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Technical efficiency and total factor productivity growth of primary schools in Zimbabwe: The case of Harare province

BY

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ABSTRACT

In light of the efforts by government to lift the Zimbabwean system of primary education, the study assesses technical efficiency of primary schools using Data Envelopment Analysis. Precisely, the study examines the technical efficiency of 27 primary schools based on obtainable inputs data on number of classrooms, teaching staff, enrollment, average class size and number of toilets and output data on performance in primary leaving examinations. The efficiency scores are then regressed against input variables and locational dummy to determine their effect on efficiency. Furthermore, the study also examines total factor productivity change in these primary schools based on the Malmquist Index using panel data for 5 years from 2011 to 2015. The results from the Data Envelopment Analysis suggest that a great number of the primary schools are not efficient because they have efficiency scores less than 1. Additionally, results from the efficiency scores suggest that primary schools could improve performance by 14.3% using the same resources. Moreover, mean annual total factor productivity growth decreased by 2.9%. Analysis of Tobit regression shows a negative significant relationship between average class size and efficiency thus congested classes are associated with inefficiency. Primary schools situated in low density areas are found to perform better than their high density counterparts. The study recommends that government policy should be geared towards reducing the average class size. The increasing levels of enrollment should be dealt with by increasing the number of classes and the number of teachers. The assessment system in primary schools should be restructured to ensure improvement in the low pass rates by implementing a competency based assessment framework which is more valid to skills improvement.

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LIST OF ACRONYMS

AE	Allocative Efficiency
AP	Average Product
BEAM	Basic Education Assistance Module
CRS	Constant Returns to Scale
CSO	Central Statistical Office
DEA	Data Envelopment Analysis
DEAP	Data Envelopment Analysis Program
DMU	Decision Making Unit
FPE	Free Primary Education
GDP	Gross Domestic Product
ICT	Information and Communication Technology
MP	Marginal Product
NER	Net Enrolment Ratio
PTR	Pupil Teacher Ratio
SDG	Sustainable Development Goals
SFA	Stochastic Frontier Analysis
TE	Technical Efficiency
TFP	Total Factor Productivity
USA	United States of America
USD	United States Dollar
VRS	Variable Returns to Scale
ZIMSTATS	Zimbabwe National Statistics Agency

CHAPTER ONE

INTRODUCTION AND BACKGROUND OF THE STUDY

1.0 Introduction

Education is an effective and catalytic vehicle for national development in all countries and the health of education like all other social services sectors is a function of the state of economy. Knowledge about the education production function and sources of inefficiency is elementary since education is fundamental for the creation of a competitive knowledge based economy. Studies concerning education production function resulted in Burtless (1996) ”Does Money Matter controversy?” Although in general, consensus appears to be that providing more money and resources to schools improve outcomes. According to the World Bank (2011), education imparts people with the right attitude and skills giving them an opportunity to make a decent living. It must therefore be given attention in the countries’ quest for the realization of the Sustainable Development Goals (SDGs) and Zimbabwe is among the sub-Saharan African countries which emphasized on the importance of education in the development of African continent since 1980.

Government and households invest massively in education to ensure that it becomes accessible to all throughout life since it is a fundamental pillar of human rights, democracy, sustainable development and peace. People have reached a consensus that countries in which most of the population is literate and in which all children complete at least basic education have higher quality institutions (Smith, 2006) and high degree of social integration. Numerous studies on the benefits of education have consistently found positive social and private returns to education at all levels. In addition, matters concerning production and efficiency of schools have been the subject of research in the past years (Hanushek, 1979; Smith, 2006 and Porcelli, 2009) but there has not been much work carried out in Zimbabwe concerning technical efficiency and productivity growth of primary schools.

Government and the general public are concerned that student receives appropriate level of education and that the service be delivered as efficiently as possible. A key component of education sector efforts to improve operating efficiency has to do with making the best use of existing resources (Parker and Newbrander, 1994). Even though there are no easy decision rules that exist for state decision makers to judge whether schools are receiving an appropriate amount of resources and whether the resources received are being used effectively it is undoubtedly acceptable that Zimbabwean education system increasingly faces critical resource constraints in its efforts to extend education services of acceptable quality to the vast majority of people. The shortage of education resources can be attributed to rapid growth of the population, poor macroeconomic performance and difficulties in domestic resource mobilization.

Primary schools are an important part of education systems in developing countries and depending on their capacity; act as the foundation for information interpretation and base for further studies. Primary schools are generally responsible for over 60 percent of government education sector expenditure in most developing countries and utilize nearly half of the total national education expenditure in many countries (Winkler, 2000). The high level of government spending on pre- primary, primary, secondary and tertiary institutions is sign that education is expanding ahead of the economy. Increasing education costs put schools as the main spenders within the education system in the limelight. In a way to find new sources of funds to finance the high cost activities of schools and utilize existing resources more efficiently, governments in some developing countries allowed schools to operate as both private and public in the hope that this would reduce the financial burden of schools on governments and strengthen the efficiency and effectiveness of schools.

1.1 Background of the study

The last decade has witnessed increased resource allocation to the education sector in Zimbabwe. From 1996 to 2007, the allocation averaged 15% of total government spending (ZIMSTAT, 2012). About 60% of the country's total education expenditures have been devoted to the primary school level. Resource constraints are likely to worsen because of high enrollment in schools and this may result in primary, secondary and other levels of education competing for funds as witnessed when the budget allocated to primary, secondary and universities received a considerable cut, from 82% in 1997 to 79% for primary and secondary, 7% to 4% for universities, in favor of the vocational training level of education. The share of the vocational education increased from 11% in 1997 to 12% in 1998 to 17% in 1999 (CSO, 2001). This brings an urgent need for an efficient production system which yields higher output for a given set of inputs, or conversely, uses fewer inputs to yield a given output. Therefore, it becomes imperative to examine the efficiency with which allocated resources are transformed into outcomes in Zimbabwe primary education subsector

The pupil per teacher ratio measures the quality of education based on the level of intake of pupils and teachers. The recommended primary school pupil teacher ratio is 40 pupils to 1 teacher. In the time period 1997 to 1999 the ratio was at 39 and jumped to 37 in 2001 (CSO, 2001). The grade seven results have not improved over the years despite a marked improvement in the teacher to pupil ratio and the increase in the number of qualified teachers between 2000 and 2001. The skewed allocation of resources across functional areas could explain part of this but extent of conversion of resources into primary leaving examination performance remains rhetoric.
Education expenditure as a percentage of Gross Domestic Product (GDP) is one important indicator that allows year on year comparison of the amount of resources allocated to education services. There was an upward trend in education spending as a percentage of GDP from 1993 and it was maintained for four years up to 1997 when the share of education services reached its pick of 9.0%. The share further increased to register 8.3% in 1998 and 6.2% in 1999 (CSO, 2001). For these years, the expenditure has been increasing but the way these resources are utilized remains unknown and how these funds tally with output remains skeptical.

1.1.0 Trend in education spending

Public expenditure on education across the world varies from as little as 1% to as much as 20% of GDP and from 9% to 35% of total government expenditure. Zimbabwe was placed highest in Africa at 9% of GDP in the year 1997. Even though it fell afterwards to 6.3% in 2001 it remained one of the highest spenders in education in Sub-Saharan Africa. Comprehensive disparities exist in education outcomes and spending efficiency across countries with similar income or education expenditure levels. According to the World Bank (2011) Zimbabwe and Lesotho spend about 10% of their GDP on education but the accomplishment rate for Zimbabwe is 114% and that of Lesotho is only 55%. Examining such performance differentials can assist in identifying the policies that give the best educational outcomes per unit of spending. The first step may be to analyze expenditure by level of education and then cross country comparisons of expenditure shares across levels and relative emphasis placed on primary versus secondary and university education and the relative efficiency of these segments of the education system in relation to other countries. However, it is not clear whether the alteration in expenditure pattern witnessed from 1999 in Zimbabwe is based on such comparisons or on other considerations.

Education sector in Zimbabwe consumes a significant portion of the total government budget from 2010 and budgetary resources in this sector have been growing in real terms maintaining an average of 15 percent share of the budget. In 2010 financial year, the budgetary allocation to the pre- primary, primary and secondary schools was USD 313 304 462 increasing to USD 507 734 445 in the year 2011 and USD 751 676 855 in 2013 (ZIMSTAT, 2013). Table 1 shows the trend in education spending for 5 years.

Table 1.1: Trend in education spending

Year	Total government expenditure (USD)	Expenditure on Pre - primary, Primary & Secondary Education (USD)	% Expenditure on Pre-primary, Primary &Secondary Education
2009	847 257 786	45,894,851	5.4
2010	1 980 167 823	313 304 462	15.8
2011	2 889 927 005	507 734 445	17.6
2012	3 537 778 330	674 171 178	19.1
2013	4 038 348 062	751 676 855	18.6

Source: ZIMSTAT, 2013

Table 1 shows the actual expenditure on education in relation to total government expenditure on education. From 2009 to 2012, expenditure on pre-primary, primary and secondary education expressed as a percentage of the total government expenditure grew from 5.4 percent to 19.1 percent. This calls for proper utilization of these funds so as to maximize on the positive gains from the education sector. Therefore, with increased budget allocation and rapid expansion, a fundamental question among policy planners in the education sector is whether primary education sub-sector is utilizing the resources efficiently. Since information on the level of efficiency in primary schools is lacking, it is necessary to establish whether the sub-sector is efficiently utilizing the scarce resources.

1.2 Problem Statement

Declaration of education as a basic human right and introduction of Free Primary Education (FPE) in Zimbabwe in 1980 followed by the Basic Education Assistance Module (BEAM) in 2001 led to a significant increase in access to primary education. This resulted in an increase in enrollment of pupils and the number of new schools being built around the country. Net Enrolment Ratio (NER) in 1994 was 81.9% and rose to 96.2% by the year 2000 (ZIMSTAT, 2012). In year 2002, it was 98.5% and 96.9% in 2005 then further rose to 97.7% in 2009

(ZIMSTAT, 2012). In addition, government expenditure in education sector showed an upward trend over the same period. Expenditure on primary school education as a percentage of the central government expenditure was 5.4% in 2009, 15.8% in 2010, 17.6% in 2011 and 19.1% in 2012 (ZIMSTAT, 2013). Although a rising proportion of Zimbabwe's resources have been directed to primary education sector the pass rate as one of the proxies for education output remained lower than 50%, thus 39.7% in 2009, 42% in 2010, 28.9% in 2011, 33% in 2012, 38.12% in 2014 and 41.82% in 2015(ZIMSTAT, 2015). The pass rate statistics may be an indication that primary schools are not taking the value for money seriously and this brings the need know if primary schools are achieving more outputs in terms of better performance in the primary leaving examinations with the resources allocated to them. Government as the main stakeholder is also interested in knowing if it is possible that higher achievements can be attained with fewer resources given that it has a limited fiscal space to finance the education sector. Thus, the extent at which the allocated resources translate into desirable education outputs is unknown and this brings the need to investigate technical efficiency and whether there is total factor productivity growth of primary schools in Zimbabwe.

1.3 Research questions

- Are primary schools in Zimbabwe technically efficient?
- To what extent have primary schools in Zimbabwe experienced progress in total factor productivity?
- Does catching up with the efficiency benchmark due to changes in technical efficiency or scale efficiency primarily drive improvements in the overall productivity?
- What are the sources of efficiency of primary schools in Zimbabwe?

1.4 Study objectives

The study aims to determine the extent at which public primary schools are utilizing available resources to produce maximum outputs.

