_{it} = \delta_0 + \delta_1 FDI_{it} + \delta_2 ElectricityAccess_{it} + \delta_3 AgriValueAdded_{it} + \delta_4 M2_{it}s + \delta_5 Insolvency_{it} + \delta_6 GovDebt_{it} + \delta_7 t + \omega_{it}$$

3.2 Results

A higher portion of the variation in the distance from the production frontier is explained in the model when government spending and the ease of doing business measure are included. Both variables are associated with increases in inefficiency as would be expected.

Negative effects of government debt on output points to excessive levels of debt over the 2003-2014 period as was shown in figure 3 in section 1.2. Government debt is often positively associated with economic growth when government spending is below its optimal level. The fact that government debt has a highly significant and positive coefficient here indicates the SADC member countries have experienced excessive levels debt since the inception of the Regional Economic Community.

The variables of the other signs from inefficiency model 1 all remain the same in inefficiency model 2 and are also similar in magnitude. Because of its superior ability to explain the distance from the production frontier, model 2 is then chosen as the indicative model of inefficiency in the SADC. The inefficiency model with integration is then:

$$u_{it} = \delta_0 + \delta_1 FDI_{it} + \delta_2 ElectricityAccess_{it} + \delta_3 AgriValueAdded_{it} + \delta_4 M2_{it}s + \delta_5 Insolvency_{it} + \delta_6 GovDebt_{it} + \delta_7 ARII + \delta_8 t + \omega_{it}$$

For which the results are as below:

Table 6: Inefficiency with integration

Inefficiency Model (3)	2010-2013			
Variable	**Estimate**	**Std. Error**	**t-ratio**	**p-value**
Intercept	0.85776	0.71528	1.1992	0.2304521
FDI	-0.01529	0.00429	-3.5592	**<0.001*** **
Elec.Access	-0.02425	0.00417	-5.8168	**<0.001*** **
Agri.ValueAdded	0.01868	0.00896	2.0841	**0.037** **
M2	-0.00869	0.00364	-2.3873	**0.016973** **
Resolving Insolvency	0.09489	0.08928	1.0629	0.2878469
Government Debt	0.01686	0.00729	2.3125	**0.021** **
ARII	-1.71156	0.95696	-1.7885	**0.073***
Time	0.05103	0.11443	0.4459	0.656
σ^2	0.05143	0.00782	6.5763	<0.001***
γ	0.84750	0.46053	1.8402	**0.06573***
Log Likelihood Value:	57.27672			
Mean efficiency:	0.80626			

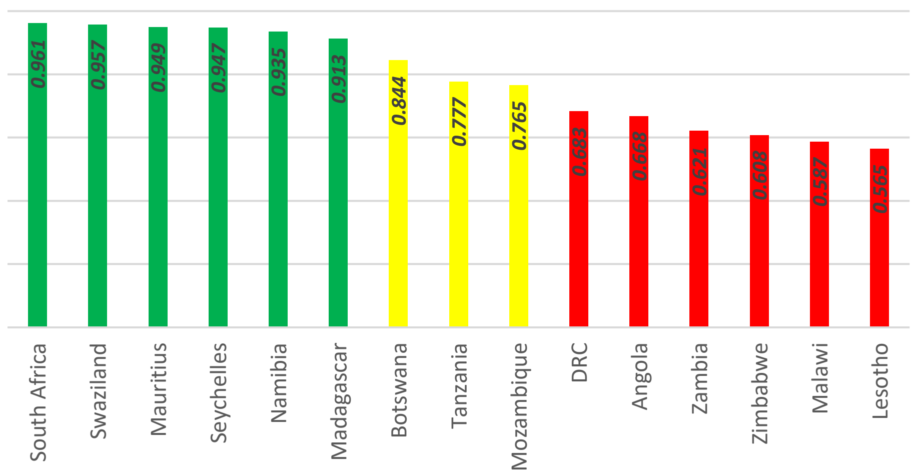
FDI, access to electricity and M2 all reduce production inefficiency as before where FDI and access to electricity are highly significant (p<0.001) and M2 is significant at the 5 percent level. Agricultural value added and government debt (both measured as a percent of GDP) are also significant at the 5 percent level and are associated with increased inefficiency in the SADC region. Time to resolve insolvency is associated with increased inefficiency as well but is not statistically significant over the 2010-2013 period. The gamma parameter is significant at the 10 percent level (p=0.066), and its magnitude implies that nearly 85% of the distance of production from its frontier is explained by the inefficiency model.

