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Does Education Help Local Economies Reach Economic Potential? Evidence from South Africa

By Brian Tavonga Mazorodze[*] & Harris Maduku[±]

It is widely understood in development circles that poverty alleviation is elusive unless local economies operate productively with limited resources and existing technology. With a high rate of poverty on the back of weak output growth at municipality level in South Africa since 1994, this background makes it necessary to establish factors that could increase the pace of economic development and help local economies produce at full capacity. Using a stochastic frontier analysis of South Africa's 234 municipalities observed between 1995 and 2018, this paper finds postgraduate education (Masters and Doctorates) relevant in explaining the ability of these local economies to reach their full potential and the effect increases with the size of the manufacturing sector, life expectancy and trade. The stock of high school, diplomas, bachelors, and honours does not significantly contribute towards productive efficiency of these 234 municipalities reinforcing concerns of a possible structural mismatch between lower-level qualifications and the labour market demands. Consequently, moving these municipalities closer to their full potential may be achievable through ensuring that the undergraduate cohorts reach Masters, and PhD level complemented by a manufacturing-oriented structural change.

Keywords: *education, technical inefficiency, structural transformation, stochastic frontier model, local municipalities, South Africa*

Introduction

Economists have long known that education matters for poor countries and its economic importance cannot be overemphasized. It increases labour productivity (Mankiw et al. 1992, Barro 2001, Krueger and Lindahl 2001, Sala-i-Martin et al. 2004, ElObeidy 2016), aids local innovation (Lucas 1998, Romer 1990, Aghion et al. 1998) and facilitates the absorption of imported innovation (Grossman and Helpman 1990, Phiri and Mbaleki 2022). Literature linking its effect on economic output is too numerous to cite but we still lack evidence on whether education helps local economies reach their economic potential. Understanding the effect of education from this angle is important and necessary given that skill shortage is generally cited as an important source of resource inefficiency in poor countries. Against this background, this study focuses on the relationship between education and the ability of local economies to reach their economic potential in South Africa. Methodologically, the analysis uses a panel dataset comprising 234

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municipalities between 1995 and 2018, 8 of which are metropolitans and 226 are local municipalities.

The study is similar in spirit with Bhorat et al. (2016) who establish a positive effect of higher tertiary education on economic growth in South Africa using a standard Cobb-Douglas production function. What Bhorat et al. (2016) do not capture methodologically is the fact that deviations from a production function not only reflect random factors. They also reflect technical inefficiency which is essentially the inability to produce maximum output with given resources and existing technology. South Africa is well known for having a skill deficit despite being technologically better-off than many countries in Africa. As a result, relying on an analytical approach that assumes full utilisation of existing technology can be empirically misleading. Secondly, Bhorat et al. (2016) do not consider an important caveat that the economic contribution of education to a larger extent depends on the economic structure, the population’s health status and the exposure of local economies to foreign trade.

In a bid to improve the work of Bhorat et al. (2016) therefore, this study makes five contributions. Firstly, it models the effect of education on technical efficiency and not frontier output. This allows the paper to explain why certain local economies operate below their maximum possible output and what efficient municipalities have done to operate efficiently with limited resources and existing technology. Secondly, it conducts the analysis in a panel data framework comprising 234 local municipalities. Relative to a time series framework employed in Bhorat et al. (2016), a panel data framework employed here brings a larger sample size while capturing the diversity of local municipalities. Thirdly, it relies on a Cobb Douglas production function that categorises labour into low-skilled, semi-skilled and skilled workers. This categorization is important empirically as the heterogeneity of skills embodied in workers implies different effects on output. Fourthly and most importantly, it measures education in a manner that distinguishes different levels of education. This contribution acknowledges the possibility that different levels of academic qualifications may have heterogeneous effects on productivity. Fifth, it examines the interactive effect of education and different economic sectors, trade, and a health indicator to determine whether the effect of education depends on structural transformation, trade, and population health, respectively.

The empirical results are striking. Firstly, they show that output correlates positively with skilled and semi-skilled workers and negatively with low-skilled workers. Secondly, undergraduate degrees, diplomas, high school, primary school and honours degreed cohorts do not have a significant effect on productive efficiency. It is only postgraduate education that correlates negatively and significantly with productive inefficiency. Thirdly, the effect of postgraduate education increases with the manufacturing sector, trade and life expectancy suggesting that expanding the manufacturing sector, increasing trade and improving life expectancy does strengthen the positive effect of postgraduate education on productive efficiency.

The rest of the paper is organised as follows. Next section provides the analytical framework. The empirical model is specified in the following section and results are presented afterwards. Finally come the concluding remarks.

Literature Review

In general, research looking at the effects of human capital on efficiency and productivity growth include both health and education aspects and they are divided into cross-countries studies and country specific studies as well. With regards to the education impact, which is the main target of this paper; variables that are commonly identified as proxies for education include but are not limited to literacy rate, mean years of schooling, educational level of workforce, and school enrolment rate and government expenditure on education. This varied approach on measuring human capital or education has led to mixed results in this area of research (effects of education on efficiency and productivity). The mixed results found might be attributed to the differences in measuring human capital, the disturbance made by influential outliers in the datasets used and lastly the endogeneity of human capital as well might seriously bias the estimation results.

The relationship between education and efficiency has gained momentum among economists overtime mainly influenced by the narrative that, high efficiency leads to economic growth, increased incomes for labour and that of entrepreneurs (Qutb 2017). Analysing the education and efficiency relationship, Chevalier et al. (2004) found that education has an effect on wages but not clear on its relation to productivity and efficiency. Knight et al. (2007), explored the external effects of education on productivity and efficiency using Ethiopian data. Their study revealed the external benefits of education of productivity but not on technical efficiency. The central argument of their paper was that education externalities affect adoption and spread of innovation hence raise productivity especially in farming. On the other hand, using average and stochastic production frontier functions, Abdullah et al. (2011), discovered that household education significantly reduces both production and technical inefficiencies. However, their discovery could not shed light on the external benefits of education. For example, a neighbour's education does not affect productivity in the context of a farming community. Results from a Belgian linked panel data suggested that educational credentials have a stronger impact on productivity but not on wage costs (Kampelmann et al. 2018). In as much as their results are in line with that of Knight (2007), findings from Rukumnuaykit and Pholphirul (2016) and Kampelmann et al. (2018), further looked at the different stages of education and made a discovery that the impact of education on productivity is found too strong on young workers and women.

Wei and Hao (2011) tested the effects of human capital on total factor productivity (TFP) using a dataset spanning from 1985-2004. They found that human capital significantly impacts TFP, meaning that high educated employees are more productive when compared to those who are less endowed. Digging deeper into the education variable, the authors discovered that increasing quality in primary school had much impact compared to other learning levels. Although contacted in different countries and in different times studies from Wei and Hao (2011), Kampelmann (2018) and Setiadi et al. (2020) agreed that education young people does have a high impact of productivity and efficiency. Still on the quality of human capital, Qutb (2017) investigated human capital quality on productivity growth in Egypt using data from 1980 to 2014. The study found that highly educated workers negatively impact labour productivity growth and those results are in contrary to the conclusions of Kampelmann et al. (2018) and Wei and Hao (2011) who reiterated that improving the quality of education does have a positive impact on productivity growth especially among young people.

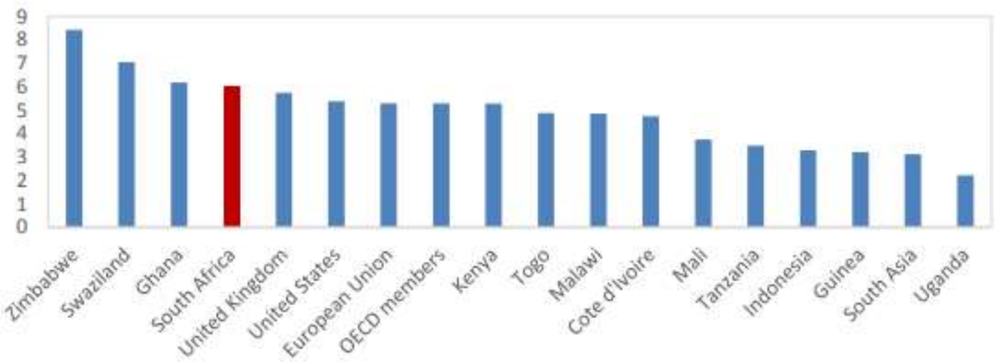
Further, Rehman and Mughal (2013), looked at the influence of skilled and unskilled labour on productivity in Pakistan using a Cobb Douglas function. Their findings reflected that skilled labour a positive impact on productivity. Interestingly, their paper found that whilst skilled labour increases productivity by more than 40%, unskilled labour actually decreases productivity by more than 70%. Also, on Malaysia, using panel data for 14 states, Arshad and Malik (2015), analysed the impact of education of production efficiency. Their study employed a General Least Squares (GLS) model and found that, higher educational levels and better health status positively improve the level of productive efficiency in the 14 sectors that they looked at in Malaysia.

Appiah and McMahon (2002), considered the relationship of education and productivity growth using the total capital approach that includes both public and private, human and knowledge capital formation in the medium term model for productivity growth. The author found that education measured in average educational attainment of the labour was significant in determining productivity growth. Looking at a more recent paper than that of Appiah and MacMahon (2002), Ajri and Ismail (2010), analysed the extent of economic benefits that an economy can derive from educational expansion. The study used both production and productivity functions. Their findings were that education expansion has a positive contribution to productivity but its role is weaker than other forms of inputs like physical capital. It is clear from this literature that studies specifically related to South Africa are scanty at best, a gap which is surprising given the country's skill gap and weak economic performance.