The specific objectives of the study are to:

- Examine scale efficiency of public primary schools in Zimbabwe
- Assess the total factor productivity changes of primary schools in Zimbabwe
- Investigate the sources of technical efficiency of public primary schools in Zimbabwe

1.5 Research Hypotheses

- Primary schools in Zimbabwe are technically efficient

- Technical efficiency and scale efficiency drive improvements in overall productivity
- Toilets, average class size, location and number of pupils (enrollment) are the sources of efficiency

1.6 Justification of the study

Robust education system is foundation for the nation when it comes to economic prosperity and given scarce resources, efficiency in education becomes important. Studies concerning efficiency of primary schools in Zimbabwe are almost non -existent and the extent to which primary schools efficiently turn their inputs into desirable better performance outputs and outcomes is not yet known. The study by Masuko (2003) examined the performance of education sector in Zimbabwe. Technical efficiency of schools was not addressed in this study since it only looked at the basic school processes and trends in education statistics. If the education sector operates efficiently amidst of scarce resources and many competing needs, tangible significant contribution towards the country's growth and development can be felt. Inefficiency in education sector affect sustainable development goals set in vision 2030 by jeopardizing quality of teaching and inclusive classroom practice and thus, the need to examine the efficiency of public primary schools and deal with any issues contributing towards inefficiency. Formulation of government policies that will guide in resource allocation is less complex if there is knowledge of efficiency levels and possible causes of inefficiency in this sector. Using Data Envelopment Analysis (DEA) the study analyzes the inputs and outputs in primary education sector and it helps current and future researchers in understanding efficiency in the education sector.

Primary education offers the foundation of knowledge to individuals and nation at large and as such it is a highly demanded service in any nation. The Zimbabwean government has however been facing financial challenges in ensuring full availability of basic services (reading materials and other support services) in primary education due to the limited fiscal space the country has been facing since dollarization. Such financial challenges are likely to affect the outcomes in primary schools if the available resources are not used efficiently. Given the importance and high demand for this service sector amid resource scarcity, it becomes imperative for primary schools to be more competitive and efficient, so that ultimately, the government and other private entities that pay for it should realize their value for money. This will in turn help address the challenges that are constraining some primary schools from being efficient and help in improving primary level performance. Apart from being useful for policy purposes, the study will also contribute to the body of academic knowledge.

1.7 Organization of the study

The structure of this study is organized as follows: Chapter 2 provides the review of the theoretical and empirical literature. Chapter three outlines the methodological approach employed in this study. Chapter 4 present and interpret the results estimated. Chapter 5 gives policy recommendations, suggestion to areas of further study and finally conclusion.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

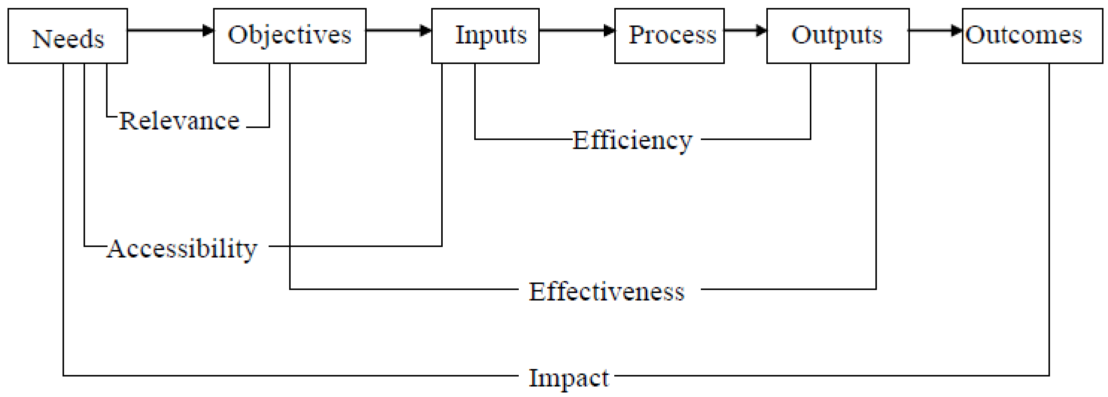
In the present chapter theoretical literature review is presented which gives an overview of theories which have been put forward with regards to education, technical efficiency and total factor productivity. The empirical literature show results obtained by different scholars in investigating technical efficiency and total factor productivity in schools.

2.1 Theoretical Literature review

2.1.1 The Systems theory

Systems theory can be applied in the analysis of production of education since there are various perspectives in which a school can be viewed as a system. Aldred *et al*., (1971) described a school as having sub-systems such as physical system of buildings; system of many interacting staff; system of complex logistics; system for educating students and an information system. This study chooses to emphasize the school as a system for educating students. In this regard, a school is a system for imparting knowledge and it provides this service through the interaction of different sub-systems like the library system; teaching system; feeding system and accounts system. A system as a collection of parts unified to accomplish an overall goal helps in understanding how decision making units operate as it comprise of inputs, processes, outputs, outcomes and impact. How these components are integrated can be summarized using Figure 2.1.

Figure 2.1: Performance framework for schools



This study investigates technical efficiency of primary schools by examining the relationship between inputs and outputs for a primary school by means of the schematic flow in Figure 2.1. Number of toilets, money, number of classrooms and pupils are some of the inputs and these inputs go through a process where they are planned, organized, motivated and controlled to eventually meet the decision making unit's goal of improving performance of students when they write their primary leaving examinations. Sink and Todd (2003) argued that system performance is a function of the complex interaction among efficiency, effectiveness, quality of work life, innovation and profitability.

2.1.1.0 Inputs

At a school setting, inputs are the resources needed to carry out a process or provide education services. Inputs required in education are usually financial, physical structures such as buildings, stationary supplies, technological equipment and personnel such as teachers, caretakers, receptionists and other school staff. The education system in general and primary school in particular utilize a variety of factor inputs in the provision of education services and these inputs can be broadly categorized into capital and labour. By its nature education provision involves the physical and mental skills of teachers, headmasters, technicians and administrators among other personnel who play a significant role in the provision of education in primary schools. Holtman and Powers (1983) stressed that although teachers supply what may be considered indispensable inputs in the teaching of pupils at a school setting, they are often paid separately, either by their principals or the government. Teachers enjoy privileged relationships with their students, which allow a wide degree of latitude in learning and choice of procedure. The inputs used in this study include: pupils; teachers; toilets and average class size.

2.1.1.1 Process

Process refers to a series of actions or activities that transform inputs or resources into a desired product, service or outcome. In a school setting, these would include amongst others: conducting lessons, giving extended work, fund raising activities and control of students as well as dealing with peer conflicts and victimisation among pupils. The process tries to mould the minors into responsible citizens and leaders of tomorrow.

2.1.1.3 Outputs

Output relates to the direct result of the interaction of inputs and processes in the system. For a school, output includes student grades, graduation rates and number of trophies won by the school from participating in sports. Defining and measuring education output may be problematic because a typical school provides a wide range of services to students with a variety of different inert abilities and conditions. School provide both teaching and sporting activities. Therefore, a school is actually a complex multi-product firm. In addition, the desire to view the school's output in terms of the student's performance in examinations delays evaluation and sometimes fail to separate the school's contribution to performance from individual's own abilities as well as from the environmental constraints under which the student operates. This study used student grades in primary leaving examinations as output.

2.1.1.4 Outcomes or Impact

Outcome refers to the consequence of a process, including outputs, effects and impacts. At the end of primary school education pupils should be able to distinguish right from wrong, cooperate, share and care for others and have healthy habits and an awareness of the arts. The outcomes of primary education include literacy, numeracy and even success in sports. Thus measurement of outcome by considering either pass or failure in primary leaving examinations is flawed.

2.1.2 Behaviourism theory of learning

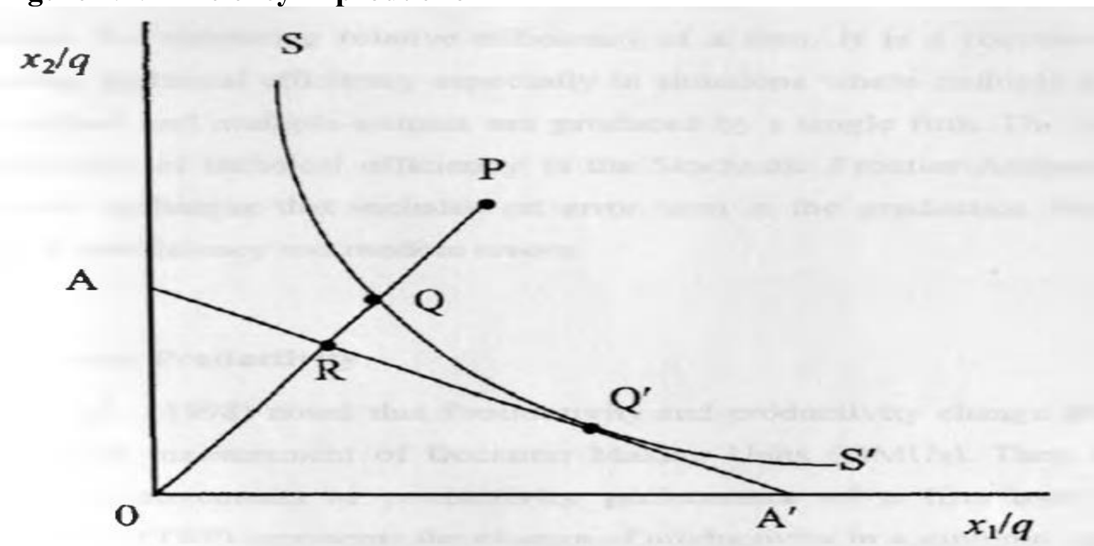
Thorndike (1911) and Pavlov (1927) were the pioneers of the behaviourism theory of learning and they suggested that teacher controlled or centered approaches are the best where the teacher is the sole authority figure responsible for improving the performance of the students. Knowledge is given out from different parts of a separated curriculum that children experience as distinct subjects and the teacher is responsible for delivering the information to the students in a set sequence with students having little or no choice. At a certain predetermined period there is an assessment which is exam oriented without teachers direct involvement. The performance pedagogies of the teacher would be highly visible and accessed through learner results. The theory is realistic and useful as it reveal that teacher's time management may be a source of inefficiency. However, the theory lies in the surface nature of the knowledge acquired and assumes the one size fits all approach which excludes students with individual differences and sometimes the teacher remains unaware of student's current knowledge or misconceptions.

2.1.3 Technical efficiency

Economic theory of production defines technical efficiency as the maximum attainable level of output from a given set of inputs. Production function shows the production process to be maximized so as to achieve the best possible level of output. The general production function of a two input case is specified as: $Q = f\left(X_1, X_2\right)$, where Q is the quantity of output, X_1 and X_2 are the input factors used in the production of output. Average product (AP) is the ratio of total product to the total quantity of an input used to produce the product while total factor productivity (TFP) refers to the average product of all inputs used in production. The marginal product (MP) of a firm's input is the change in output resulting from an additional input holding other inputs constant. The theory of production is concerned with the range of output for which the MP is positive since this is the efficient part of the production function (Varian, 1992).

According to Farrel (1957), efficiency refers to the ability of a decision making unit to produce the largest attainable output from a given set of inputs. Technical inefficiency thus represents the amount by which inputs could be reduced without reducing the amount of output. This is illustrated in figure 2.2; according to Coelli *et al*., (1998), the technical inefficiency of this firm is represented by the distance QP, which is the amount by which all inputs (X) could be proportionally reduced without reducing the output. This is represented by the ratio $\frac{QP}{OP}$, which represents the percentage by which all inputs could be reduced.