The African Regional Integration Index appears to be picking up on a significant feature of efficiency in African production (p=0.073): increases in the score are associated with reduced economic inefficiency. The magnitudes in the inefficiency model should be interpreted with caution. In terms of the relative magnitude of the coefficients, the variables have differing units of measurement. The ARII, for example, has a possible range of [0:1], and hence the coefficient for this variable also represents the total possible reduction in inefficiency achievable through regional economic integration, hence it is far larger than the other variables.

A relative comparison is nevertheless possible if one takes into consideration the total range of each variable rather than the coefficient. Given many of the variables are measured as percentages of GDP or the population their magnitudes can be compared to the integration index by multiplying by 100[7]. For example one could, somewhat crudely, infer that going from no economic regional integration whatsoever to being as integrated as the highest integrated member in the SADC for the 2010-2013 period would more than offset the inefficiency resulting from a 100 percentage point rise in the debt-to-GDP ratio.

That being said, the absolute effect of these coefficients does not have an absolute economic interpretation. This is because, in the stochastic frontier framework, inefficiency is measured as an index from [0:1] where a score of 1 represents the best practice use of inputs to attain a level of output. It is still useful to compare the relative efficiency of the members in the region. The average scores for each of the 15 members are reported below.

Figure 8: SADC Average Efficiency Scores (2010-2013)



Section 3.3 Discussion

The fact that integration is associated with measurable improvements in economic efficiency and growth has significant implications for the region. Importantly, it shows that regional integration as a political goal outlined in the Regional Indicative Strategic Development Plan (RISDP) is

[7] Access to electricity and agricultural value added percentages necessarily range from 0-100 and hence are comparable to the ARII in magnitude by multiplying their coefficients by 100. Government debt and FDI can and do exceed 100% of GDP. M2 and time to insolvency are measured in different units and hence are not coefficients do not give a sense of their relative magnitudes.

aligned with the economic interests of the region. Where previous find ambiguous results on the overall effect of integration, this result shows that the region as a whole stands to benefit by furthering regional integration.

In addition, the measurement of integration in this study covers a range of variables for economic integration which are specifically aligned to the integration goals of this regional economic community. The findings in the stochastic frontier model suggest not only that regional integration is statistically significant but also that it is practically significant. In terms of policy, this means that regional integration should be regarded as having the similar efficacy as factors like government debt and infrastructure development, as far as efficiency gains are concerned.

This has important significant implications for the SADC. To the extent that economic efficiency is an important driver of economic growth in the SADC, pursuing regional economic integration could create significant efficiency gains across the region, particularly for those countries such as Zimbabwe Malawi and Lesotho who score lowest on the efficiency scores in the SADC. Some degree of caution is still required when interpreting this result because it is an aggregate result for the region and does not explicitly model the heterogeneity of integration effects across the region. Thus while integration may be beneficial to the SADC as a whole, this does not mean it will benefit each member equally or even that it will necessarily benefit every member in a significant way.

Section 5 Conclusion

This paper set out to measure empirically the effect of regional economic integration for SADC members. It has shown that deepening regional integration within the SADC can be expected to improve economic efficiency in the region and therefore increase economic output. By measuring the effects of integration on economic efficiency it was also necessary to identify the most important determinants for economic inefficiency in the SADC. Several variables were found to be significant including: government debt, high dependence on the primary sector, poor basic infrastructure, financial development and FDI. By empirically quantifying the inefficiency effects of regional economic integration, this study has shown that it plays a comparable role to government finances and basic infrastructure development in improving economic efficiency.