An Overview of South Africa's Education System

South Africa negotiated a new political path to move from an authoritarian governance system into one that seeks to re-align the balance of forces in favour of those that were historically excluded. One of the sectors that reflected that exclusion was the education sector. In the new democratic path since 1990, South Africa has drafted numerous policies that seek to improve access, participation and also boost societal class representation. However, in as much as progress has been made to improve the inclusion of those that were traditionally disadvantaged, there are concerns that, the expansion of access has failed to deal with the question on quality of output. Mlachila and Moeletsi (2019), iterated that the poor quality of education in South Africa deserves to be apportioned part of the blame for critical skills shortages and also the long-run low economic growth the country has been facing. They highlighted that low quality education has an impact on skills and employability of citizens, hence its negative impact on economic growth. The researchers, however, argued that, the low quality of education in the country is not mainly as a result of low or poor public funding into the sector (See Figure 1). South Africa ranks high by international standards with respect to public funding into the education sector but the country still suffers from the inequality legacy of the colonisation era (Mongale and Magongoa 2020).

Figure 1. *Government Expenditure on Education as a Percentage of GDP*



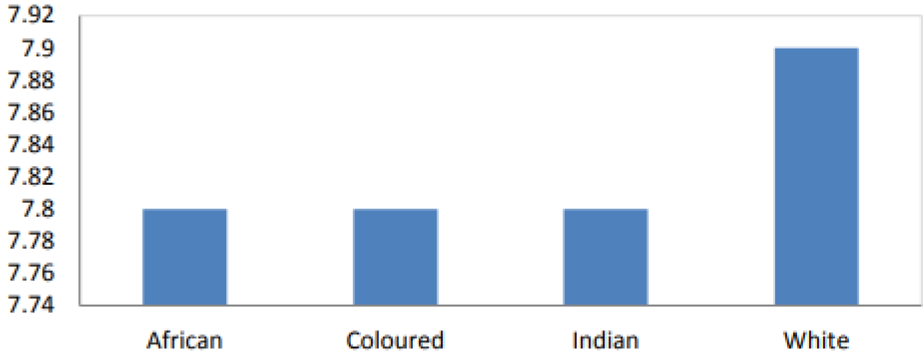
Source: World Bank Data (2017).

To add, the country's budget on education (6% of GDP) is comparable to the Organisation for Economic Co-Operation and Development (OECD), which puts it way ahead of many of its peers in Sub-Sahara Africa (Mlachila and Moeletsi 2019). This significant spending on education has however failed to improve the quality of output in the country. Mlachila and Moeletsi (2019), observed that most of the countries that spend less per learner in Sub-Sahara Africa have better quality on output compared to South Africa. The explanations for the inferior quality are multidimensional and considered complex as they range from history, race, inequality, corruption, socio-economic status, geographical location and in some cases low quality teachers (Sempijja and Letlhogile 2021).

Whilst on the quality of education in South Africa, Murtin (2013), cited infrastructure deficit as one of the main challenges leading to inferior quality of graduates in the country at both high school and University level. The study reiterated that primary and secondary schools are heavily underfunded in South Africa. Some of the things that come as a result of the underfunding are lack of classrooms, textbooks and shortage of teachers. However, this shortage is mainly in poor and rural communities mirroring the high level of inequality that engulfed the country during the apartheid era. So, one can argue that in as much as at macro level, public spending on the education sector is high, the distribution of that funding has failed to correct the high inequality between rural schools, township and those in affluent places. Besharati and Tsotsotso (2015), complimented Murtin's findings on the quality of primary and secondary education. However, he went further to suggest that teachers in government schools lack content and they have low accountability, hence the poor results they produce. They further went on to argue that, teachers have a huge wage bill and the salaries of entry level teachers is the same with those that have massive experience in the sector, killing motivation which then go on to impact the quality of output.

Linking the status of education in South Africa on productivity and growth, Mangale and Magongoa (2020) explained that, inequality and poverty have been hindering students from poor and rural communities from accessing University mainly because they attend dysfunctional schools compared to those in cities and from affording families. The scholars further argued that the dysfunctionality of rural and township schools has a long-term impact on completion rates which most public Universities are grappling with today. The poor quality of education from primary school is likely to impact more than just completion rates but also quality of the graduates as well, which also has an impact on productivity and later economic growth (Besharati and Tsotsotso, 2015, Mangale and Magongoa 2020).

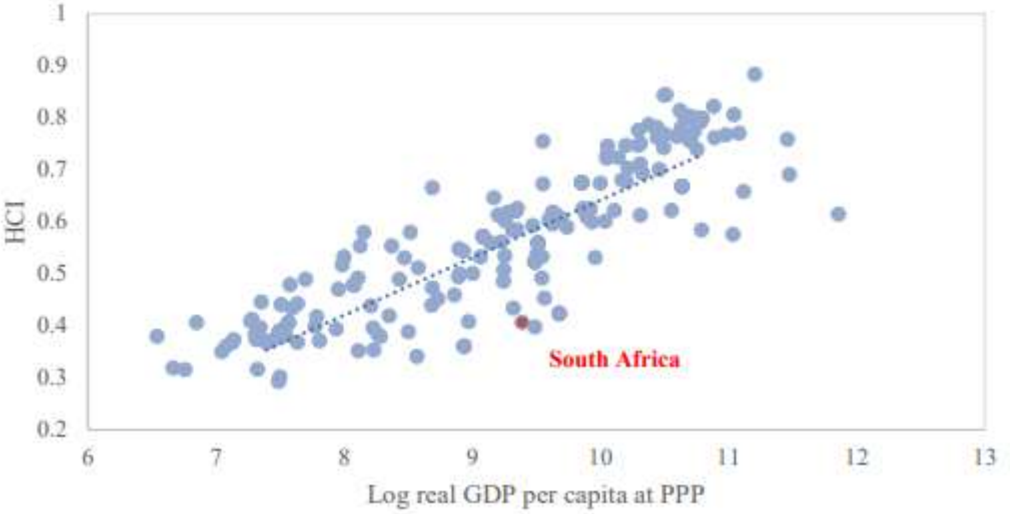
Figure 2. *Average Years of Primary Schooling by Population Group in South Africa*



Source: Stats SA (2016).

The quality problem on output from the education sector is concerning given the importance of education as a variable that affects skills, productivity and economic growth. Also education increases the quality and quantity of innovation incidences in an economy. A country that has high innovation incidences benefits from new products, new knowledge and new processes that can drive economic growth (Mlachila and Moeletsi 2019). All those possible benefits are threatened if a country's quality of education does not improve overtime. To boost the chances of innovation incidences and also on quality of graduates, a country should have a considerable quantity of learners that graduate with good mathematics and science grades. Looking at the International Association for the Evaluation of Educational Achievement (IAEEA), South Africa ranked second from last on learner performance in mathematics and last in science performance in 2015 (Bisseker 2019). Those rankings combined with low completion rates in Universities should be worrisome for a country struggling with poverty, unemployment, skills shortage and low growth.

Figure 3. *Human Capital Index versus GDP per Capita*



Source: World Bank (2019).

Figure 3 provides more evidence with regards to the lagging quality of basic education in South Africa. The Human Capital Index (HCI) measures the amount of human capital that a child born this year (2022) can expect to have by the time they are 18 years old. It also indicates the productivity of the generation of workers to come versus a benchmark of complete education and full health. Looking at the HCI rankings closely, South Africa ranks 126th out of a total of 157 countries that had available data. The ranking is not in line with expectations of a country with a respectable per capita income level which further shed light on the foundation of skills shortages the country.

Analytical Framework

Local Economic Development (LED) is, in the main, intended to maximise the economic potential of all municipal localities throughout the country. This description clearly acknowledges that local economies, to a large extent, operate below their potential level and policy interventions to improve efficiency are imperative as far as local economic development is concerned. As indicated in the introductory section, the objective here is to determine the contribution of education on local economies' ability to close their productivity gap. To achieve this objective, a stochastic frontier analysis (SFA, hereafter) is applied. Pioneered independently by Farrell (1957) and Aigner et al. (1977), the SFA is a parametric method that relies on a production function to measure the gap between observed output and potential output. The study prefers this method over its alternative, the Data Envelopment Analysis (DEA) due to its advantage of separating random noise from technical inefficiency. As a starting step, the analysis is benchmarked with a stochastic frontier model for panel data proposed by Battese and Coelli (1995) and it builds from the following equation.