Figure 2.2: Efficiency in production



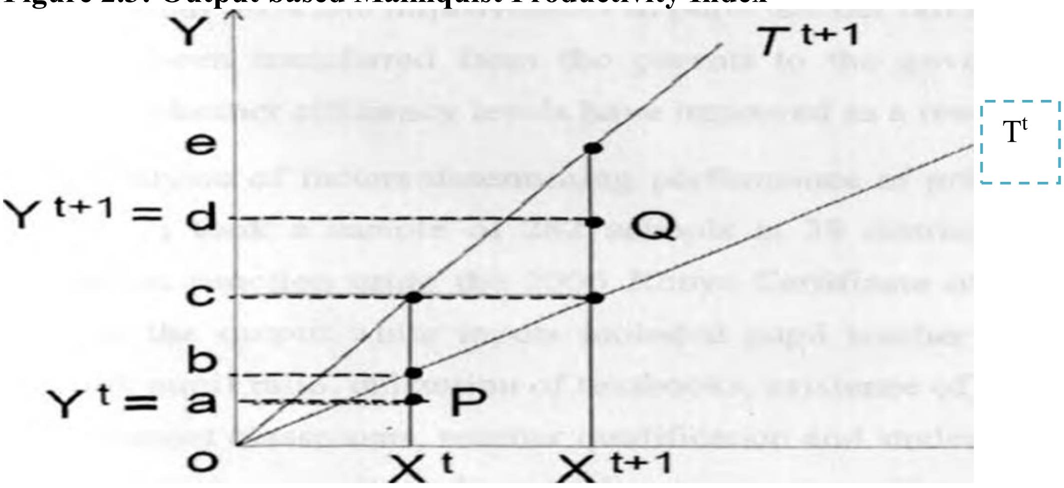
Source: Coelli et al. (1998).

The technical efficiency (TE) of a firm is calculated as; TE=$\frac{OQ}{OP} = 1 - \frac{QP}{OP}$, which denotes the ratio of the minimum input required to the actual input use given the input mix used. Technical efficiency scores take the value between zero and one and hence provides an indicator of the degree of inefficiency of a firm. A value of one implies that a firm is technically efficient for example at point Q, which lies on the efficient isoquant (Coelli *et al*., 1998). AA' is the isocost line and it represents the minimum cost of producing one unit of output given the prices of inputs. Q' is both allocative and technically efficient. The allocative efficiency (AE) for the firm is given as $AE_P = \frac{OR}{OQ}$. The ratio $\frac{RQ}{OQ}$ represents the cost reduction that would occur if a firm operating at point P is to operate at an allocative efficient point Q' (Coelli et al., 1998).

2.1.4 Total factor productivity

In general terms productivity refers to an economy's ability to convert inputs into outputs. It is a relative concept which deals with comparisons being made either across time or between different production units. Coelli *et al*., (1998) defined productivity change as movements in productivity performance of a firm over time. They also noted that productivity and productivity change are important parts of performance measurement of Decision Making Units (DMUs). Total Factor Productivity (TFP) represents the change of productivity in a multiple input-output firm. For example, if more output can be produced in period *t* +1 using the same amount of inputs that were used in period *t*, then there is an improvement in productivity. Thus, productivity is higher in the second period compared to the first period. TFP levels are sensitive to the units of measurement of inputs and outputs, so it is rarely of primary interest thus TFP growth becomes more appealing. Therefore, the notation TFP often refer to growth rather than levels and this is the convention adopted in this study. This study employs the Malmquist TFP index which is a distance function based approach in total factor productivity growth measurement. The concept of TFP index is illustrated in Figure 2.3.

Figure 2.3: Output based Malmquist Productivity Index



Source: Eyob, 2000

The observed inputs and outputs are X and Y respectively. T^t and T^{t+1} are the production technology in period t and t+1 respectively. For a firm producing at point P in period t and at point Q in period t+1, Malmquist Productivity Index is computed as the ratio of the Farrel (1957) technical efficiency in period t+1 to that in period t. This is expressed as:

Efficiency change = $\frac{od/oe}{oa/ob}$.

The geometric mean of the shift in technology evaluated at X^t and the shift in technology evaluated at X^{t+1}. Technical efficiency change = $\left(\frac{od/oc}{od/oe} X \frac{oa/ob}{oa/oc}\right)^{0.5}$, which is a combination of both scale efficiency and technical change.

2.2 Empirical literature review

Abagi and Odipo (1997) analyzed the basic school processes using a process perspective in Kenya to determine efficiency in a sample of hundred and twenty primary schools in the period 1993 - 1996. The results showed that primary education system was inefficient in Kenya. Teachers' poor time management, low pupil teacher ratio and wide curriculum were the sources of inefficiency. In addition, the attitude of the teachers, school environment, poverty and socio-cultural factors were also among the factors which influence efficiency.

In UK, Mancebon and Malinero (2000) used DEA to assess whether schools were efficient and the bases of inefficiency. The sample size was 176 schools and used test scores as outputs and inputs as number of variables reflecting school, home and teacher characteristics. The mean efficiency score was 78.50 percent and the lowest efficiency score was 41.7 percent while 8 of the schools were technically efficient. The poverty situation was reflected by the proportion of students eligible for free meals and this was found to be the main cause of inefficiency. Tobit regression was used to explain the cause of inefficiency and parental support was found to be positively related to efficiency. Teacher pupil ratio and school size were not insignificant in explaining inefficiency levels.

Chakraborty et al. (2001) determined the technical efficiency of 40 school districts in the state of Utah, USA using SFA and two-stage DEA. The classifications of inputs were those that the school can control and those beyond the control of the school while examination results were used as outputs. The mean efficiency score was 85.8 percent with the highest score being 99.1 percent and the least score 62.5 percent. The results were obtained under the assumption of half normal distribution in SFA. Alternatively, the mean score of 89.7 was found under the assumption of exponential distribution in SFA with the highest and the lowest scores being

98.1 percent and 67.2 percent respectively. Student teacher ratio was negatively related to efficiency while the percentage of population with high school education was found to have a positive significant effect on efficiency. Based on simple Variable Returns to Scale (VRS) DEA twenty three school districts were technically efficient and the least efficiency score was 67.3 percent. The two-stage DEA model showed that socioeconomic and environmental variables were important in explaining changes in efficiency. These results were consistent with those of Mancebon and Malinero (2000) where socioeconomic variable like the percentage of poor students in a school negatively influenced efficiency.

In Chile, Mizala *et al*. (2002) used DEA and SFA to estimate technical efficiency of schools. The inputs used were number of schools, student and teacher characteristics while mean scores in mathematics and Spanish examinations were outputs. SFA results revealed that the average school efficiency score was 93.18 percent with 73.04 percent being the lowest and 98.19 percent being the highest score. A mean efficiency score was 93.9 percent with the lowest score being 53 percent and 100 percent being the highest score were the DEA results. In DEA and SFA models, the size of the school, school's locality, student teacher ratio and level of education of the parents were significant in explaining the efficiency levels of the schools while teachers experience did not have any effect. Furthermore, the findings also disclosed that performance of private schools was better than that of public schools.

Portela and Camanho (2007) used DEA to estimate efficiency in a sample of 22 secondary schools in Portugal. Student entry behaviour, parents' literacy level and teacher's remuneration were used as inputs while retention and completion rates as well as mean scores on final examination were the outputs. The results indicated that the mean efficiency score was 98.6 percent and the schools were assessed on the viewpoint that they are converting all their resources into students' achievement. The study concluded that teacher characteristics were the most important variables in explaining inefficiency in the schools.

Denaux (2007) also used DEA to evaluate the technical efficiency of 153 schools in the state of Georgia. Student teacher ratio, teacher's experience and number of students under school feeding programme were the inputs while outputs comprised of graduation rate and examination scores. The results indicated that schools in urban areas were 93 percent efficient while schools in the rural area were 88 percent efficient. Through Tobit regression, inhabitants' level of education and white pupils were positively related to efficiency. The results of this study were consistent with those of Mizala et al. (2002), Mancebon and Malinero (2000) and Chakraborty et al. (2001) where students' socioeconomic background is important in explaining inefficiency.

Muvawala and Hisali (2012), in their investigation of technical efficiency in Uganda's primary education showed that private and urban schools are relatively more efficient than public and rural schools. They found out that private schools would improve learning outcomes without increasing spending and improvements in learning outcomes for government-aided schools require increased resources.

Agasisti et al. (2012) used two-stage DEA on a sample of 1062 schools in the Lombardy region to examine efficiency of Italian schools. Examination scores in reading and mathematics were used as outputs and a wide range of inputs including the pupil teacher ratio, teacher characteristics and home variables in their study. 80 percent was the mean efficiency score. Tobit regression results indicated that higher efficiency scores were associated with students with better socioeconomic background thus emphasizing on the roles of factors beyond school control in explaining efficiency.

2.3 Conclusion

The literature reviewed show that in efficiency analysis the most common used output in schools are the scores in a given exam at the end of the period. There are a variety of inputs used but they are generally classified as those that the school can control and those beyond the control of the schools. In addition, the inputs can further be broken into those reflecting teachers' ability, school inputs, student and finally the family background of the student as well as the surrounding region. In most of the studies, pupil-teacher ratio and teacher characteristics were found to be insignificant.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter describes the analytical framework, methodology and data used in the study. It also expounds on how the relevant data and information is used to address the research objectives and provide an insight on the estimation procedure that was adopted in estimating efficiency and total factor productivity growth in primary schools.

3.1 Data Envelopment Analysis (DEA)

DEA is a nonparametric method for measuring efficiency attributed to Chames *et al*. (1978). It is a linear programming model, assuming no random mistakes, used to measure technical efficiency of production units. Efficient firms are those that produce a certain amount of outputs while spending a given amount of inputs or use the same amount of or fewer inputs to produce a given amount of outputs, as compared with other firms in the test group. The DEA formulation can incorporate both input-reducing and output-augmenting orientations as well as constant and variable returns to scale. This study is based on output increasing orientation. The DEA methodology gives a tool to estimate relative efficiency of a chosen entity in a given group of units and criteria. Coelli *et al.* (1998) noted that the main advantages of DEA are the ability to handle multiple inputs and outputs and it does not require a specification model relating inputs to outputs. Each unit produces S outputs while employing M inputs. The estimation of performance is based on the efficiency of a DMU in utilization of the existing resources to generate the optimal output. It is therefore, a ratio of DMU's total outputs to total inputs. Technical inefficiency means that a DMU is producing less output per input or is using more inputs per output as compared to the DMUs on the production possibility frontier (Chames *et al*., 1978).

3.1.0 The Constant Returns to Scale DEA model

Chames *et al*., (1978) proposed a DEA model based on constant returns to scale (CRS) and an input orientation approach. They specified a fractional linear programme for each decision making unit (DMU) that computes the relative efficiency and compared it to all the other observations in the sample. The exposition can be explained by means of an illustration as follows. Suppose that there are data on K inputs and M outputs on each of N decision making units. The data for all the DMUs are given by KxN input matrix, X, and the MxN output matrix,

Y. DEA is introduced by means of ratio and for each DMU (thus, a primary school in this study) one seeks to obtain a measure of the ratio of all outputs over all inputs, which takes the following form: $\frac{u'y_i}{v'x_i}$, where u' is an Mx1 vector of output weights and v' is a Kx1 vector of input weights. Selection of optimal weights involves solving the following mathematical programming problem:

$$Max_{\ u,v}\left(\frac{u'y_i}{v'x_i}\right)$$

Subject to ……………………………………..(1)

$$\frac{u'y_j}{v'x_j} \leq 1 \quad \text{j=1,2,…,N}$$

$$u, v \geq 0$$

The mathematical programming problem entails finding values for u' and v', such that the efficiency measure of the i[th] primary school is maximized subject to the constraint such that the overall efficiency measures must be equal to or less than unity. However, formulation (1) has the disadvantage of having an infinite number of solutions. For example ($u*, v*$) and ($\alpha u*, \alpha v*$) are solutions for the same problem. To deal with this problem one can impose the constraint $v'x_i = 1$ which yields the following linear programming problem:

$$Max\ u, v[u'y_i]$$

Subject to

$$v'x_i = 1$$

$$u'y_j - v'x_j \leq 0 \quad \text{j = 1,2,…,N} \qquad \text{…………………………(2)}$$

$$u, v \geq 0$$

This form is known as the multiplier form of the linear programming problem. An equivalent envelopment form of this linear programming model can be derived by means of duality (Coelli, 1996):

$$Min_{\theta\,\lambda}\,\theta$$

Subject to

$$-y_i + Y\lambda \geq 0$$

$$\theta x_i - X\lambda \geq 0 \qquad \text{..(3)}$$

$\lambda \geq 0$

θ is a scalar and λ is an Nx1 vector of constants. This envelopment form consists of fewer constraints than the multiplier form and thus, it is the generally preferable form to solve. The value of θ obtained is the efficiency score for an individual school and it has to satisfy $0 \leq \theta \leq 1$. According to Farrell's (1957) definition a value of 1 is a point on the production frontier which shows a technically efficient decision making unit.