This paper has contributed in several ways to the existing literature. Firstly it represents, to the best of the author's knowledge, the first stochastic frontier analysis as specifically applied to the SADC region, and certainly with respect to measuring the effects of regional economic integration in the stochastic frontier framework. This methodology has provided a more nuanced view of changes in output by empirically demonstrating that the production function models in SADC economies exhibit significant inefficiency effects. This implies that leaving inefficiency out of the growth accounting specification may falsely attribute changes in economic efficiency to technical change.

The analysis could also be extended beyond the SADC to other regional economic communities and indeed to other integrated regions in the world such as the EU – for which data is more readily available and therefore a more sophisticated analysis would be possible. For present purposes however, the results from this paper show that regional integration is a matter that should be taken seriously by the SADC and that by furthering regional integration, the community is likely to experience significant economic efficiency gains.

Appendix A: Data

Variable (type)	Measured by:	Time Period available	Total number of observations	Source
Integration (ARII)	Index [0:1]	2010-2013	60	AU, AfDB, UNECA
Real GDP (expenditure)	Ln(GDP expenditure)	1992-2014	345	PWT 9.0
Real Physical Capital	Ln(Gross Fixed Capital Formation)	1992-2014	345	PWT 9.0
Labour	Ln(Total employed population)	1992-2014	345	PWT 9.0
FDI	Net inflows % of GDP	1992-2014	344	World Bank (WDI)
Access to electricity	% of total population	1992-2014	339	World Bank (WDI)
Value added by agriculture sector	% GDP	1992-2014	332	World Bank (WDI)
Rents from Natural Resources	% GDP	1992-2014	345	World Bank (WDI)
Financial Development (M2)	Currency, demand deposits, time and savings deposits	1992-2014	319	World Bank (WDI)
Government Debt (Gross ..?	% of GDP	1992-2014	258	IMF
Trade Openness	$\frac{(imports + exports)}{GDP}$	1991-2014	327	World Bank (WDI)
Time to resolve Insolvency	Average days to resolve insolvency	2003-2014	151	World Bank (WDI)

Appendix B: Unit Roots, Cointegration and Granger Causality

B.1 Unit Roots

It is first necessary to rule out the possibility of spurious correlations (Granger and Newbold, 1974). To do this, one can check the production variables and inefficiency variables for stationarity. The author employs the method used by Choi's (2001)[8] unit root Fisher test which is based on Augmented Dickey-Fuller tests (Dickey and Fuller 1979, 1981) in the panel data setting. This is more appropriate than other panel data unit root tests such as Levin-Lin (1992, 1993) or Im-Pesaran-Shin (Im et al., 1997) given the data is unbalanced. Choi's Fisher test runs unit root tests for each panel individually and then combines the values from this test to produce an overall result for the variable. The test combines these p-values using the inverse chi-squared, inverse-normal, inverse-logit transformations and a modified version of the inverse chi-squared transformation which performs better for larger values of N (Choi, 2001). The inverse chi-squared and modified chi-squared scores are shown below.

Table A: Panel Unit Root Test Results:

H_0: *All panels contain unit roots.* H_a: *At least one panel is stationary.*

Variable	Inverse χ^2	Modified Inv. χ^2	H_0 vs. H_a
ARII	58.5288***	3.6830***	H_a
FDI	70.3624***	5.2108***	H_a
Elec. Access	50.5993**	2.6594*	H_a
Agri. Val. Added	71.4492***	5.3511***	H_a
Nat. Res. Rent	28.9884	-0.1306	H_0
M2	51.6015***	2.7887***	H_a
Gov. Debt	41.6458*	1.5035*	H_a
Trade Openness	40.1402	1.3091*	Inconclusive
Insolvency	92.7021***	9.2499***	H_a

where ***: p<0.01; **: p<0.05; *p<0.1

Seven of the nine variables considered are found to conclusively reject the null that in favour of the alternative that at least one panel is stationary. Rents of natural resources as a percent of GDP is found to contain unit roots in all panels while the trade openness variable is found to lie just outside the lowest traditionally acceptable level of significance (10%) for the inverse chi-square

[8] Itself similar in design to Maddala and Wu's (1999) panel unit root methodology

statistic and just inside the this level for the modified statistic. These two variables are not included in the specification for the inefficiency model with integration.