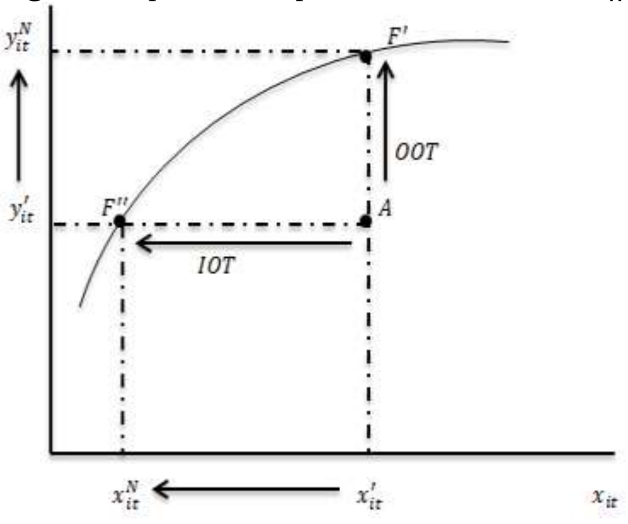
$$Y_{it} = \exp(x_{it}\beta + V_{it} - U_{it}) \ (1)$$
$$i = 1, \dots, N \quad t = 1, \dots, T$$

where x is a vector of factors of production used to produce output Y, β is a vector of unknown parameters to be estimated, subscripts i and t capture local municipality and time respectively, V is an error term capturing random noise[1] and U is a non-negative component capturing technical inefficiency. Technical inefficiency in this case measures the gap between observed output Y_{it} and potential output Y_{it}^*.

$$TE = {Y_{it}}/{Y_{it}^*} = \frac{\exp(x_{it}\beta + \mathrm{V_{it}} - \mathrm{U_{it}})}{\exp(x_{it}\beta + \mathrm{V_{it}})} = \exp(-\mathrm{U_{it}}) \ (1.1)$$

Graphically from Figure 4, an inefficient municipality sitting at point **A** can reach the production possibility frontier by going upwards to point F' or leftwards to point F''. The upwards direction increases output from y' to Y^N with fixed inputs x'. This is termed outward-oriented technical efficiency (OOT). Going leftwards reduces the amount of inputs used in production from x' to x^N without compromising output level y'. This is termed input-oriented technical efficiency (IOT).

Figure 4. *Input and Output Oriented Technical Efficiency*



Source: Own illustration.

By definition, LED is essentially about getting more from existing resources and available technology and not cutting back on factors of production such as labour and capital. In other words, it would be self-defeating to celebrate reaching economic potential through a process that sends people out of jobs (input-oriented

[1]The random term $V_{it}$is assumed to be $\mathrm{N}(0, \sigma_V^2)$ and independent of the inefficiency term U_{it} which is assumed to follow a truncated normal distribution with mean, $z_{it}\delta$ and variance σ^2. Vector z here captures the level of education while δ is the correlate of education on technical efficiency.

technical efficiency). Based on this reasoning therefore, an output-oriented technical efficiency is assumed in this paper.

Intuitively, the paper assumes that inefficient municipalities fall short of their potential output partly due to the lack of knowhow. This is a reasonable assumption since the lack of knowhow often leads to a suboptimal use of resources. With this assumption, the hypothesis that education reduces technical inefficiency can be tested. An educated workforce is equipped with skills that make it more efficient with fixed resources. Therefore, the idea here is to test whether differences in education can explain the heterogeneity of output-oriented technical efficiency levels across municipalities.

Analytically, the usual starting point involves choosing the input variables and selecting the appropriate stochastic frontier model. Regarding the former, the standard practice uses conventional factors of production namely capital and labour where capital is measured by gross capital investment and labour by number of people employed. Regarding the latter, the common model particularly applied in panel data contexts is the Battese and Coelli (1995) which treats unobserved heterogeneity as part of technical inefficiency. These two conventional choices suffer important limitations. First in relation to the Battese and Coelli (1995) model, it is hard to intuitively explain how education reduces technical inefficiency that is arising from time-invariant factors such as geographical location. If a municipality is failing to produce at its best because of a geographical disadvantage, running a regression with schooling as a source of inefficiency would be unreasonable. uLundi local municipality of KwaZulu-Natal is naturally placed in an economically unproductive district. Mandeni on the other hand is geographically located in a district where manufacturing activities thrive. It is situated near 1) sea ports, 2) one of the country's largest airport – King Shaka international airport – and 3) a good road network. Such locational attributes do not change with time and if they are giving Mandeni the advantage to set the productive frontier, it is hard to explain how education in uLundi will help it close the productivity gap (i.e. reduce inefficiency) and catch up with the frontier set by Mandeni when the two are faced with the same level of technology and fixed capital stock. There are scenarios of course where unobserved heterogeneity is mostly your culture, norms, religious practices and so on which can change with education. However, such a change is not guaranteed in practice and the probability of that happening is miniscule at best. To improve this methodological weakness, the paper applies instead the true-fixed effects stochastic model by Greene (2005) which controls time-invariant factors that are specific to each municipality and generate technical inefficiency scores that are free from unobserved heterogeneity.

Secondly, in relation to the measurement of labour, using aggregate employment figures treats labour as a homogenous factor which is highly problematic. In practice, labour is not homogenous. Workers have different skills and it is important to accommodate such differences as skilled and unskilled workers for example may have different effects on frontier output. Thirdly, measuring education using average years of schooling as did Barro (2001) and Arendt (2005) is limited in so far as it captures the time spent in school and not the quality of education. To accommodate these improvements, which this paper presents as its key contribution, consider the following production function.

$$Y_{it} = AK_{it}^{\alpha}L_{it}^{1-\alpha}e^{\varepsilon_{it}} \quad (2)$$

in which output Y of municipality i in year t is a function of labour L, capital stock K, the technology parameter A and an error term ε. Note here that $K_{it}^{\alpha}L_{it}^{1-\alpha}$ are part of vector x in equation (1), β would embed here α and $1-\alpha$ while $V_{it} - U_{it}$ would be ε_{it}. Parameters α and $1-\alpha$ represent capital and labour shares on output respectively and since the error term comprises two parts

$$\varepsilon_{it} = V_{it} - U_{it}$$

one can write the stochastic frontier production function as

$$Y_{it} = AK_{it}^{\alpha}L_{it}^{(1-\alpha)}e^{(V_{it}-U_{it})} \quad (3)$$

This production function implausibly assumes homogeneity of labour as indicated shortly above. In practice, workers are heterogenous in terms of skills. To accommodate this heterogeneity, the paper improves equation (3) by decomposing labour into three groups namely low-skilled, semi-skilled and skilled workers. Letting,

$$L_{it} = L_{it}^{\phi_j}, \quad j = 1,..,3$$

where j1, j2 and j3 represent low-skilled workers (LSW), semi-skilled workers (SSW) and skilled-workers (SW), equation (3) can be rewritten as,

$$Y_{it} = AK_{it}^{\alpha}(L_{it}^{\phi_1}L_{it}^{\phi_2}L_{it}^{\phi_3})^{(1-\alpha)}e^{(V_{it}-U_{it})} \quad (4)$$

Algebraically, one can re-specify equation (4) as

$$Y_{it} = AK_{it}^{\alpha}L_{it}^{(1-\alpha)\phi_1}L_{it}^{(1-\alpha)\phi_2}L_{it}^{(1-\alpha)\phi_3}e^{(V_{it}-U_{it})} \quad (5)$$

Parameters $(1-\alpha)\phi_1$, $(1-\alpha)\phi_1$ and $(1-\alpha)\phi_1$now capture shares of low-skilled, semi-skilled and skilled workers on output respectively. Replacing $L_{it}^{\phi_1}$, $L_{it}^{\phi_2}$ and $L_{it}^{\phi_3}$ with $LSW_{it}^{\phi_1}$, $SSW_{it}^{\phi_2}$ and $SW_{it}^{\phi_3}$ respectively yields

$$Y_{it} = AK_{it}^{\alpha}LSW_{it}^{(1-\alpha)\phi_1}SSW_{it}^{(1-\alpha)\phi_2}SW_{it}^{(1-\alpha)\phi_3}e^{(V_{it}-U_{it})} \quad (6)$$

Equation (6) shows that output is affected by capital stock, low-skilled, semi-skilled and skilled workers, random noise and technical inefficiency. As it is non-linear in parameters, the linearization of parameters is possible through taking natural logs.

$$\ln Y_{it} = \ln A + \alpha \ln K_{it} + (1-\alpha)\phi_1 \ln LSW_{it} + (1-\alpha)\phi_2 \ln SSW_{it} + (1-\alpha)\phi_3 \ln SW_{it} + V_{it} - U_{it} \quad (7)$$
$$i = 1, \dots, N \quad t = 1, \dots, T$$

The technical inefficiency model will then be specified as,

$$U_{it} = \beta Z_{it} + W_{it} \quad (8)$$

where equation (8) captures improved measures of education. The study essentially advances and empirically tests the hypothesis that different education qualifications (i.e., primary, high school, diploma, bachelors, honours and masters and doctorate) can have different effects on technical inefficiency. This is novel.

Data Description

The study relies on Quantec[2] municipality data stretching from 1995 to 2018. The panel dataset is balanced $i = 234$ and $t = 24$ yielding a total of 5616 observations (234×24). According to the constitution of South Africa, there are 278 municipalities in the country, comprising 8 metropolitans, 44 district and 226 local municipalities. In this study, focus is on metropolitans and local municipalities since district municipalities are essentially an aggregation of these two. The 8 metropolitans are Buffalo City (East London), City of Cape Town, Ekurhuleni Metropolitan Municipality (East Rand), City of eThekwini (Durban), City of Johannesburg, Mangaung Municipality (Bloemfontein), Nelson Mandela Metropolitan Municipality (Port Elizabeth) and the City of Tshwane (Pretoria). Due to the high number of local municipalities (226), their list is annexed in Table 1.

Model Specification

Methodologically, there are four empirical issues that deserve attention. First, one needs to make a choice between a one-step and a two-step approach. In the two-step approach, a stochastic frontier model is firstly estimated, and the computed technical efficiency scores are then used as the dependent variable in the second step. This approach is biased as the model estimated in the first stage is misspecified (Wang and Schmidt 2002). Therefore, as a remedial measure, a one-step approach has been proposed in literature and it simultaneously estimates the stochastic frontier model along with the inefficiency specification. This is the approach used in this paper.