3.1.1 The Variable Returns to Scale DEA model

The model by Chames *et al*., (1978) assumes constant returns to scale (CRS). Returns to scale refer to the changes in output as a result of change in all inputs by the same proportion. CRS implies that output changes by the same proportion as the change in inputs and thus the size of schools becomes irrelevant when measuring efficiency since all schools are deemed to be operating at their best scale size. However, size of a school is an important factor in this analysis and thus the assumption of variable return to scale (VRS) which allows the level of outputs to inputs to vary with the size of the schools is more binding. Banker *et al*., (1984) added an intercept term to the Chames *et al*., (1978) model to take care of the variable returns to scale. The CRS linear programming problem can be modified to account for VRS by adding the convexity constraint: $N1'\lambda = 1$, where N1 is an Nx1 vector of ones and provides technical efficiency scores which are equal to or greater than those obtainable by the CRS model.

Thus the model becomes:

$Min_{\theta\,\lambda}\,\theta$

Subject to

$-y_i + Y\lambda \geq 0$

$\theta x_i - X\lambda \geq 0$

$N1'\lambda = 1$ ....(4)

$\lambda \geq 0$

This approach provides technical efficiency scores which are equal to or greater than those obtainable by the CRS model since they form a convex hull of intersecting planes that envelope the data points more tightly than the CRS canonical hull.

3.2 The Malmquist Productivity Index

The Malmquist TFP index is a measure of total factor productivity. The index is constructed by measuring the radial distance of the observed output and input vectors in period t and t+1, relative to a reference technology (Eyob, 2000). Distance functions allow one to describe a multi-input and multi-output production technology without the need to specify a behavioural objective. Output oriented TFP index focuses on the maximum level of outputs that could be produced using a given input vector and a given production technology relative to the observed level of outputs. Since Malmquist productivity index can be defined using the technology of period t as well as that of period t+1, it is defined as the geometric mean of the two indices based on periods t and t+1 technologies. It is estimated as the ratios of distance functions of observations from the frontier (Coelli *et al.*, 1998).

The panel data set permits the use of DEA-like linear programming and a (input-oriented or output-oriented) Malmquist TFP Index to measure productivity change and to decompose this productivity change into technical change and technical efficiency change. Following Fare *et al*. (1994), an output-oriented Malmquist Productivity Change

Index is specified as follows:

$$M_0^{t+1}\left(x^{t+1}, y^{t+1}, x^t, y^t\right) = \left[\frac{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_0^t\left(x^t, y^t\right)}\right] X \left[\frac{D_0^t\left(x^{t+1}, y^{t+1}\right)}{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)} X \frac{D_0^t\left(x^t, y^t\right)}{D_0^{t+1}\left(x^t, y^t\right)}\right]^{\frac{1}{2}}$$

Where,

Efficiency change = $\left[\frac{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_0^t\left(x^t, y^t\right)}\right]$ and

Technological change = $\left[\frac{D_0^t\left(x^{t+1}, y^{t+1}\right)}{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)} X \frac{D_0^t\left(x^t, y^t\right)}{D_0^{t+1}\left(x^t, y^t\right)}\right]^{\frac{1}{2}}$

Where the subscript indicates output orientation, *M* is the productivity of the production point (x^{t+1},y^{t+1}) relative to the earlier production point (x^t,y^t) and *D* is the output distance while x^t and y^t are the inputs and outputs respectively. When M is greater than 1, productivity is improving in that the DMU delivers a unit of output in period t+1 using fewer inputs compared to period *t*. and is therefore more efficient in period t+1 than in period *t*.

3.3 Determinants of inefficiency

Data Envelopment Analysis generates efficiency scores but does not explain the possible causes of inefficiency. In order to reveal the possible causes of inefficiency, studies reviewed showed that factors like average class size, pupil teacher ratio, socioeconomic factors, environmental factors and school location may influence efficiency of schools. Based on studies carried out by Chakraborty *et al.*, (2001), Denaux (2007), Rassouli-Currier (2007) and Agasisti *et al.*, (2012), two-stage DEA can be applied when identifying the factors influencing inefficiency in the schools. Therefore, this study borrows from these studies.

This study also applied Data Envelopment Analysis second stage where DEA efficiency scores in the first stage are transformed into inefficiency scores to be regressed on the inputs and other external variables to determine the possible causes of inefficiency in primary schools. The Tobit regression model is applied because the efficiency scores are truncated between 0 and l and the dependent variable is limited in nature.

According to Green (2004), the Tobit regression model is defined as follows:

$Y_i^* = B_i X_i + \mu_i$

$y_i = y_i^* \ if \ Y^* > 0$

$y_i = 0 \ if \ y_i^* \leq 0$

Where $\mu_i \sim N(0, \sigma^2)$

Y^* - Latent (unobservable) variable

y_i - Observed inefficiency score

B_i - $Kx1$ vector of parameter

X_i - $Kx1$ vector of explanatory variables

The model for this study can be specified as:

$Inef = \alpha_0 + \alpha_1 TO + \alpha_2 PPL + \alpha_3 ACS + \alpha_4 LD + \mu_t$

Where:

$Inef$ - Inefficiency score calculated as $\frac{1}{DEA\ Score} - 1$

TO- Number of toilets

PPL- Number of pupils

ACS- Average class size

LD - Location dummy and is 1 if high density and 0 otherwise

μ_t - Normally and independently distributed with mean zero and constant variance

The residuals of the Tobit regression model separate the effects of these factors and measure pure technical efficiency that is bounded between $-\infty$ and 1. The higher the value of the residual, the better is the performance of the school. Estimation of the marginal effects from the Tobit regression establish the effect of the explanatory variables on efficiency.

3.5 Definition and measurement of variables

3.5.1 Input variables

The inputs used in the study are the teachers, pupils, classrooms, toilets and average class size.

Teachers (TR)

Teachers' includes the total number of teachers in each primary school, irrespective of level of education. Following Carrington *et al*., (2005) the number of teaching staff is selected as the input for the school teaching efficiency assessment. This measure is commonly accepted in evaluating the primary teaching efficiency since if divided by number of students gives the student to teacher ratio which is a proxy for work load.

Pupils (PPL)

Pupils relates to the total number of pupils in a primary school. The pupils can be regarded as both inputs and outputs in the education system. When the students start their primary education they are transformed through knowledge impartation by their teachers which shape their thinking capacity. After writing their primary leaving examination their results are regarded as the output. Therefore, it is important to know how many students entered into the transformation system and how many were successfully transformed.

Classrooms (CLR)

Classrooms relates to the total number of classrooms in a primary school. Availability of enough classrooms signifies a proper environment for learning. During some seasons like winter and summer the students are not vulnerable to disturbing issues like rain, scorch sun and extreme cold which affect student's information absorption rate. Thus, classrooms are an important input in the education system

Toilets (TO)

Toilets comprise the total number of toilet cubicles in a primary school. The number of toilet cubicles is lumped together and is not decomposed by sex. Jaiyeoba and Atanda (2011) have noted that toilets (conveniences) represent one of the strong school based quality factors that contribute to students' academic achievement and sanitation.

Average class size (ACS)

Average class size is constructed by dividing the total student population by the number of classrooms in a primary school. This variable is usually considered a school input in efficiency analysis. Higher average class size means more work load for the teacher and it is expected to be negatively related to efficiency.

Location (LD)

The study introduced a dummy variable for the location of the primary schools. The dummy variable takes a value of 1 if the decision making unit is located in low density locality and 0 otherwise.

3.2.2 Output variables

The outputs in this study are primary leaving examinations results separated into division1, division 2, division 3 and division 4.

Division1 (DIV1)

The number of students who passed primary leaving examinations with grades between 4 and 12 units are the ones found under this division.

Division2 (DIV2)

Comprise the number of pupils who passed primary leaving examinations with 13 and 23 units inclusive.

Division 3 (DIV3)

Comprise the number of pupils who passed primary leaving examinations with division 3. Qualifying for division 3 entails obtaining between 24 and 29 units.

Division 4 (DIV4)

This division comprises the number of pupils who passed primary leaving examinations with division 4. Qualifying for division 4 entails obtaining between 30 and 36 units.

3.4 Orientation

Data envelopment models can be estimated by assuming either output or input orientation. Output oriented technical efficiency refers to the decision making unit's ability to obtain maximum output from a given amount of inputs. Formally, the level of technical efficiency is measured by the distance a particular firm is from the production frontier and a firm is said to be technically efficient if it is operating at a point sitting on the production frontier. The input orientation attempt the following question: By how much can input quantities be proportionally reduced without changing the output quantities produced? But this question can be posed alternatively as: "By how much can output quantities be proportionally expanded without altering the input quantities used?" Both input and output oriented measures provide equivalent measures of technical efficiency when constant returns to scale exist in all the decision making units, but differs when increasing or decreasing returns to scale are present (Coelli, 1996).

The study has adopted the output orientation because it is more suitable under the objectives of the researcher than an input orientation. Output orientation implies the goal of achieving greater output that is higher student proficiency for given inputs under the assumption that primary schools exercise sufficient control over inputs, so the inputs are not conceived as environmental factors but de facto as explanatory variables. Since a primary school has a higher efficiency score of the educational system or performance score if, for the given inputs the students have a higher level of performance for the national primary leaving examinations output orientation becomes appropriate approach.

3.4 Data sources

Panel data set is obtained from Harare province primary schools and a common set of input and output indicators constructed to support the estimation of DEA and Malmquist models. Inputs as well as outputs data were gathered for the 27 primary schools over the period 2011–2015.

3.5 Conclusion

This chapter outlined the methodology used in the study. Besides that, the chapter also shed light on inputs and outputs used in measuring technical efficiency and total factor productivity growth. The next chapter deals with estimation, presentation and interpretation of results.

CHAPTER FOUR

RESULTS PRESENTATION, ANALYSIS AND INTERPRETATION

4.0 Introduction

The results of the analysis of efficiency scores in 27 primary schools in Zimbabwe under variable returns to scale are presented in this chapter. The analysis is done for the period 2011 to 2015 where efficiency score of one indicate efficient decision making units (DMUs) and scores less than one indicates levels of inefficiency. The estimated results are categorized under descriptive statistical analysis; correlation analysis; technical efficiency and total factor productivity growth.

4.1 Descriptive statistical analysis

Table 4.1 provides descriptive statistics of the educational inputs and outputs for 27 primary schools over 2011- 2015 for all variables used in the model.

Table 4.1: Descriptive Statistics

Variable	DIV2	DIV3	DIV4	DIV1	PPL	TR	TO	CLR	ACS
Mean	26.82	53.97	46.19	76.88	1020.3	31.57	23.8	28.84	45.33
Median	25.2	45.28	38.22	81.50	1034.0	32.00	21.0	27.00	37.36
Maximum	94.6	137.6	114.7	143.4	1721.0	47.00	55.0	44.00	53.26
Minimum	2.49	15.00	15.60	19.50	234.00	20.00	11.0	15.00	9.80
Std. Dev.	19.2	23.45	21.22	29.78	328.20	5.49	10.4	6.34	9.00
Skewness	1.28	0.92	1.00	-0.17	-0.31	0.50	1.16	0.58	-0.80
Kurtosis	4.31	3.71	3.32	2.26	2.89	3.62	3.55	2.63	3.48

Table 4.1 shows that the average number of teachers in the sampled primary schools stood at 31.57. Based on the fact that a primary school has seven classes with several streams, the average number of teachers is very low to an extent that it makes it difficult for teachers to adequately attend to the learners to produce satisfactory academic achievement. The average number of classrooms in the sampled schools stood at 28.84 and this translates into an average class size of 45 pupils which is more than the recommended size of 40 students. On average,

classes in primary schools are overcrowded. According to USAID (2007) overcrowded or large classrooms are the ones which have a pupil-teacher ratio (PTR) exceeding 40:1 and primary teachers in these classes face many obstacles when attempting to teach in overcrowded classes because students perform better when the teacher is able to give one on one or small group instruction on a regular basis but as the average class size increases one on one class instruction becomes increasingly difficult to do. Furthermore, in congested classrooms indiscipline issues increase and there are more opportunities for personal conflicts, tension and general disruptive behavior among the students.