B.2 Endogeneity and Granger Causality

Greene (2011) points out that there is no agreed upon measure to diagnose or mitigate the effects of endogeneity in the framework of non-linear stochastic frontier models such as the one used in this paper. The growth accounting framework, being a single equation model, only allows a one-way causal direction from independent variables to the dependent variable, which, if simultaneity effects are present, could lead to biased estimation results because of the endogeneity this would implies. For variables with longer time periods it is possible to test the direction of causality (Granger, 1988). When testing for Granger-causality in a multivariate panel model, there must at least $T > 5 + 3K$ time periods in the panel (Dumitrescu and Hurlin, 2012) where K is the desired lag order.

Given Granger-causality testing requires at least one lag, this means the only panels with 8 time periods or more are subject to such an analysis. With the data used in this paper, this means only the panel variables used in inefficiency model 1 and 2 (the models the 1992-2014 period) can be assessed. The test also requires that the panel be strongly balanced for the period being tested. Given none of the inefficiency variables are balanced for the entire 1992-2014, Granger-causality is tested only for the periods in which each of the panel data variables are balanced.

The testable variables are: FDI, access to electricity, agricultural value added, trade and human capital. The only variable which exhibits simultaneity effects is human capital. Human capital is therefore not included in any of the model specifications in order to avoid endogeneity bias. Two of the variables come close to exhibiting simultaneity are FDI and M2 with statistics that lie close to, but nevertheless outside of, the traditionally acceptable level of significance of 10%. The test also shows that all independent variables Granger-cause the dependent variable, with FDI, trade and human capital lying just outside the 5% level of significance. M2 is significant at the 5% level while access to electricity and agricultural value added are both found to be highly significant ($p<0.01$). In summary, the results show that for all of the testable variables except human capital, we may reject the presence of simultaneity for these variables.

Table B: Panel Unit Root Test Results:

Variable	$\widetilde{Z}$ for H_0: GDP causes variable	$\widetilde{Z}$ for H_0: Variable causes GDP
FDI	1.5399 (p=0.1236)	1.9043* (p=0.0569)
Access to Electricity	0.5585 (p=0.5765)	5.2020*** (p=0.0000)
Agricultural Value Added	0.6462 (p=0.5182)	3.0163*** (p=0.0026)
Broad Money (M2)	1.5155 (p=0.1297)	1.9625** (p=0.0497)
Trade Openness	1.1552 (p=0.2480)	1.9511* (p=0.0510)
Human Capital	2.2110 (p=0.0270)	1.7857* (p=0.0741)

Cointegration

Finally, to check that the production function represents a long-run relationship between output and the two inputs one can run tests for cointegration between these variables. This is done by using the panel cointegration framework as in Pedroni (1999, 2001, 2004) which adapts the time-series, residuals based approach to cointegration testing in Engle and Granger (1987) to a panel data. The statistics reported below are the Panel Dynamic Ordinary Least Squares estimates for each panel variable (capital and labour). For both variables the resulting t-statistic are highly significant (p<0.001) and we may therefore conclude that a long-run relationship between output and the production inputs exists. This implies that by differencing the data, one would be losing out on long-run information in the model (Engle and Granger, 1987).

Table C: Cointegration Test Results:

Variable	Measured by	PDOLS	t-stat
Real Physical Capital	Ln(Gross Fixed Capital Formation)	-0.02566	9.685***
Labour	Ln(Total employed population)	1.975	23.81***

***: p<0.001

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