The second issue relates to the choice of an appropriate functional form. Two functional forms common in literature are the Cobb and Douglas (1928) and the

[2]Quantec data provider which is a local consultancy firm that gathers macro and micro data for South Africa.

Translog specification by Christensen et al. (1973) and Diewert (1971). These two approaches have their advantages and disadvantages. For example, the Cobb Douglas specification is convenient and easy to interpret but it is criticized for being overly restrictive. The Translog on the other hand is flexible but faces collinearity and curvature problems due to the addition of interactions and second order terms. Notwithstanding these pros and cons, the Cobb Douglas and Translog specification continue to be widely used in efficiency literature and statistical tests are generally conducted to determine the one that best fits the data.

The third issue relates to the distribution of the inefficiency component. Common distributions used in literature include the half-normal, exponential and the truncated normal[3] (see Aigner et al. 1977, Meeusen and van der Broeck, 1977, Jondrow et al. 1982, Greene 1990). Although there are no written rules for choosing one distribution over the other, Bhattacharyya et al. (1995) encourages an understanding of the data generating process. The half-normal and exponential distributions have a mode of zero which implies a high proportion of perfectly efficient decision-making units. In a developing world where market imperfections are the rule rather than the exception, this assumption is less appealing. A more appealing distribution is the truncated-normal which has a non-zero mode. In addition, it is the truncated-normal distribution that allows one to estimate the conditional mean inefficiency specification in a one-step approach. Based on these two considerations, the truncated-normal distribution was assumed in this paper.

The fourth aspect is the endogeneity of labour and capital inputs in the stochastic frontier specification. Theory does treat labour and capital as exogenous to output but in practice, they can be both causes and consequences of output growth since an increase in output can also spur investment and more employment. In order to partially address this potential endogeneity problem, all right-hand side variables are included with a lag.

The first step was to conduct a likelihood ratio test on functional form. This test preferred a stochastic frontier model based on a Cobb Douglas functional form as the additional interactions and polynomial terms were jointly insignificant. The estimated frontier equation therefore took the following form.

$$\ln(\mathrm{Y}_{it}) = \beta_1 \ln(\mathrm{K}_{it-1}) + \beta_2 \ln \mathrm{LSW}_{it-1} + \beta_3 \ln(\mathrm{SSW}_{it-1}) + \beta_4 \ln(\mathrm{SW}_{it-1}) + \sum_{t=1}^{T-1} \beta_t(\mathrm{Year}_t) + V_{it} - U_{it} \qquad (9)$$
$$i = 1, \dots, 234 \quad t = 1995, \dots, 2018$$

where β_0 or $\ln A$ is eliminated through the within transformation to control for unobserved heterogeneity, $\alpha = \beta_1,\ \beta_2 = (1-\alpha)\phi_1,\ \beta_3 = (1-\alpha)\phi_2\ ,\beta_4 = (1-\alpha)\phi_3$ and the remaining variables Y , K , V_{it} and U_{it} are as defined before. The new variables LSW, SSW and SW are empirically measured by the employment of workers classified at Quantec as low-skilled, semi-skilled and

[3]There is also a gamma distribution which is often computationally unfeasible.

skilled respectively. Unlike the previous section, the technical inefficiency model here contains five different levels of education as explanatory variables.

$$\mathrm{U_{it}} = \delta_0 + \delta_1 \ln(\mathrm{PhD\_MSc}_{it-1}) + \delta_2 \ln(\mathrm{Hons}_{it-1}) + \delta_3 \ln(\mathrm{Bsc}_{it-1}) + \delta_4 \ln(\mathrm{HighScDip}_{it-1}) + \delta_5 \ln(\mathrm{Prim}_{it-1}) + W_{it} \qquad (10)$$

where PhD_Msc[4] is the total number of individuals with masters and doctorates in each municipality over time, Hons captures the total number of individuals with an honours degree, Bsc is the total number of individuals with a Bachelors degree, HighScDip captures the total number of individuals with high school and a diploma while Prim is the total number of individuals with less than high school level. The logic behind equation (10) is that education cannot be assumed to have a linear effect on technical inefficiency. There is no guarantee that a diploma holder is as efficient as a doctoral graduate even though both are educated. In practice, different education levels may have different effects on technical efficiency and exploring these potentially heterogeneous effects is a unique feature of this study. Notwithstanding these potentially heterogeneous effects, the general consensus in literature is that education increases efficiency and reduces wastage in production. Educated workers have better skills and improved decision making. They are productive and able to effectively execute managerial instructions. Therefore, $\delta_1 - \delta_5$ are expected to be negative[5] implying that inefficiency decreases with education.

Empirical Results

Results from the estimated stochastic frontier model are presented in Table 1a variant (1). They confirm that the positive effect of labour on output only comes from semi-skilled and skilled workers. According to the results in Table 1a, a percentage increase in semi-skilled and skilled workers is associated with a subsequent increase in output within the 0.374 – 0.40 and 0.307 – 0.336 percent range, respectively. Low-skilled workers, which from descriptive statistics account for a third of total employment on average, have a negative effect on frontier output which is highly significant across all the variants. Based on Table 1, a percentage increase in low-skilled workers correlates with a subsequent decrease in output within the 0.278-0.34 percent range. This result is self-explanatory.

Secondly, Table 1 shows that education has a positive effect on efficiency, but the effect is only significant for masters and doctorates. In other words, honours, bachelors, diplomas and primary cohorts do not have any effect on technical inefficiency. There are two possible explanations for this. The first is that lower levels of education do not significantly enhance an effective utilization of existing technology. In other words, there may be a structural mismatch between the skills

[4]For interpretation purposes, we will refer to the PhD_Msc category as postgraduates.

and academic content embedded in honours level and the demands of the economy. If students are schooled with content that is economically redundant, having a large stock of such may not significantly help municipalities reach their economic potential.

A second possible explanation could be attributed to unemployment that disproportionately affects those with lower level qualifications (see Altbeker and Storme 2013). It is easier for a postgraduate to get a job that an undergraduate in the labour market hence the significant effect of masters and PhD on technical efficiency may be simply reflecting their improved chances of getting formal employment unlike people with honours degree and below. In other words, the cohorts with honours degree and below may be entering insignificantly because they are marginalised from productive jobs.

For robustness check, the insignificant levels of education were dropped in variant (2) and the total number of individuals with masters and doctorates entered as the only explanatory variable. As variant (2) shows, the association between technical inefficiency and the MscPhD variable remains highly negative demonstrating that the exclusion of other levels of education does not alter the way postgraduates correlate with technical inefficiency. To check whether the association is stable over time, two separate regressions were estimated. Variant (3) is estimated based on the true-fixed effects model but the sample is limited to 1995 – 2008. Variant (4) comprises the 2000 – 2018 sampling period. Clearly, the negative association between postgraduates and technical inefficiency is robust to the exclusion of other levels of education as well as the decomposition of the total sampling period into different sub-periods.

In terms of diagnostic tests, lambda is above 1 across all the four variants. This shows that the technical inefficiency component highly dominates the noise term which is an indication that a stochastic frontier model is appropriate over the average production function with normal errors. In other words, the value of lambda provides justification for examining sources of technical inefficiency among these municipalities. The marginal effects associated with coefficients in variant (4) are reported in Table 1b. They are observation specification hence the paper presents them in purely descriptive sense.

Table 1a. *Education and Technical Efficiency*

	Variant (1)	Variant (2)	Variant (3)	Variant (4)
VARIABLES	(1995-2018)	(1995-2018)	(1995-2008)	(2009-2018)
	TFE	TFE	TFE	TFE
L.lnCapital	0.174***	0.196***	0.112***	0.0731***
	(0.0188)	(0.0133)	(0.0186)	(0.0184)
L.lnSkilled	0.307***	0.324***	0.325***	0.336***
	(0.0330)	(0.0314)	(0.0334)	(0.0330)
L.lnLowskilled	-0.278***	-0.263***	-0.319***	-0.340***
	(0.0230)	(0.0211)	(0.0230)	(0.0228)
L.lnSemiskilled	0.399***	0.374***	0.391***	0.404***
	(0.0287)	(0.0255)	(0.0288)	(0.0284)
Time dummies	--------	-------	-------	-------

Mu				
L.lnMscPhD	-3.439**	-3.863***	-3.390**	-3.269**
	(1.424)	(1.314)	(1.426)	(1.443)
L.lnHons	1.320		1.334	0.491
	(1.971)		(2.075)	(1.913)
L.lnBsc	-3.378		-3.197	-2.830
	(3.272)		(3.329)	(3.266)
L.lnHighScDip	0.0883		-0.0641	0.374
	(3.306)		(3.397)	(3.330)
L.lnPrim	-0.768		-0.895	-0.960
	(1.409)		(1.466)	(1.462)
Constant	-18.42**	-15.85**	-17.68**	-18.76**
	(8.569)	(8.336)	(8.754)	(8.597)
Usigma constant	1.706***	1.811***	1.695***	1.699***
	(0.0345)	(0.0217)	(0.0346)	(0.0343)
Vsigma_constant	-5.378***	-2.879***	-5.452***	-5.476***
	(0.0476)	(0.0336)	(0.0485)	(0.0493)
Sigma_u	2.346*** (0.040)	1.128*** (0.021)	2.333*** (0.040)	2.338*** (0.040)
Sigma_v	0.067*** (0.001)	0.043*** (0.033)	0.065*** (0.001)	0.064*** (0.001)
Lambda	34.542*** (0.040)	26.232*** (0.033)	35.637*** (0.040)	36.151*** (0.040)
Observations	5,382	5,382	3,042	3,042
Number of id	234	234	234	234
Prob > chi2	0.000	0.000	0.000	0.00

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 1b. *Marginal Effects*

Variable	Mean	Std Dev	Min	Max
lnMscPhD	-0.007	0.0026	-0.0735	-0.0024
lnHons	0.002	0.0010	0.0009	0.0282
lnBsc	-0.007	0.0026	-0.0722	-0.0023
lnDip	0.0001	0.0001	0.0001	0.001
lnPrim	0.0017	0.0005	-0.0164	-0.0005

From Table 1a, a potential criticism of the results is that the model does not include control variables. It is almost implausible to view education as the only source of inefficiency in these municipalities. In practice, there are many other factors that can significantly influence technical inefficiency and if correlated with education, the association between education and technical inefficiency presented in Table 1b will be biased. In light of this potential criticism, the paper considered additional control variables. Based on literature, the analysis particularly selected variables that are commonly cited in literature as relevant sources of technical inefficiency. These variables include health proxied by life expectancy, trade and shares of agriculture, manufacturing and services on total output to capture how technical inefficiency correlates with the economic structure.