Considering average educational outputs, average number of pupils who attained division 1 stood at 77 with a standard deviation of 30. Twenty seven was the mean number of pupils who attained division 2 with a standard deviation of about 19. The mean number of pupils who attained division 3 stood at 54, with a standard deviation of 23 while the mean number of students who attained division 4 stood at 46, with a standard deviation of 21. Thus, a higher proportion of pupils in schools in Harare province pass their primary leaving examinations under division 1. This is because teachers in Harare tutor struggling students that need more attention time after school and assign seating positions as well as rotating them continuously based on end of month written tests. This improves performance as the students are motivated by affiliating in the well performing and teacher appraised groups.

4.2 Correlation analysis

Table 4.2 shows the pairwise correlation matrix of the input and output variables used in assessing technical efficiency for 27 decision making units sampled. Some variables are positively correlated while others are negatively associated. The reported figures contain both significant and insignificant correlation coefficients. Significant coefficients are regarded as those which are greater than 50 and insignificant coefficients are those with a score less than 50. The sign of the score for the variables are also important in that they show the direction of effect of each variable on others and as a result its effect on academic performance.

Table 4.2: Pairwise Correlation Matrix for Input and Output Variables

Variable	DIV2	DIV3	DIV4	DIV1	PPL	TR	TO	CLR	ACS
DIV2	1.00								
DIV3	0.31	1.00							
DIV4	0.43	0.84*	1.00						
DIV1	-0.01	0.26	0.25	1.00					
PPL	0.17	0.51*	0.43	0.39	1.00				
TR	-0.03	-0.01	0.06	0.06	0.72*	1.00			
TO	0.20	0.28	0.39	-0.13	-0.02	0.05	1.00		
CLR	0.09	0.11	-0.01	0.28	0.66*	-0.19	0.34	1.00	
ACS	0.17	-0.58	-0.31	0.34	0.75*	0.11	0.07	0.47	1.00

Significant scores are marked by (*)

Table 4.2 clearly shows that divisions 3 and 4 have a higher degree of association which is positive. This implies that a primary school which had many of its students in one of the divisions had a high probability of having more candidates in the other division. There is a strong positive correlation between number of teachers and number of pupils as shown by a score of 0.72.This is due to the fact that as schools enroll more students, more teachers are needed to provide the service to the students. The number of classrooms and toilets are positively and highly correlated. The degree of association between average class size and divisions 3and 4 are negative indicating that overcrowded classes are likely to work against the good academic performance of students.

4.3 Technical Efficiency scores

DEAP Program version 2.1 by Coelli (1996) was used to obtain the efficiency scores and the program is run under output orientation Malmquist DEA instruction mode for 27 DMUs over the 5 year period. The estimated results for technical efficiency scores and total factor productivity growth reported in this section were obtained by allowing for variable returns to scale since it is more reasonable in the real world to present variable returns to scale because primary schools operate in less than optimal conditions. Table 4.3 presents the mean variable returns to scale efficiency scores by school.

Table 4.3: The efficiency scores for schools in the period 2011-2015

DMU	YEAR Code	2011 score	2012 score	2013 score	2014 score	2015 Score
Warren park 1	1	0.963	0.915	0.987	1.000	1.000
warren park 3	2	0.792	0.956	0.871	1.000	0.941
Chirodzo	3	1.000	0.730	0.982	1.000	1.000
Budiriro1	4	0.540	1.000	0.980	1.000	1.000
Budiriro 5	5	0.732	1.000	1.000	1.000	1.000
Kuwadzana 2	6	0.739	0.781	1.000	0.509	1.000
kuwadzana 6	7	0.860	1.000	0.764	0.773	1.000
Glen norah A	8	0.736	1.000	1.000	1.000	1.000
Kudakwashe	9	1.000	0.723	1.000	1.000	1.000
Glenview 1	10	0.717	1.000	0.777	0.997	0.718
Glenview 3	11	0.754	0.874	0.795	1.000	0.980
Avondale	12	0.894	0.786	0.987	1.000	0.969
Workington	13	0.689	0.612	1.000	1.000	1.000
Milton park	14	0.696	1.000	1.000	1.000	1.000
Borrowdale	15	1.000	0.956	1.000	1.000	1.000
Chisipite	16	1.000	1.000	1.000	1.000	0.539
Helensvale	17	1.000	0.912	1.000	1.000	1.000
Greendale	18	1.000	1.000	1.000	1.000	1.000
Greystone Park	19	1.000	1.000	1.000	1.000	1.000
Glen Lorne	20	0.659	1.000	0.763	0.954	0.735
Philadelphia	21	1.000	1.000	1.000	0.736	1.000
Mufakose	22	0.567	1.000	1.000	0.755	0.986
Houghton Park	23	1.000	0.732	1.000	1.000	1.000
Mabvuku	24	0.897	1.000	1.000	1.000	0.966
Southerton	25	0.789	0.987	0.999	0.999	0.842
Marimba Park	26	0.567	0.964	1.000	1.000	0.858
Westwood	27	1.000	1.000	1.000	1.000	1.000
Average score	-	**0.893**	**0.990**	**0.984**	**0.953**	**0.946**

In the years 2011, 2012, 2013, 2014 and 2015 out of the 27 primary schools 10,14,17,20 and 16 are found to have technical efficiency score of 1 respectively which imply that they operated efficiently relative to other primary schools. Therefore, these primary schools are operating on the production frontier and they cannot increase their output without an increase in their current level of inputs. The remainder are found to be inefficient with efficiency scores less than unity implying that they can increase their output without altering the current level of inputs. In addition, scale efficiency scores for these schools or decision making units when assessed under variable returns to scale are less than unity suggesting that they operated below capacity in these years. The mean scale efficiency score for all inefficient schools is 0.857 suggesting that the decision making units have 14.3% unused capacity.

On average, along the high density- low density divide, primary schools located in low density areas such as Philadelphia, Greendale, Borrowdale and Chisipite are more technically efficient as compared to schools in high density areas like Budiriro, Southerton and Warren Park. Since technical efficiency scores only refer to the relative performance within the sample, it follows that decision making units with an efficiency score of unity are efficient relative to all other DMUs in the sample, but they may not be necessarily efficient by some absolute standard. Therefore, it is important to disclose that inefficiency is inherently unobservable and what can be done is benchmarking primary schools against each other, not against an absolute standard.

Technical efficiency results are associated with discretionary variables, in what follows schools were arbitrarily categorized into three cohorts which are low performers (with a mean variable returns to scale technical efficiency score between 53-70 percent); average performers (with a mean variable returns to scale technical efficiency score between 71-85 percent class) and high performers (with a mean variable returns to scale technical efficiency score between 86–100 percent). Table 4.4 presents the means of the discretionary variables for the three categories.

Table 4.4: Means of discretionary variables by category of performance

Discretionary variable	Low performers VRS TE (53-70%)	Average Performers VRS (71-85%)	High performers VRS (86-100%)
Class rooms	22	31	42
Pupils	1131	925	852
Average class size	51	30	20
Teachers	22	26	39
Toilets	14	32	44

Table 4.4, shows that there is a direct relationship between the number of teachers, classrooms, toilets and a school's technical efficiency score while there is an indirect relationship between number of pupils, average class size and technical efficiency. This implies

that big classes negatively affect academic achievement. The differences in technical efficiency scores of various cohorts of schools can also be linked to family poverty levels; parental literacy in different school locations; effort of the teacher and teacher remuneration packages. There are marked differences between low density and high density poverty levels in Harare, with poverty remaining higher in high density areas than in low density areas. There is a negative correlation between poverty levels and mean technical efficiency score of a school as confirmed by Lacour and Tissington (2011) who carried out a research on the effects of poverty on academic achievement in United States and found that low achievement is closely correlated with lack of resources and low socioeconomic status.

Teacher effort is a significant input into learning and most noticeable form of quiet corruption in education is the low levels of teacher effort which emanates from teacher absence as well as low effort while in school. According to the World Bank (2010) at least half of the teachers in Zimbabwe were absent least one day in the preceding week and about one quarter of teachers were absent for two or more days and nearly one third of teachers were not in the classroom during learning periods. Since schools combine instructional materials and teacher and pupil interaction to produce cognitive skills it means if a teacher has few or no instructional materials he or she finds it difficult to impart the necessary skills to the pupils leading to inefficiency of decision making units.

4.5 Total Factor Productivity growth

Total factor productivity measures the efficiency with which all factor inputs such as information and communication technology (ICT), labour and non-ICT equipment and structures are utilized. The Malmquist productivity change index allows decomposing TFP into technical efficiency change which shows if a school is moving close to the production frontier and technological change which shows whether the production possibility boundary is moving outwards. The change of productive efficiency shows catching up or imitation as well as innovation which is the shifts in technology over time. The ratio of two distance functions is the efficiency change which measures the change in the output oriented technical efficiency between period t and t + 1. An efficiency score which is more than one indicates that a primary school is diverging from the production frontier and less than one means productivity regress while a unit score shows constant productivity.

Table 4.5 shows a summary of annual means for the Malmquist TFP indices. It reports the means for each year of technical efficiency change, technical change, pure efficiency change, scale efficiency change and total factor productivity change over the period of study.

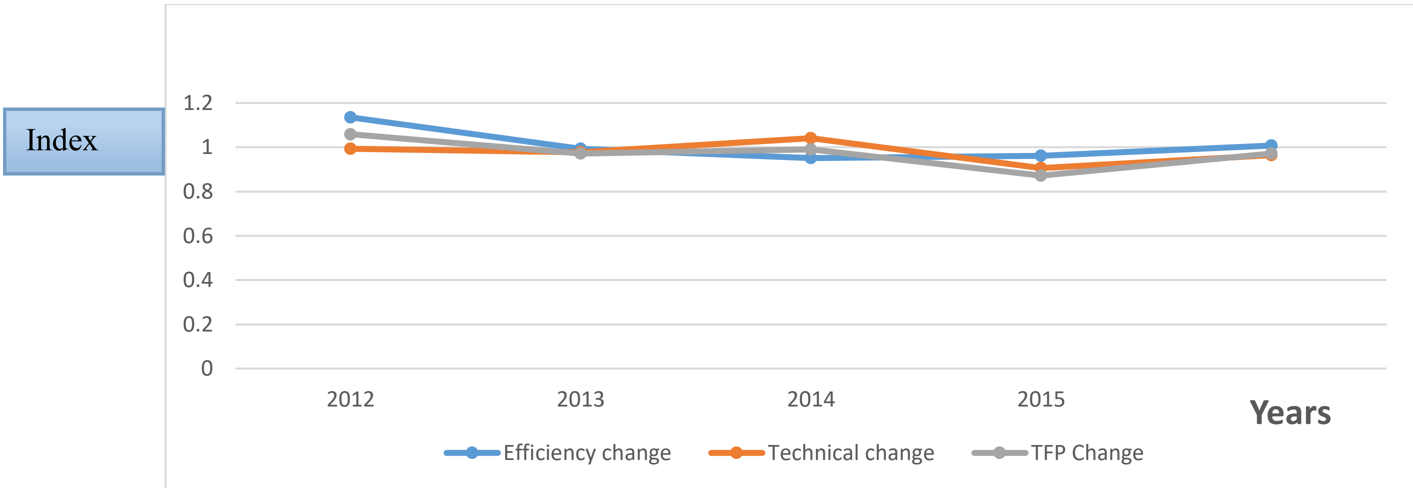
Table 4.5: Malmquist TFP Index summary of annual means

Year	Efficiency change	Technical change	Pure efficiency change	Scale efficiency change	TFP Change
2012	1.135	0.993	1.122	1.012	1.059
2013	0.993	0.978	0.994	0.998	0.971
2014	0.951	1.041	0.961	0.990	0.990
2015	0.962	0.906	0.994	0.968	0.872
Mean	**1.008**	**0.964**	**1.016**	**0.992**	**0.971**

Note that 2012 refers to change between 2011 and 2012 and so on

Table 4.5 shows the estimated indices of the output-oriented Malmquist productivity change indices. Considering an output-oriented Malmquist TFP Index, the mean TFP change of 0.971 indicates that on average between 2012 and 2015 there was a 2.9% productivity decline. The mean technical efficiency change of 1.008 which is larger than the mean technical change of 0.964 implies that productivity losses largely resulted from technological inefficiency. Furthermore, since the overall technical efficiency change is found by multiplying pure technical efficiency change with scale efficiency, the pure efficiency change was 1.016 while scale efficiency change stood at 0.992 implies that scale inefficiency becomes the major source of technical inefficiency. Figure 4 shows the evolution of total factor productivity change.