In the dual economy model by Lewis (1954), productivity is low in agriculture and high in the manufacturing sector. Based on this model therefore, it can be hypothesized that municipalities can reduce inefficiency and reach their economic frontier if they move away from agriculture to manufacturing and other high productivity sectors. Trade is expected to increase technical efficiency through external competition that forces domestic producers to rationalise their operations and give up inefficient production practices that are not consistent with the output maximization objective. Health on the other hand is viewed as an important dimension of human capital. A healthy workforce is productive and records less absenteeism from work which collectively increases the chances of municipalities reaching their maximum output level. I therefore report results based on the following specification.

$$\begin{aligned} \mathrm{U_{it}} = \delta_0 + \delta_1 \ln(\mathrm{PhD\_MSc}_{it-1}) + \delta_2 \ln(\mathrm{Lifeexp}_{it-1}) + \delta_3(\mathrm{Trade}_{it-1}) \\ + \delta_4(\mathrm{Agric}_{it-1}) + \delta_5(\mathrm{Manuf}_{it-1}) + \delta_6(\mathrm{Servi}_{it-1}) \\ + W_{it} \qquad (11) \end{aligned}$$

where Trade is measured by the sum of exports and imports as a percentage of total output for each municipality, Lifeexp is life expectancy at birth, Agric, Manuf and Servi are percentage shares of agriculture, manufacturing and the service sector respectively. These controls vary across municipalities and over time. Agric is specifically agriculture, forestry and fishing. Servi covers wholesale and retail trade, catering and accommodation, transport, storage and communication, finance, insurance, real estate and business services, general government and community, social and personal services. Essentially comprises financial intermediary, retail and tourism. Data on these control variables are sourced from Quantec.

Again, the right-hand side variables are lagged to circumvent the potential reverse causality. As customary in literature, the study includes the control variables in a stepwise fashion. Across all the four regression variants, the postgraduate category remains negative, sizeable and statistically significant at 5 percent. The negative causal effect of postgraduates on technical inefficiency therefore exists in data even after controlling for other significant sources of technical inefficiency. In terms of the control variables themselves, life expectancy enters with an expected negative sign across all the regression variants. The negative sand significant sign on life expectancy validates the hypothesis that health increases productive efficiency and reduces inefficiency. Similarly, the negative and significant sign on trade is consistent with the discipline hypothesis which predicts an inverse relationship between trade exposure and technical inefficiency. It is widely accepted in literature that trade exposes local economies to immense competition from the global economy and increased competition eliminates lax in production which consequently raises efficiency levels. This is confirmed in Table 2 in which an increase in trade intensity is associated with a decline in technical inefficiency on impact.

In terms of the economic structure, evidence in Table 2 shows no evidence that agriculture and services correlate significantly with technical inefficiency. It is only the manufacturing sector that enters with a negative effect that is sizeable and statistically significant at 1 percent level across all the four variants. This is indirectly confirmatory to the Lewis (1954) dual economy model in which expansion of manufacturing activities on economic output is an important source of productivity gains and economic catch up. Diagnostic tests still support the use of a stochastic frontier model as opposed to a standard production function with normal errors since the lambda value exceeds one in all cases.

Table 2. *Education and Technical Efficiency*

	Variant (1)	Variant (2)	Variant (3)	Variant (4)
VARIABLES	(1995-2018)	(1995-2018)	(1995-2008)	(2009-2018)
	TFE	TFE	TFE	TFE
L.lnCapital	0.106***	0.150***	0.173***	0.0801***
	(0.0184)	(0.0189)	(0.0193)	(0.0188)
L.lnSkilled	0.386***	0.313***	0.305***	0.334***
	(0.0303)	(0.0335)	(0.0339)	(0.0337)
L.lnLowskilled	-0.426***	-0.293***	-0.282***	-0.339***
	(0.0225)	(0.0234)	(0.0237)	(0.0233)
L.lnSemiskilled	0.508***	0.411***	0.403***	0.404***
	(0.0269)	(0.0291)	(0.0295)	(0.0291)
Time dummies	--------	-------	-------	-------
Mu				
L.lnMscPhD	-3.321**	-3.486**	-3.451**	-3.554**
	(1.416)	(1.448)	(1.461)	(1.471)
L.lnLifeexp	-0.759***	-0.168***	-0.117***	-0.327***
	(0.033)	(0.0422)	(0.0430)	(0.0391)
L.Trade	-1.066***	-0.179***	-0.0941***	-0.302***
	(0.133)	(0.0395)	(0.0362)	(0.0373)
L.Agric		-0.601	-0.0304	-0.069
		(0.543)	(0.0364)	(0.0553)
L.Manuf			-1.447***	-0.164***
			(0.312)	(0.0344)
L.Servi				-0.566
				(0.893)
Constant	-18.93**	-17.97**	-19.12**	-19.53**
	(8.272)	(8.706)	(8.890)	(9.110)
Usigma constant	1.757***	1.763***	1.778***	1.766***
	(0.0328)	(0.0341)	(0.0343)	(0.0343)
Vsigma_constant	-5.555***	-5.336***	-5.307***	-5.421***
	(0.0611)	(0.0475)	(0.0475)	(0.0491)
Sigma_u	2.407*** (0.039)	2.414*** (0.041)	2.432*** (0.041)	2.418*** (0.041)
Sigma_v	0.062*** (0.001)	0.069*** (0.001)	0.0704*** (0.001)	0.066*** (0.001)
Lambda	38.697*** (0.039)	34.784*** (0.041)	34.546*** (0.041)	36.367*** (0.041)
Observations	5,382	5,382	5,382	5,382
Number of id	234	234	234	234
Prob > chi2	0.000	0.000	0.000	0.00

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The analysis proceeds to ask the question, does the effect of postgraduates depend on some of the significant correlates of technical inefficiency? In practice it makes sense to assume an interactive effect between education, health, trade and the economic structure. For example, it is generally plausible to assume that an educated and healthy workforce is more productive than an educated but unhealthy workforce. The intuition is that an educated but unhealthy workforce may be less productive due to frequent sick leaves unlike an educated and healthy workforce. On the other hand, the interactive effect between education and trade is well documented in literature. Miller and Upadhyay (2000) for example argue that trade openness increases productivity and the effect is more sizeable in countries that have educated labour. The explanation is that an educated workforce is better able to learn, adopt and efficiently utilise technology facilitated by global trade. Interacting education with the economic structure on the other hand helps us determine whether the effect of postgraduates increases or decreases with an expansion of the manufacturing sector. The estimated model capturing these potential interactive effects can be specified as

$$\begin{aligned} \mathrm{U_{it}} = \delta_0 + \delta_1 \ln(\mathrm{PhD\_MSc}_{it-1}) + \delta_2 \ln(\mathrm{Lifeexp}_{it-1}) + \delta_3(\mathrm{Trade}_{it-1}) \\ + \delta_4(\mathrm{Manuf}_{it-1}) + \delta_5 \ln(\mathrm{PhD\_MSc}_{it-1}) \times \ln(\mathrm{Lifeexp}_{it-1}) \\ + \delta_6 \ln(\mathrm{PhD\_MSc}_{it-1}) \times (\mathrm{Trade}_{it-1}) + \delta_7 \ln(\mathrm{PhD\_MSc}_{it-1}) \\ \times (\mathrm{Manuf}_{it-1}) + W_{it} \qquad (12) \end{aligned}$$

For trade from equation (12) the effect of postgraduates will be δ_1 plus δ_6 which depends on the level of trade. For life expectancy, the effect of postgraduates will be δ_1 plus δ_5 which depends on life expectancy. The study included only the manufacturing sector and dropped agriculture and services to avoid unnecessary model overfitting as the latter entered insignificantly in Table 2. The total effect of postgraduates is therefore δ_1 plus δ_7 which depends on the share of manufacturing on total output. From Table 3, the analysis finds postgraduate education reducing inefficiency and the effect increases with life expectancy (although the interactive effect is significant in one out of three cases), the share of manufacturing and trade. The results suggest that postgraduate education is more effective in reducing technical inefficiency in municipalities that 1) have a higher life expectancy, 2) participate more in global trade and 3) that have high shares of manufacturing activities on total output.

The negative interactive effect between manufacturing and postgraduate education might be explained by two things. Firstly, the manufacturing is labour intensive and therefore creates more opportunities for postgraduates. Secondly, it is a high productivity sector which pays relatively high levels of wages. An educated worker earning a relatively high wage is more motivated and more efficient which is crucial for raising overall technical efficiency level. Life expectancy captures health and healthy workers spend more time at workplace rather than hospitals. A combination of good health and high education is therefore expected to improve the efficiency of workers. The interactive effect of postgraduate education and trade on the other hand might be explained by the fact that trade creates competition and educated workers are better able to adapt to competition by working harder than uneducated workers.

Table 3. *Education and Technical Efficiency*

	Variant (1)	Variant (2)	Variant (3)	Variant (4)
	(1995-2018)	(1995-2018)	(1995-2008)	(2009-2018)
	TFE	TFE	TFE	TFE
L.lnCapital	0.155***	0.135***	0.188***	0.137***
	(0.0183)	(0.0142)	(0.0133)	(0.0142)
L.lnSkilled	0.262***	0.369***	0.336***	0.414***
	(0.031)	(0.0322)	(0.0314)	(0.0381)
L.lnLowskilled	-0.316***	-0.308***	-0.277***	-0.234***
	(0.0211)	(0.0213)	(0.0233)	(0.0213)
L.lnSemiskilled	0.548***	0.432***	0.426***	0.422***
	(0.0231)	(0.0252)	(0.0251)	(0.0241)
Time dummies	--------	-------	-------	-------
Mu				
L.lnMscPhD	-1.393***	-2.821**	-1.151**	-1.813**
	(0.336)	(0.638)	(0.391)	(0.221)
L.lnLifeexp	-0.247***	-0.144***	-0.228***	-0.214***
	(0.041)	(0.041)	(0.0310)	(0.0331)
L.Trade	-1.338***	-0.9713***	-0.189***	-0.152***
	(0.026)	(0.022)	(0.0331)	(0.0351)
L.Manuf	-0.693***	-0.781***	-0.891***	-0.133***
	(0.221)	(0.167)	(0.171)	(0.0381)
L.lnMscPhD×L.lnLifeexp		-0.134***	-0.088	-0.0433
		(0.0325)	(0.0811)	(0.0391)
L.lnMscPhD×L.Trade			-0.108***	-0.0387***
			(0.0303)	(0.0131)
L.lnMscPhD×L.Manuf				-0.103***
				(0.0277)
Constant	-17.63**	-17.33**	-15.32**	-19.53**
	(4.232)	(4.746)	(5.330)	(9.110)
Usigma constant	1.667***	1.773***	1.838***	1.766***
	(0.0301)	(0.0321)	(0.0331)	(0.0343)
Vsigma_constant	-5.417***	-5.136***	-5.366***	-5.421***
	(0.0363)	(0.0375)	(0.0425)	(0.0491)
Sigma_u	2.408*** (0.033)	2.335*** (0.031)	2.431*** (0.040)	2.418*** (0.041)
Sigma_v	0.061*** (0.001)	0.068*** (0.001)	0.0702*** (0.001)	0.066*** (0.001)
Lambda	38.699*** (0.035)	34.783*** (0.042)	34.549*** (0.041)	36.367*** (0.041)
Observations	5,382	5,382	5,382	5,382
Number of id	234	234	234	234
Prob > chi2	0.000	0.000	0.000	0.00

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Next, the study sought to compute the contribution of postgraduates on technical efficiency during the sampling period. This was achieved by estimating two separate regressions. In the first regression, postgraduates enter as an explanatory variable in the technical inefficiency specification. Technical efficiency is then calculated as

$$TE_{it} = \exp(-U)$$

The average technical efficiency score is then,

$$\overline{TE} = \frac{\sum TE_{it}}{n}, \qquad n = 1, \ldots, 5616$$

These technical efficiency scores net out the effect of education and therefore they are called net technical efficiency. In the second regression, the stochastic frontier model is estimated without the postgraduate variable in the technical inefficiency specification. Technical efficiency scores are calculated again using the formula above. These technical efficiency scores are called gross technical efficiency as the postgraduate variable is excluded. The difference between these two efficiency scores therefore reflects the percentage contribution of postgraduates on technical efficiency.

$$\text{cont}_J = \frac{\overline{TE}_G - \overline{TE}_N}{\overline{TE}_N} \times 100, \quad J = 1, .., 4$$

where cont_J is the percentage contribution of variable j on technical efficiency and j includes four variables were found to have a significant effect on technical efficiency i.e. postgraduates, trade, life expectancy and the size of manufacturing sector. Table 4 reports these computations. When all explanatory variables are excluded from the technical inefficiency specification i.e. when the analysis estimates,

$$\text{U}_{\text{it}} = \delta_0 + W_{it} \qquad (13)$$

gross average technical efficiency (TE) is 0.87. This value means that on average, these municipalities are only producing 87 percent of their potential output. Put differently, they are operating 13 percent below their maximum possible output level. Since this is an output-oriented measure of technical efficiency, it means that the municipalities had, during the sampling period, scope to increase output by 13 percent with the same level of inputs and technology. The average observed output during the sampling period was 20.6 billion Rands in constant prices. A 13 percent output shortfall therefore translates to approximately 2,6 billion[6] output which is more than the 2.5 billion Rands allocated to small businesses in the country's 2020/2021 national budget.

When the postgraduate variable is included in the specification,

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[6] x-20 653 000 000/20 653 000 000 = 0,13
x-20 653 000 000 = 0,13*20 653 000 000
x-20 653 000 000 = 2 684 890 000

$$U_{it} = \delta_0 + \delta_1 \ln(PhD\_MSc_{it-1}) + W_{it} \qquad (14)$$

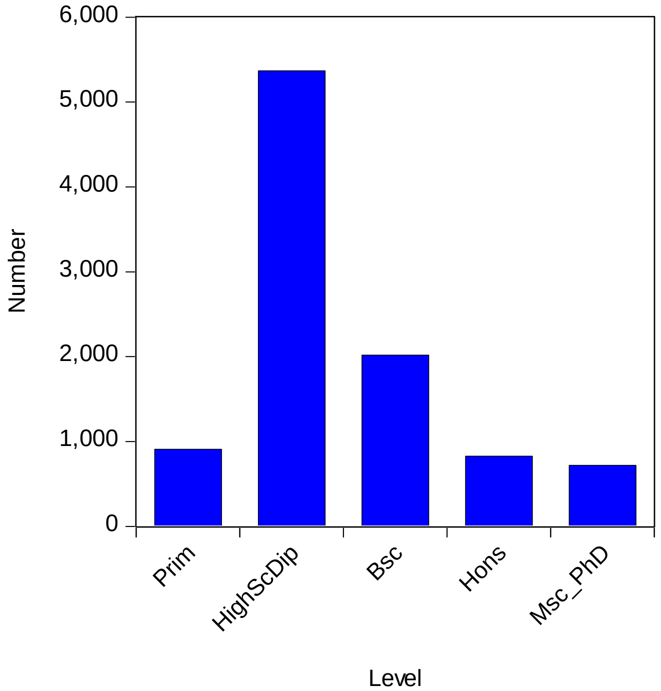
the net average technical efficiency increases to 0.938 indicating a contribution of 7.79 percent. When the exercise is repeated for all the four variables, postgraduate education is found to have the largest contribution on technical efficiency (7.69%) followed by expansion of the manufacturing sector (3.56%). The contribution of trade is miniscule (0.69%) while life expectancy contributes only 1.38%.

Table 4. *Contribution on Technical Efficiency*

Variable	Gross TE	Net TE	Contribution (%)
MscPhD	0.871	0.938	7.69
Life expectancy	0.871	0.883	1.38
Trade	0.871	0.877	0.69
Manufacturing	0.871	0.902	3.56

Overall, the results observed in this study support the hypothesis that higher education increases technical efficiency and that life expectancy, trade and the manufacturing sector strengthen this relationship. This finding can be equivalently used to suggests that local economies in South Africa could be failing to reach their economic potential due to a disproportionately high stock of undergraduate degrees, diplomas and high school qualifications relative to postgraduate education. Figure 5 substantiates this generalization. Each municipality in the sample has a disproportionately high number of primary, diploma and bachelors which do not significantly contribute towards moving local economies closer to their potential output level. The masters and PhD level which provides a significant productivity lift has the least number.

Figure 5. *Average Number by Qualification*



In some municipalities such as Cederberg of North-West, Ikwezi of Eastern Cape and Moretele of North-West, the number of people with masters and doctorate is less than 100. Therefore, there is room for productivity gains if the country's stock of graduates with honours level and below is supported to reach masters and PhD level.

Discussion of Findings

In this section, the paper discusses and reconciles two key findings with previous literature and South Africa's socio-economic fabric.

Key Result One - Post Graduation Training Matters More to Development

One of the important insights stemming from the results is that education levels have different effects on the ability of South Africa's local economies to reach their full potential and what appears to have a relevant and significant effect are postgraduate qualifications. This result to a larger extent agrees with Bloom et al. (2006) who emphasize the need for shifting focus from overly supporting lower level of schooling to equally considering higher level qualifications as a vital source of economic development. Intuitively, there are several reasons why postgraduate training may have a more significant effect on economic development than lower-level qualifications. The first possibility is that high-end qualifications are likely to earn higher salaries than workers with lower-level qualifications. With higher earnings serving as an important source of motivation that is in turn linked to productivity as argued in Casey (2009), one expects Masters, and PhD holders to have a more contribution to the productivity-catch up process relative to lower-level qualified workers. In addition, conventional economic theory teaches that wages reflect marginal productivity. The relatively higher wages paid to postgraduates is therefore likely to reflect their relatively higher productivity levels.