Figure 4: Malmquist total factor productivity index versus technical change and efficiency change, 2012- 2015



TFP growth over the period of study is uneven and no single factor can explain this behaviour since there are several policy changes that have taken place in the policy context of primary education in Zimbabwe. However, the striking results for 2012 and 2014 can be partly attributed to the sharp rise in enrolment figures due to the BEAM programme.

4.5 Econometric analysis of the determinants of inefficiency

To investigate the determinants of technical efficiency, there is need for regressing the inefficiency scores against input variables and a locational dummy variable. STATA 13 statistical software is used to perform the analysis. The Tobit model which is left censored at zero is estimated and regression results are presented in table 4.6.

Table 4.6: Tobit model regression results
Dependent variable: Inef

Variable	Coefficient	t- ratio
Constant	-0.3023347	-1.56
TO	-0.003232	-1.51
PPL	0.000472	-0.88
ACS	- 0.0097931	2.76
LD	0.2187903	2.51

The primary school enrollment (PPL) has a positive coefficient of 0.000472 while number of toilets has a negative coefficient of 0.003232 but both are statistically insignificant at 5% level of significance. The coefficient of average class ratio (ACS) has a negative coefficient of 0.0097931 and is significant at 5% level. The sign is opposite to the prior expectation and it shows that as average class size increases classes become efficient. This may not plausible given that high average class size means high pupil teacher ratio which is associated with congestion and low quality of teaching. However, given that classes may be conducted under the trees and in shades as well as that there might be morning and afternoon classes, the average class sizes indicated in the sampled data may be lower than the ones physically on the ground since class sessions, shades and under the tree classes were not taken into account.

The location of the primary school is significant at 5% level and has a positive coefficient of 0.218 meaning that a school located in low density is more efficient than a primary school located in high density. This finding tally with the results found by Muvawala and Hisali (2012) who found out that urban locality have positive influence on efficiency of education providing units. Thus primary schools in high density location perform better than their high density counterparts. This may be attributed to the differences in the socio-economic factors such as poverty level, parental involvement and teachers' appreciation from the school development committee. In addition, it could also be the fact that schools located in low density areas have much better facilities than those in high density.

4.7 Conclusion

This chapter presented the results obtained from the DEAP version 2.1 and STATA 13 statistical package and these results were interpreted. Average class size and location dummy were found to be statistically significant while number of pupils and number of toilets were insignificant in explaining the sources of inefficiency. The next chapter provides policy recommendations and suggestion to areas of further study.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND POLICY RECOMMENDATIONS

5.0 Introduction

The study investigated technical efficiency and total factor productivity growth of primary schools in Zimbabwe focusing specifically on decision making units under Harare Province from 2011 to 2015 using DEA with an output orientation. In addition, the study also estimated the efficiency scores of the primary schools and investigated the possible causes of inefficiency. This chapter therefore, focuses on summarizing and giving conclusions on the study and also making policy recommendations based on the results discussed in chapter four.

5.1 Summary of findings and conclusions

Primary schools in Zimbabwe have efficiency scores ranging from 53% to 100%. Variation in academic achievement among schools with same characteristics in Zimbabwe are shown by larger dispersion in efficiency scores. When technical efficiency scores were estimated for primary schools and analyzed according to their locational divide, it was concluded that schools located in low density are more efficient than public schools located in high density areas. The mean efficiency score of the 27 primary schools using DEA and assuming VRS is 0.93 percent. This value shows that on average, if primary schools fully utilize their inputs, their efficiency scores would rise by 7 percent.

The mean total factor productivity change of 0.971 shows that, on average over the study period, there was a 2.9 percent productivity regress. Considering the mean technical efficiency change score of 1.008 and average technological change score of 0.964, it can be concluded productivity losses largely emanated from technological inefficiency.

Tobit regression analysis indicates that location of the primary school is positively related to efficiency. This means that for primary schools located in low density, their students perform better than schools in high density areas. Location on its own does not positively impact efficiency but factors associated with location such as attraction of highly experienced staff, high parental involvement and low pupil teacher ratio may affect efficiency.

Average class size contribute negatively to inefficiency and this may be because the data on the number of classes reflect that classes are congested but because of morning and afternoon sessions the average class size of 51 pupils may be different to what is physically in the classrooms and thus the sessions on their own reduce the number of pupils per class. Number of toilets and enrollment are insignificant in explaining sources of inefficiency.

5.2 Policy recommendations

This study demonstrated that primary schools in Harare Province are technically inefficient. The magnitudes by which inputs and outputs could be varied to make the inefficient schools efficient were suggested using the DEA methodology. Based on the output oriented approach, primary schools in Harare Province can improve their performance by 7% without altering their current levels of inputs. The study also finds that primary schools in Harare province are operating at 2.9% below capacity. Based on these indicators, the schools' administrators should check the internal management mechanism and compare this with other schools with good efficiency scores in an effort to see where they can improve the decision making unit's efficiency. In addition, primary schools should leverage on innovations through e-learning platforms and technology to give an impetus to their productivity. In addition the drop in pure and scale efficiency changes indicates deteriorating contribution of management and improved operations to total productivity. The contribution of primary school management can be improved through offering financial motivators such as wage increments and non-financial motivators such as training and development through workshops and seminars.

From the Tobit regression results, average class size is negatively related to inefficiency and it can be conjectured that this is due to sessions and classes being conducted under trees and shades at school. Thus, it can be inferred that schools should structure their learning time into different sessions. Furthermore, primary schools should buy movable boards and construct temporary shades to facilitate the learning process outside the classroom. Motivating teachers through improved remuneration and reducing the students' time in schools may also be helpful in enhancing education efficiency. Although this might work there is still need for construction of classrooms since learning outside may inconvenience both the pupils and teachers when the weather conditions change.

Since location contributes positively to efficiency and this is due to socio- economic factors then the primary schools should provide the atmosphere for high parental involvement so as to ensure higher student achievement outcomes. To attract highly skilled workers in all areas where primary schools are located there is need for adequate investment in modern technology such as the use of projectors and audio visual equipment and this may help schools to attain satisfactory efficiency.

5.3 Suggested areas of further study

This study estimated technical efficiency and total factor productivity growth of primary schools in Harare province in Zimbabwe. Succeeding researchers may examine the extent to which Harare Province primary schools are provided with discretionary and non -discretionary resources in fulfilling their mandates which is an area that remains unattended in this study. Performance in academics is also affected by student characteristics, parental and community involvement as well as other environmental factors. Thus, revealing a clear need to find out how student characteristics are connected to school characteristics and community variables impact upon one’s academic achievement. Comparing private and public primary schools to determine whether there are differences in efficiency scores and examination of how environmental, socioeconomic and demographic factors explain inefficiency is also an area which is important for the formulation of policy.

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APPENDICES

Appendix 1: Descriptive Statistics

	CLR	DIV2	ACS	DIV3	DIV4	DIV_1	PPL	TR
Mean	26.55556	33.36709	36.69306	69.32252	58.40572	81.87963	978.1407	32.08889
Median	26.00000	25.21875	38.21739	73.87500	56.13889	84.33333	1000.000	32.00000
Maximum	44.00000	94.68000	56.00000	137.6800	114.7333	147.0000	1721.000	47.00000
Minimum	15.00000	4.410000	9.360000	10.68000	8.900000	19.50000	234.0000	20.00000
Std. Dev.	5.268417	23.22559	10.10041	27.40265	23.49098	29.68111	328.7778	6.158923
Skewness	0.639728	0.805602	-0.743631	0.095514	0.129000	-0.223737	-0.315999	0.339940
Kurtosis	3.478515	2.441031	3.315031	2.311578	2.237755	2.525185	2.720645	3.134033
Jarque-Bera	10.49617	16.35990	13.00045	2.871096	3.642646	2.394457	2.685710	2.701129
Probability	0.005258	0.000280	0.001503	0.237985	0.161812	0.302030	0.261099	0.259094
Sum	3585.000	4504.558	4953.563	9358.540	7884.772	11053.75	132049.0	4332.000
Sum Sq. Dev.	3719.333	72283.35	13670.45	100621.3	73944.71	118049.7	14484710	5082.933
Observations	135	135	135	135	135	135	135	135

Appendix 2: Correlation Matrix

	CLR	DIV2	ACS	DIV3	DIV4	DIV_1	PPL	TR
CLR	1.000000	0.115398	0.070737	0.348156	0.313714	0.493021	0.624792	0.034805
DIV2	0.115398	1.000000	0.264421	0.380267	0.385278	0.161040	0.261753	-0.024139
ACS	0.070737	0.264421	1.000000	0.768440	0.761537	0.654200	0.811903	0.160473
DIV3	0.348156	0.380267	0.768440	1.000000	0.983323	0.658945	0.809664	0.139240
DIV4	0.313714	0.385278	0.761537	0.983323	1.000000	0.669951	0.782565	0.135384
DIV_1	0.493021	0.161040	0.654200	0.658945	0.669951	1.000000	0.789438	0.214672
PPL	0.624792	0.261753	0.811903	0.809664	0.782565	0.789438	1.000000	0.157642
TR	0.034805	-0.024139	0.160473	0.139240	0.135384	0.214672	0.157642	1.000000

Appendix 3: Tobit Results

Tobit regression Number of obs = 135

LR chi2(4) = 15.20

Prob > chi2 = 0.0043

Log likelihood = -65.778224 Pseudo R2 =0.1036

inef	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
ACS	-.0097931	.0065012	-2.76	0.034	-.022654	.0030677
TO	-.003232	.0036869	-0.88	0.382	-.0105256	.0040616
PPL	.000472	.0001713	0.76	0.217	.0001332	.0008109
LD	.2187903	.0872286	2.51	0.013	.0462313	.3913494
_cons	-.3023347	.1941056	-1.56	0.122	-.6863218	.0816525

Appendix 4: DEA Technical Efficiency scores

Results from DEAP Version 2.1

Instruction file = eg2-ins.txt

Data file = eg2-dta.txt

Output orientated Malmquist DEA

DISTANCES SUMMARY

year = 1

firm no.	crs te rel to tech in yr ************************ t-1	t	t+1	vrs te
1	0.000	0.939	1.196	0.963
2	0.000	0.784	1.200	0.792
3	0.000	0.929	1.550	1.000
4	0.000	0.535	1.183	0.540
5	0.000	0.725	0.709	0.732
6	0.000	0.706	0.886	0.739
7	0.000	0.849	1.165	0.860
8	0.000	0.709	1.272	0.736
9	0.000	1.000	1.633	1.000
10	0.000	0.655	1.001	0.717
11	0.000	0.754	1.230	0.754
12	0.000	0.884	1.703	0.894