It is also important to note that the progression from one level of education to another in the main comes with improvements in intellectual, abstract, and analytical thinking which is now central in modern days given the increasingly becoming complex working environments. Industries are now faced with complex situations with technological progress and increased competition almost demanding the employment of workers with high-end problem-solving abilities. While one can plausibly have good problem-solving techniques at honours, chances are that a PhD graduate is more likely to be a critical thinker relative to an average bachelor's degree graduate. Postgraduate training also increases one ability to adopt modern technologies which is key to raising output with limited resources. Supportive of this idea, Bloom et al. (2006) supports the idea that expanding post graduate training fosters technological catch-up and improves a country's ability to maximize its economic output. From finding Sub-Saharan Africa's current production level about 23 per cent below its production possibility frontier, they find a one-year increase in post-graduate training raising the region's long-run per capita income by 12.2%. Results presented in this paper are consistent with this conclusion.

There is also a case that unlike undergraduate qualifications, postgraduate training may generate more tax revenue, increase savings and investment, and lead to a more entrepreneurial and civic society. This is particularly relevant for a country like South Africa with a progress tax system (which taxes higher earners more) and an entrepreneurship-oriented government that has designed various entities meant to support people with innovative and entrepreneurial mindsets. While one might argue that entrepreneurship can equally even without schooling, evidence suggests that businesses established and run by highly qualified personnel are likely to be more sustainable and well-run.

Postgraduate training can also have an indirect effect on an economy's ability to produce at full capacity. This includes the likelihood of Masters, and PhD holders being relatively better teachers than those with undergraduate qualifications. This in turn means teachers with postgraduate qualifications are more likely to produce skilled engineers, efficient bankers, physicians, skilled medical doctors, and other critical professions which ultimately helps a region raise its productivity level.

Key Result Two – Lower-level Qualifications Do Not Have a Discernible Effect on Productivity Growth

The insignificant effect of lower-level qualifications can have two interpretations. One is that lower-level qualifications do not have a meaningful contribution on productivity growth when one is controlling for postgraduate training. In other words, this would mean that lower-level qualifications complemented postgraduate training so that the former seizes to have a statistically significant effect once the latter is held constant. While there is some plausibility to this possibility in methodological sense, South Africa's education system and dynamics in the labour market suggest that the insignificance of lower-level qualifications could be telling a story that is more than just an issue of model specification. South Africa primary and secondary education which provide the foundation for tertiary learning have been criticised over the years for being far from international standards. Modisaotsile (2012) described this as a crisis in basic education that is driven by a myriad of factors ranging from poor exam marks, poorly designed curriculum (Mseleku 2022), drug abuse and a lack of adequate infrastructure. In addition to these factors, the 30% pass mark for example and the existence of maths literacy means majority of primary and secondary school students at best end with undergraduate degrees as progression to Masters, and PhD requires high analytical skills especially in quantitative disciplines such as engineering, information and technology, maths, and science. The few that succeed to earn postgraduate qualification are those that would have been exceptional at lower levels, a characteristic which makes it plausible to have a significant productivity effect of postgraduate training in the paper. There is also a possibility that labour market demands are outpacing the level of knowledge provided at undergraduate level heading into the fourth industrial revolution.

It is important to note however that our key findings disagree with the results observed in Baharin et al. (2020). Studying the impact of human capital on productivity of labor in Indonesia in a dynamic model framework, they find primary and secondary qualifications having a significant positive influence on labor productivity while tertiary education variables are found to have a significant negative effect. The difference in findings can be explained by at least three factors. Firstly, their analysis was based on a dynamic specification which makes it difficult to compare with results from a statistic specification. Secondly, their analysis was based on a partial productivity indicator that disregards the presence of inefficiency. Third, the difference in results could simply be explained by the stark heterogeneity in country circumstances.

Limitations of the Study

While the study yields important findings, it is not without limitations. One area of weakness relates to the handling of endogeneity in the frontier specification. Addressing endogeneity in a production function framework within a stochastic frontier framework remains at infancy. Efforts to exogenize variation in factors of production are undermined by the lack of appropriate and relevant instruments as majority of factors that affect factors of production also tend to have an independent effect on output. To ameliorate this methodological challenge, the study made us of lags hoping that the elasticities attached to lagged terms would crudely serve as causal effects of changes in inputs on output. While this is a reasonable and plausible, the analysis cannot definitively and conclusively argue that lagging guarantees exogeneity as there remains a real possibility that decisions to employ workers and investment in capital for example could be based on expectations of future output. It is important to note that the paper separated the education component from the health component. In practice, it may be argued that the pair are better analysed as an aggregate index of human capital with appropriate weights.

Concluding Remarks and Policy Implications

This paper has provided evidence that postgraduate education is the only relevant stock of education that significantly pushes local economies towards their economic frontier and the effect is strong in municipalities where the manufacturing sector, trade and life expectancy are high. Other levels of education such as high school, diploma and undergraduate degrees do not significantly contribute to economic productivity. While this conclusion holds a considerable degree of plausibility, it needs to be interpreted with caution as the possibility of endogeneity cannot be ruled out. Assuming that the use of lags in the methodology partly addressed this estimation challenge, these findings, which we find consistent with South Africa's social fabric and education system, have two policy implications. First, local economic development strategies in South Africa may need to support the accumulation of postgraduate qualifications reinforced by increased participation in global trade, improved life expectancy coupled with a structural transformation that expands the manufacturing sector. Second, the government may continue supporting high school, diplomas and undergraduate degrees but improvements in economic efficiency required by municipalities to reach their economic potential will not be guaranteed. This latter implication therefore calls for interventions that enable students to acquire education at least up to a postgraduate level. With data from the department of higher education, further studies can benefit from checking the specific postgraduate qualifications that matter for these local economies as far as reaching economic potential is concerned.

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Appendix

Table 5. *List of Municipalities in the Analysis*

P1D01M01: City of Cape Town (CPT)	P2D02M07: Nkonkobe (EC127)	P3D03M06: Thembelihle (NC076)
P1D02M01: Matzikama (WC011)	P2D02M08: Nxuba (EC128)	P3D03M07: Siyathemba (NC077)
P1D02M02: Cederberg (WC012)	P2D03M01: Inxuba Yethemba (EC131)	P3D03M08: Siyancuma (NC078)
P1D02M03: Bergrivier (WC013)	P2D03M02: Tsolwana (EC132)	P3D04M01: Mier (NC081)
P1D02M04: Saldanha Bay (WC014)	P2D03M03: Inkwanca (EC133)	P3D04M02: Kai! Garib (NC082)
P1D02M05: Swartland (WC015)	P2D03M04: Lukanji (EC134)	P3D04M03: //Khara Hais (NC083)
P1D03M01: Witzenberg (WC022)	P2D03M05: Intsika Yethu (EC135)	P3D04M04: !Kheis (NC084)
P1D03M02: Drakenstein (WC023)	P2D03M06: Emalahleni (EC136)	P3D04M05: Tsantsabane (NC085)
P1D03M03: Stellenbosch (WC024)	P2D03M07: Engcobo (EC137)	P3D04M06: Kgatelopele (NC086)
P1D03M04: Breede Valley (WC025)	P2D03M08: Sakhisizwe (EC138)	P3D05M01: Sol Plaatjie (NC091)
P1D03M05: Langeberg (WC026)	P2D04M01: Elundini (EC141)	P3D05M02: Dikgatlong (NC092)
P1D04M01: Theewaterskloof (WC031)	P2D04M02: Senqu (EC142)	P3D05M03: Magareng (NC093)
P1D04M02: Overstrand (WC032)	P2D04M03: Maletswai (EC143)	P3D05M04: Phokwane (NC094)
P1D04M03: Cape Agulhas (WC033)	P2D04M04: Gariep (EC144)	P4D01M01: Letsemeng (FS161)
P1D04M04: Swellendam (WC034)	P2D05M03: Ngquza Hill (EC153)	P4D01M02: Kopanong (FS162)
P1D05M01: Kannaland (WC041)	P2D05M04: Port St Johns (EC154)	P4D01M03: Mohokare (FS163)
P1D05M02: Hessequa (WC042)	P2D05M05: Nyandeni (EC155)	P4D01M04: Naledi (FS164)
P1D05M03: Mossel Bay (WC043)	P2D05M06: Mhlontlo (EC156)	P4D03M01: Masilonyana (FS181)
P1D05M04: George (WC044)	P2D05M07: King Sabata Dalindyebo (EC157	P4D03M02: Tokologo (FS182)
P1D05M05: Oudtshoorn (WC045)	P2D06M01: Umzimvubu (EC442)	P4D03M03: Tswelopele (FS183)
P1D05M06: Bitou (WC047)	P2D06M02: Matatiele (EC441)	P4D03M04: Matjhabeng (FS184)
P1D05M07: Knysna (WC048)	P2D06M03: Mbizana (EC443)	P4D03M05: Nala (FS185)
P1D06M01: Laingsburg (WC051)	P2D06M04: Ntabankulu (EC444)	P4D04M01: Setsoto (FS191)
P1D06M02: Prince Albert (WC052)	P2D07M01: Nelson Mandela Bay (NMA)	P4D04M02: Dihlabeng (FS192)
P1D06M03: Beaufort West (WC053)	P2D08M01: Buffalo City (BUF)	P4D04M03: Nketoana (FS193)
P2D01M01: Camdeboo (EC101)	P3D01M01: Joe Morolong (NC451)	P4D04M04: Maluti a Phofung (FS194)
P2D01M02: Blue Crane Route (EC102)	P3D01M02: Ga-Segonyana (NC452)	P4D04M05: Phumelela (FS195)
P2D01M03: Ikwezi (EC103)	P3D01M03: Gamagara (NC453)	P4D04M07: Mantsopa (FS196)
P2D01M04: Makana (EC104)	P3D02M01: Richtersveld (NC061)	P4D05M01: Moqhaka (FS201)
P2D01M05: Ndlambe (EC105)	P3D02M02: Nama Khoi (NC062)	P4D05M02: Ngwathe (FS203)
P2D01M06: Sundays River Valley (EC106)	P3D02M03: Kamiesberg (NC064)	P4D05M03: Metsimaholo (FS204)
P2D01M07: Baviaans (EC107)	P3D02M04: Hantam (NC065)	P4D05M04: Mafube (FS205)
P2D01M08: Kouga (EC108)	P3D02M05: Karoo Hoogland (NC066)	P4D06M01: Mangaung (MAN)
P2D01M09: Kou-Kamma (EC109)	P3D02M06: Khâi-Ma (NC067)	P5D01M01: Vulamehlo (KZN211)
P2D02M01: Mbhashe (EC121)	P3D03M01: Ubuntu (NC071)	P5D01M02: Umdoni (KZN212)
P2D02M02: Mnquma (EC122)	P3D03M02: Umsobomvu (NC072)	P5D01M03: Umzumbe (KZN213)
P2D02M03: Great Kei (EC123)	P3D03M03: Emthanjeni (NC073)	P5D01M04: UMuziwabantu (KZN214)
P2D02M04: Amahlathi (EC124)	P3D03M04: Kareeberg (NC074)	P5D01M05: Ezingoleni (KZN215)
P2D02M06: Ngqushwa (EC126)	P3D03M05: Renosterberg (NC075)	P5D01M06: Hibiscus Coast (KZN216)
P5D02M01:E3:H31 uMshwathi (KZN221)	P5D10M01: Ingwe (KZN431)	P8D01M05: Lekwa (MP305)
P5D02M02: uMngeni (KZN222)	P5D10M02: Kwa Sani (KZN432)	P8D01M06: Dipaleseng (MP306)
P5D02M03: Mpofana (KZN223)	P5D10M03: Greater Kokstad (KZN433)	P8D01M07: Govan Mbeki (MP307)
P5D02M04: Impendle (KZN224)	P5D10M04: Ubuhlebezwe (KZN434)	P8D02M01: Victor Khanye (MP311)
P5D02M05: The Msunduzi (KZN225)	P5D10M05: Umzimkhulu (KZN435)	P8D02M02: Emalahleni (MP312)