13	0.000	0.681	0.844	0.689
14	0.000	0.691	1.124	0.696
15	0.000	1.000	2.344	1.000
16	0.000	1.000	1.453	1.000
17	0.000	1.000	2.528	1.000
18	0.000	1.000	1.770	1.000
19	0.000	1.000	1.066	1.000
20	0.000	1.000	2.049	0.659
21	0.000	1.000	1.140	1.000
22	0.000	1.000	0.976	0.567
23	0.000	0.999	0.986	1.000
24	0.000	1.000	1.001	0.897
25	0.000	1.000	0.994	0.789
26	0.000	0.994	1.774	0.567
27	0.000	1.000	1.101	1.000
mean	0.000	0.883	1.329	0.893

year = 2

firm	crs te rel to tech in yr			vrs
no.	************************			te
	t-1	t	t+1	
1	0.920	1.000	0.995	0.915
2	1.309	1.000	1.167	0.956
3	1.000	1.000	1.118	0.730
4	1.384	1.000	1.373	1.000
5	1.558	1.000	1.741	1.000
6	1.942	1.000	1.746	0.781
7	1.251	1.000	1.068	1.000

8	1.121	1.000	1.040	1.000
9	0.705	0.702	0.660	0.723
10	1.153	1.000	1.041	1.000
11	1.352	1.000	1.143	0.874
12	1.387	1.000	1.180	0.786
13	1.311	1.000	1.114	0.612
14	1.608	1.000	1.475	1.000
15	1.081	0.994	1.025	0.956
16	1.325	1.000	1.124	1.000
17	1.488	1.000	1.308	0.912
18	1.114	1.000	1.050	1.000
19	1.139	1.000	1.032	1.000
20	1.115	1.000	1.043	1.000
21	1.430	1.000	1.654	1.000
22	1.496	1.000	1.454	1.000
23	1.226	1.000	1.048	0.732
24	1.199	1.000	1.135	1.000
25	1.523	1.000	1.271	0.987
26	1.068	1.000	1.006	0.964
27	1.174	1.000	1.000	1.000
mean	1.273	0.989	1.185	0.990

year = 3

firm no.	crs te rel to tech in yr ************************ t-1	t	t+1	vrs te
1	1.039	1.000	1.000	0.987
2	1.126	1.000	1.000	0.871

3	1.035	1.000	0.997	0.982
4	1.066	0.998	0.999	0.980
5	1.260	1.000	1.115	1.000
6	1.196	1.000	1.000	1.000
7	1.200	1.000	1.000	0.764
8	1.550	1.000	1.000	1.000
9	1.183	0.995	0.855	1.000
10	0.709	0.747	0.684	0.777
11	0.886	0.778	0.751	0.795
12	1.165	1.000	1.000	0.987
13	1.272	1.000	1.000	1.000
14	1.015	0.998	0.995	1.000
15	1.064	1.000	1.147	1.000
16	1.244	1.000	1.006	1.000
17	1.066	1.000	1.020	1.000
18	1.004	0.998	0.991	1.000
19	1.065	1.000	1.004	1.000
20	1.157	1.000	1.000	0.763
21	1.039	1.000	1.010	1.000
22	1.174	1.000	1.004	1.000
23	1.048	1.000	1.003	1.000
24	1.039	1.000	1.001	1.000
25	1.030	0.998	0.993	0.999
26	1.034	0.998	0.998	1.000
27	1.439	1.000	1.203	1.000
mean	1.115	0.982	0.992	0.984

year = 4

firm crs te rel to tech in yr vrs

no.	************************			te
	t-1	t	t+1	
1	0.999	1.000	1.245	1.000
2	1.124	1.000	1.792	1.000
3	1.001	0.998	1.088	1.000
4	1.186	1.000	2.001	1.000
5	1.313	1.000	2.069	1.000
6	0.512	0.508	0.515	0.509
7	0.756	0.745	0.963	0.773
8	0.951	0.908	1.271	1.000
9	1.197	1.000	1.082	1.000
10	1.007	0.997	1.557	0.997
11	1.003	1.000	1.491	1.000
12	1.009	1.000	0.873	1.000
13	1.103	1.000	1.734	1.000
14	1.001	0.987	1.038	1.000
15	1.957	1.000	1.214	1.000
16	1.160	1.000	1.782	1.000
17	1.000	1.000	1.000	1.000
18	1.000	1.000	1.000	1.000
19	1.000	1.000	1.000	1.000
20	0.995	0.855	0.673	0.954
21	0.747	0.684	0.963	0.736
22	0.778	0.751	0.968	0.755
23	1.000	1.000	1.000	1.000
24	1.000	1.000	1.000	1.000
25	1.000	0.999	1.295	0.999
26	1.323	1.000	2.052	1.000
27	1.048	1.000	1.655	1.000

mean	1.043	0.942	1.271	0.953

year = 5

firm no.	crs te rel to tech in yr ************************ t-1	t	t+1	vrs te
1	0.996	1.000	0.000	1.000
2	0.812	0.728	0.000	0.941
3	1.575	1.000	0.000	1.000
4	1.156	1.000	0.000	1.000
5	1.326	1.000	0.000	1.000
6	0.864	1.000	0.000	1.000
7	1.000	1.000	0.000	1.000
8	1.000	1.000	0.000	1.000
9	1.000	1.000	0.000	1.000
10	0.855	0.673	0.000	0.718
11	0.684	0.963	0.000	0.980
12	0.751	0.968	0.000	0.969
13	1.000	1.000	0.000	1.000
14	1.000	1.000	0.000	1.000
15	1.007	0.694	0.000	1.000
16	0.484	0.472	0.000	0.539
17	2.263	1.000	0.000	1.000
18	2.894	1.000	0.000	1.000
19	0.908	0.976	0.000	1.000
20	0.527	0.732	0.000	0.735
21	0.727	0.946	0.000	1.000
22	0.835	0.908	0.000	0.986
23	0.833	0.893	0.000	1.000

24	0.884	0.962	0.000	0.966
25	0.795	0.841	0.000	0.842
26	0.828	0.848	0.000	0.858
27	0.787	0.925	0.000	1.000
mean	1.029	0.909	0.000	0.946

[Note that t-1 in year 1 and t+1 in the final year are not defined]

MALMQUIST INDEX SUMMARY

year = 2

firm	effch	techch	pech	sech	tfpch
1	1.065	0.850	1.039	1.025	0.905
2	1.276	0.925	1.263	1.010	1.180
3	1.077	0.774	1.000	1.077	0.834
4	1.870	0.791	1.853	1.009	1.479
5	1.379	1.262	1.366	1.009	1.740
6	1.416	1.244	1.353	1.046	1.762
7	1.178	0.955	1.163	1.013	1.125
8	1.411	0.790	1.358	1.039	1.115
9	0.702	0.784	0.723	0.972	0.551
10	1.526	0.869	1.395	1.094	1.326
11	1.327	0.910	1.326	1.001	1.208
12	1.132	0.848	1.118	1.012	0.960
13	1.468	1.028	1.452	1.011	1.510
14	1.447	0.994	1.436	1.007	1.438
15	0.994	0.681	1.000	0.994	0.677

16	1.000	0.955	1.000	1.000	0.955
17	1.000	0.767	1.000	1.000	0.767
18	1.000	0.793	1.000	1.000	0.793
19	1.000	1.033	1.000	1.000	1.033
20	1.000	0.738	1.000	1.000	0.738
21	1.000	1.120	1.000	1.000	1.120
22	1.000	1.238	1.000	1.000	1.238
23	1.001	1.115	1.000	1.001	1.116
24	1.000	1.095	1.000	1.000	1.095
25	1.000	1.238	1.000	1.000	1.238
26	1.006	0.773	1.000	1.006	0.778
27	1.000	1.032	1.000	1.000	1.032
mean	1.135	0.933	1.122	1.012	1.059

year = 3

firm	effch	techch	pech	sech	tfpch
1	1.000	1.022	1.000	1.000	1.022
2	1.000	0.983	1.000	1.000	0.983
3	1.000	0.962	1.000	1.000	0.962
4	0.998	0.882	1.000	0.998	0.880
5	1.000	0.851	1.000	1.000	0.851
6	1.000	0.828	1.000	1.000	0.828
7	1.000	1.060	1.000	1.000	1.060
8	1.000	1.221	1.000	1.000	1.221
9	1.416	1.125	1.384	1.023	1.593
10	0.747	0.955	0.777	0.962	0.713
11	0.778	0.998	0.795	0.979	0.777
12	1.000	0.994	1.000	1.000	0.994

13	1.000	1.069	1.000	1.000	1.069
14	0.998	0.831	1.000	0.998	0.829
15	1.006	1.016	1.000	1.006	1.022
16	1.000	1.052	1.000	1.000	1.052
17	1.000	0.903	1.000	1.000	0.903
18	0.998	0.979	1.000	0.998	0.977
19	1.000	1.016	1.000	1.000	1.016
20	1.000	1.053	1.000	1.000	1.053
21	1.000	0.792	1.000	1.000	0.792
22	1.000	0.899	1.000	1.000	0.899
23	1.000	1.000	1.000	1.000	1.000
24	1.000	0.957	1.000	1.000	0.957
25	0.998	0.901	0.999	0.999	0.899
26	0.998	1.015	1.000	0.998	1.012
27	1.000	1.199	1.000	1.000	1.199
mean	0.993	0.978	0.994	0.998	0.971

year = 4

firm	effch	techch	pech	sech	tfpch
1	1.000	0.999	1.000	1.000	0.999
2	1.000	1.060	1.000	1.000	1.060
3	0.998	1.003	1.000	0.998	1.001
4	1.002	1.088	1.000	1.002	1.091
5	1.000	1.085	1.000	1.000	1.085
6	0.508	1.004	0.509	0.998	0.510
7	0.745	1.008	0.773	0.963	0.750
8	0.908	1.024	1.000	0.908	0.929
9	1.005	1.180	1.000	1.005	1.186

10	1.335	1.050	1.284	1.040	1.402
11	1.285	1.019	1.258	1.021	1.310
12	1.000	1.004	1.000	1.000	1.004
13	1.000	1.050	1.000	1.000	1.050
14	0.989	1.008	1.000	0.989	0.998
15	1.000	1.306	1.000	1.000	1.306
16	1.000	1.074	1.000	1.000	1.074
17	1.000	0.990	1.000	1.000	0.990
18	1.002	1.003	1.000	1.002	1.006
19	1.000	0.998	1.000	1.000	0.998
20	0.855	1.079	0.954	0.896	0.922
21	0.684	1.040	0.736	0.929	0.711
22	0.751	1.016	0.755	0.995	0.763
23	1.000	0.999	1.000	1.000	0.999
24	1.000	0.999	1.000	1.000	0.999
25	1.001	1.003	1.000	1.001	1.004
26	1.002	1.150	1.000	1.002	1.153
27	1.000	0.934	1.000	1.000	0.934
mean	0.951	1.041	0.961	0.990	0.990

year = 5

firm	effch	techch	pech	sech	tfpch
1	1.000	0.894	1.000	1.000	0.894
2	0.728	0.789	0.941	0.774	0.574
3	1.002	1.202	1.000	1.002	1.204
4	1.000	0.760	1.000	1.000	0.760
5	1.000	0.801	1.000	1.000	0.801
6	1.970	0.923	1.965	1.002	1.818

7	1.343	0.879	1.293	1.038	1.181
8	1.101	0.845	1.000	1.101	0.931
9	1.000	0.961	1.000	1.000	0.961
10	0.675	0.902	0.720	0.937	0.609
11	0.964	0.690	0.980	0.983	0.665
12	0.968	0.943	0.969	0.999	0.913
13	1.000	0.759	1.000	1.000	0.759
14	1.013	0.975	1.000	1.013	0.988
15	0.694	1.093	1.000	0.694	0.759
16	0.472	0.759	0.539	0.876	0.358
17	1.000	1.504	1.000	1.000	1.504
18	1.000	1.701	1.000	1.000	1.701
19	0.976	0.965	1.000	0.976	0.942
20	0.856	0.956	0.770	1.111	0.819
21	1.383	0.739	1.358	1.019	1.022
22	1.209	0.845	1.305	0.926	1.021
23	0.893	0.966	1.000	0.893	0.863
24	0.962	0.959	0.966	0.996	0.922
25	0.841	0.854	0.843	0.999	0.719
26	0.848	0.690	0.858	0.988	0.585
27	0.925	0.717	1.000	0.925	0.664
mean	0.962	0.906	0.994	0.968	0.872