P5D02M06: Mkhambathini (KZN226)	P5D11M01: eThekwini (ETH)	P8D02M03: Steve Tshwete (MP313)
P5D02M07: Richmond (KZN227)	P6D01M01: Moretele (NW371)	P8D02M04: Emakhazeni (MP314)
P5D03M01: Emnambithi/Ladysmith (KZN232)	P6D01M02: Madibeng (NW372)	P8D02M05: Thembisile (MP315)
P5D03M02: Indaka (KZN233)	P6D01M03: Rustenburg (NW373)	P8D02M06: Dr JS Moroka (MP316)
P5D03M03: Umtshezi (KZN234)	P6D01M04: Kgetlengrivier (NW374)	P8D03M01: Thaba Chweu (MP321)
P5D03M04: Okhahlamba (KZN235)	P6D01M05: Moses Kotane (NW375)	P8D03M02: Mbombela (MP322)
P5D03M05: Imbabazane (KZN236)	P6D02M01: Ratlou (NW381)	P8D03M03: Umjindi (MP323)
P5D04M01: Endumeni (KZN241)	P6D02M02: Tswaing (NW382)	P8D03M04: Nkomazi (MP324)
P5D04M02: Nqutu (KZN242)	P6D02M03: Mafikeng (NW383)	P8D03M05: Bushbuckridge (MP325)
P5D04M03: Msinga (KZN244)	P6D02M04: Ditsobotla (NW384)	P9D01M01: Greater Giyani (LIM331)
P5D04M04: Umvoti (KZN245)	P6D02M05: Ramotshere Moiloa (NW385)	P9D01M02: Greater Letaba (LIM332)
P5D05M01: Newcastle (KZN252)	P6D03M01: Kagisano/Molopo (NW397)	P9D01M03: Greater Tzaneen (LIM333)
P5D05M02: Emadlangeni (KZN253)	P6D03M02: Naledi (NW392)	P9D01M04: Ba-Phalaborwa (LIM334)
P5D05M03: Dannhauser (KZN254)	P6D03M03: Mamusa (NW393)	P9D01M05: Maruleng (LIM335)
P5D06M01: eDumbe (KZN261)	P6D03M04: Greater Taung (NW394)	P9D02M01: Musina (LIM341)
P5D06M02: UPhongolo (KZN262)	P6D03M06: Lekwa-Teemane (NW396)	P9D02M02: Mutale (LIM342)
P5D06M03: Abaqulusi (KZN263)	P6D04M01: Ventersdorp (NW401)	P9D02M03: Thulamela (LIM343)
P5D06M04: Nongoma (KZN265)	P6D04M02: Tlokwe City Council (NW402)	P9D02M04: Makhado (LIM344)
P5D06M05: Ulundi (KZN266)	P6D04M03: City of Matlosana (NW403)	P9D03M01: Blouberg (LIM351)
P5D07M01: Umhlabuyalingana (KZN271)	P6D04M04: Maquassi Hills (NW404)	P9D03M02: Aganang (LIM352)
P5D07M02: Jozini (KZN272)	P7D01M01: Emfuleni (GT421)	P9D03M03: Molemole (LIM353)
P5D07M03: The Big 5 False Bay (KZN273)	P7D01M02: Midvaal (GT422)	P9D03M04: Polokwane (LIM354)
P5D07M04: Hlabisa (KZN274)	P7D01M03: Lesedi (GT423)	P9D03M05: Lepele-Nkumpi (LIM355)
P5D07M05: Mtubatuba (KZN275)	P7D03M01: Mogale City (GT481)	P9D04M01: Thabazimbi (LIM361)
P5D08M01: Mfolozi (KZN281)	P7D03M02: Randfontein (GT482)	P9D04M02: Lephalale (LIM362)
P5D08M02: uMhlathuze (KZN282)	P7D03M03: Westonaria (GT483)	P9D04M03: Mookgopong (LIM364)
P5D08M03: Ntambanana (KZN283)	P7D03M04: Merafong City (GT484)	P9D04M04: Modimolle (LIM365)
P5D08M04: uMlalazi (KZN284)	P7D04M01: Ekurhuleni (EKU)	P9D04M05: Bela-Bela (LIM366)
P5D08M05: Mthonjaneni (KZN285)	P7D05M01: City of Johannesburg (JHB)	P9D04M06: Mogalakwena (LIM367)
P5D08M06: Nkandla (KZN286)	P7D06M01: City of Tshwane (TSH)	P9D05M01: Makhuduthamaga (LIM473)
P5D09M01: Mandeni (KZN291)	P8D01M01: Albert Luthuli (MP301)	P9D05M02: Fetakgomo (LIM474)
P5D09M02: KwaDukuza (KZN292)	P8D01M02: Msukaligwa (MP302)	P9D05M03: Ephraim Mogale (LIM471)
P5D09M03: Ndwedwe (KZN293)	P8D01M03: Mkhondo (MP303)	P9D05M04: Elias Motsoaledi (LIM472)
P5D09M04: Maphumulo (KZN294)	P8D01M04: Pixley Ka Seme (MP304)	P9D05M05: Greater Tubatse (LIM475)

Table 6. *Variable Description and Data Source*

Variable	Description	Data Source
Output	Total output deflated using 2010 prices	Quantec
Labour	Number of formally and informally employed workers	Quantec
Capital	Capital stock computed using the perpetual inventory method	Quantec
Agriculture share	Agricultural output as a percentage of total output	Quantec
Manufacturing share	Manufacturing output as a percentage of total output	Quantec
Mining share	Mining output as a percentage of total output	Quantec
Schooling	Average number of years of schooling	Quantec
Masters and Doctorates	Number of masters and doctoral graduates	Quantec
Honours	Number of honours degree graduates	Quantec
Diploma and Matric	Number of individuals with matric and a diploma	Quantec
Primary	Individuals with less than matric	Quantec
Skilled workers	managerial/ professional, artisans, technicians, welders	Quantec
Semi-skilled workers	Machinery operators	Quantec
Low-skilled	Labourers, security guards	Quantec
Life expectancy	Number of years a newly born child is expected to live under current mortality levels	Quantec
Trade	Exports plus imports as a percentage of total output	Quantec

Table 7. *Descriptive Statistics*

Variable	Description	Mean	Std Dev	Min	Max
Output	Real output at 2010 prices (million Rands)	20653.02	72795.45	137.23	847244.5
Capital formation	Real gross fixed capital formation (million Rands)	1846.841	7318.541	3.938	111648.8
Low-skilled workers	Employment of unskilled workers	13111	33520	378	338029
Semi-skilled workers	Employment of semi-workers	21058	69236	422	771722
Skilled workers	Employment of skilled workers	10685	41603	136	483513
Masters and doctorates	Number of people with Masters and doctorates	719	3797	0	63027
Honours	Number of people with honours degree	829	4307	2	80480
Bachelors	Number of people with bachelors	2020	9068	13	142372
High School	Number of people with a diploma and high school	5368	20190	65	298469
Primary	Number of people with less than high school	910	3122	5	44031