MALMQUIST INDEX SUMMARY OF ANNUAL MEANS

year	effch	techch	pech	sech	tfpch
2	1.135	0.933	1.122	1.012	1.059
3	0.993	0.978	0.994	0.998	0.971

4	0.951	1.041	0.961	0.990	0.990
5	0.962	0.906	0.994	0.968	0.872
mean	1.008	0.964	1.016	0.992	0.971

MALMQUIST INDEX SUMMARY OF FIRM MEANS

firm	effch	techch	pech	sech	tfpch
1	1.016	0.939	1.009	1.006	0.953
2	0.982	0.934	1.044	0.940	0.917
3	1.019	0.973	1.000	1.019	0.992
4	1.169	0.872	1.167	1.002	1.019
5	1.084	0.983	1.081	1.002	1.065
6	1.091	0.988	1.079	1.011	1.078
7	1.042	0.973	1.039	1.003	1.014
8	1.090	0.956	1.079	1.010	1.042
9	1.000	1.000	1.000	1.000	1.000
10	1.007	0.942	1.000	1.006	0.948
11	1.063	0.894	1.068	0.996	0.951
12	1.023	0.945	1.020	1.003	0.967
13	1.101	0.968	1.098	1.003	1.065
14	1.097	0.949	1.095	1.002	1.041
15	0.913	0.997	1.000	0.913	0.910
16	0.829	0.951	0.857	0.967	0.788
17	1.000	1.008	1.000	1.000	1.008
18	1.000	1.073	1.000	1.000	1.073
19	0.994	1.003	1.000	0.994	0.997
20	0.925	0.946	0.926	0.999	0.875
21	0.986	0.909	1.000	0.986	0.896

22	0.976	0.988	0.996	0.980	0.965
23	0.972	1.018	1.000	0.972	0.990
24	0.990	1.001	0.991	0.999	0.991
25	0.957	0.989	0.958	1.000	0.947
26	0.961	0.888	0.963	0.998	0.854
27	0.981	0.954	1.000	0.981	0.936
mean	1.008	0.964	1.016	0.992	0.971

[Note that all Malmquist index averages are geometric means]

Appendix 5: Data Used

DMU	Year	DIV 1	DIV 2	DIV 3	DIV 4	TR	PPL	TO	CLR	ACS
Warren park 1	2011	103	30	41	51	30	1034	17	25	41
warren park 3	2011	113	8	45	38	32	1132	21	30	38
Chirodzo	2011	92	28	37	31	25	921	15	41	22
Budiriro1	2011	57	10	23	19	38	574	23	25	23
Budiriro5	2011	29	34	63	38	30	1578	21	39	40
Kuwadzana 2	2011	75	10	54	38	27	1345	19	36	37
kuwadzana 6	2011	101	32	44	36	33	1112	14	28	40
Glen norah A	2011	95	14	38	32	32	951	11	27	35
Kudakwashe	2011	140	46	63	51	27	1578	16	44	36
Glenview 1	2011	102	9	57	43	40	1421	21	36	39
Glenview 3	2011	98	29	39	33	34	978	17	31	32
Avondale	2011	125	10	35	33	38	876	18	25	35
Workington	2011	77	32	48	35	37	1200	16	32	38
Milton park	2011	96	12	41	33	32	1021	22	28	36
Borrowdale	2011	135	39	51	44	42	685	19	22	31
Chisipite	2011	136	8	101	71	35	1345	16	35	38
Helensvale	2011	99	27	35	30	31	467	13	26	18
Greendale	2011	107	20	59	45	24	789	19	34	23
Greystone Park	2011	35	67	92	74	28	1231	32	27	46
Glen Lorne	2011	147	15	74	57	33	987	10	24	41

Philadelphia	2011	77	51	86	56	36	1142	11	25	46
Mufakose	2011	69	13	75	58	32	997	19	29	34
Houghton Park	2011	40	45	66	50	31	879	14	23	38
Mabvuku	2011	30	15	75	52	32	1002	10	27	37
Southerton	2011	47	51	74	57	25	985	16	25	39
Marimba Park	2011	98	17	49	38	38	657	21	23	29
Westwood	2011	55	57	80	63	30	1065	28	32	33
Warren park 1	2012	103	20	93	86	27	1234	26	32	39
warren park 3	2012	88	66	79	73	33	1056	17	28	38
Chirodzo	2012	57	18	51	47	32	678	9	21	32
Budiriro1	2012	82	62	74	68	27	986	12	23	43
Budiriro5	2012	100	25	90	83	40	1200	11	35	34
Kuwadzana 2	2012	112	84	101	93	34	1345	13	40	34
kuwadzana 6	2012	103	15	92	86	38	1232	21	28	44
Glen norah A	2012	66	49	59	55	37	789	20	24	33
Kudakwashe	2012	121	15	109	101	32	1456	37	31	47
Glenview 1	2012	66	49	59	55	42	789	50	30	26
Glenview 3	2012	85	19	77	71	35	1023	26	22	47
Avondale	2012	82	62	74	69	31	987	39	20	49
Workington	2012	121	15	109	101	24	1456	40	26	56
Milton park	2012	66	49	59	55	28	789	28	21	38
Borrowdale	2012	47	25	43	39	33	567	15	22	26
Chisipite	2012	112	84	101	93	36	1345	40	35	38
Helensvale	2012	93	9	83	77	32	1112	20	26	43
Greendale	2012	38	29	34	32	31	457	19	15	30
Greystone Park	2012	65	12	59	54	25	781	44	27	29
Glen Lorne	2012	54	40	48	45	31	643	23	24	27
Philadelphia	2012	103	20	93	86	47	1234	12	25	49
Mufakose	2012	88	66	79	73	20	1056	19	26	41
Houghton Park	2012	84	19	75	70	23	1003	22	23	44
Mabvuku	2012	83	62	75	69	31	995	34	21	47
Southerton	2012	100	12	96	80	27	1200	33	25	48
Marimba Park	2012	57	41	54	45	42	678	21	23	29
Westwood	2012	103	14	99	82	35	1232	41	32	39

Warren park 1	2013	66	47	63	53	31	789	37	25	32
warren park 3	2013	86	12	83	69	24	1034	44	24	43
Chirodzo	2013	56	41	54	45	28	675	55	21	32
Budiriro1	2013	85	18	82	68	33	1023	23	23	44
Budiriro5	2013	82	59	79	66	36	987	21	35	28
Kuwadzana 2	2013	102	22	98	81	32	1221	32	27	45
kuwadzana 6	2013	100	72	96	80	31	1205	21	28	43
Glen norah A	2013	65	24	63	52	25	785	20	19	41
Kudakwashe	2013	112	81	108	90	31	1345	37	31	43
Glenview 1	2013	132	17	126	105	47	1578	50	30	53
Glenview 3	2013	81	58	77	64	20	967	26	22	44
Avondale	2013	54	8	52	43	23	645	39	20	32
Workington	2013	35	25	34	28	31	423	40	26	16
Milton park	2013	47	18	45	38	27	567	28	21	27
Borrowdale	2013	81	59	78	65	36	976	15	22	44
Chisipite	2013	103	19	99	82	34	1234	40	35	35
Helensvale	2013	88	63	84	70	45	1056	20	26	41
Greendale	2013	25	8	24	20	28	300	19	15	20
Greystone Park	2013	38	27	37	30	33	457	44	27	17
Glen Lorne	2013	100	4	96	80	36	1200	23	24	50
Philadelphia	2013	20	15	20	16	32	245	12	25	10
Mufakose	2013	103	14	99	82	31	1232	19	26	47
Houghton Park	2013	66	47	63	53	25	789	22	23	34
Mabvuku	2013	66	14	63	52	31	786	34	21	37
Southerton	2013	65	47	62	52	47	781	33	25	31
Marimba Park	2013	47	22	45	38	20	567	21	23	25
Westwood	2013	104	75	100	83	23	1245	41	32	39
Warren park 1	2014	78	20	75	62	31	934	37	25	37
warren park 3	2014	93	67	89	74	27	1112	44	24	46
Chirodzo	2014	57	21	54	45	36	678	55	21	32
Budiriro1	2014	98	71	94	79	34	1178	23	23	51
Budiriro5	2014	143	22	138	115	45	1721	21	35	49
Kuwadzana 2	2014	103	74	99	82	29	1234	32	27	46
kuwadzana 6	2014	88	18	84	70	35	1056	21	28	38
Glen norah A	2014	84	61	81	67	32	1012	20	19	53

Kudakwashe	2014	71	22	68	57	31	856	37	31	28
Glenview 1	2014	100	72	96	80	34	1204	50	30	40
Glenview 3	2014	83	6	80	67	40	1000	26	22	45
Avondale	2014	29	21	28	23	20	345	39	20	17
Workington	2014	100	10	96	80	23	1205	40	26	46
Milton park	2014	45	33	43	36	31	543	28	21	26
Borrowdale	2014	20	28	19	16	27	234	15	22	11
Chisipite	2014	132	95	126	105	36	1578	40	35	45
Helensvale	2014	45	8	43	36	34	543	20	26	21
Greendale	2014	36	26	34	29	45	431	19	15	29
Greystone Park	2014	62	17	59	49	29	742	44	27	27
Glen Lorne	2014	78	56	75	62	35	934	23	24	39
Philadelphia	2014	20	22	19	16	32	234	12	25	9
Mufakose	2014	103	74	99	82	31	1234	19	26	47
Houghton Park	2014	88	18	84	70	34	1056	22	23	46
Mabvuku	2014	82	59	79	66	40	987	34	21	47
Southerton	2014	82	22	78	65	33	978	33	25	39
Marimba Park	2014	100	72	96	80	26	1200	21	23	52
Westwood	2014	112	22	108	90	27	1345	41	32	42
Warren park 1	2015	103	74	99	82	36	1232	37	28	44
warren park 3	2015	66	14	63	53	27	789	44	24	33
Chirodzo	2015	63	45	60	50	47	756	55	21	36
Budiriro1	2015	64	24	61	51	20	765	23	24	32
Budiriro5	2015	112	81	108	90	23	1345	21	35	38
Kuwadzana 2	2015	132	24	126	105	31	1578	32	33	48
kuwadzana 6	2015	112	81	108	90	27	1345	21	28	48
Glen norah A	2015	83	26	80	66	36	995	20	19	52
Kudakwashe	2015	121	87	116	97	34	1456	37	32	46
Glenview 1	2015	132	14	126	105	45	1578	50	30	53
Glenview 3	2015	64	46	61	51	29	764	26	22	35
Avondale	2015	103	19	99	82	35	1234	39	25	49
Workington	2015	88	63	84	70	32	1056	40	26	41
Milton park	2015	45	4	43	36	31	543	28	21	26
Borrowdale	2015	20	15	20	16	34	245	15	22	11
Chisipite	2015	100	6	96	80	40	1204	40	35	34
Helensvale	2015	29	21	28	23	20	345	20	26	13

Greendale	2015	22	10	11	9	23	267	19	26	10
Greystone Park	2015	93	33	44	37	31	1112	44	33	34
Glen Lorne	2015	94	8	45	38	27	1131	23	31	36
Philadelphia	2015	72	26	35	29	36	864	12	25	35
Mufakose	2015	103	8	50	41	34	1241	19	30	41
Houghton Park	2015	75	27	36	30	45	897	22	23	39
Mabvuku	2015	94	8	45	38	29	1131	34	27	42
Southerton	2015	73	26	35	29	35	874	33	25	35
Marimba Park	2015	83	12	40	33	32	996	21	26	38
Westwood	2015	112	40	54	45	31	1345	41	32	42