ASSESSING TECHNICAL EFFICIENCY OF PROVINCIAL HEALTH AND EDUCATION SECTORS IN SOUTH AFRICA

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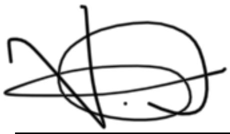

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ABSTRACT

The current population of South Africa is 59 million. However, it is fast-growing, poverty-stricken, unequal and has an unemployment rate approaching 30 per cent. These challenges are further worsened by high migration rates. Moreover, 49 million people (or 83 per cent of the population) rely on the public healthcare system and approximately 12 million or 95 per cent of learners are registered in public schools. In the public education sector, there are teacher shortages in essential learning areas and the ratio of learners to teachers is disproportionate. In the health sector, there is a shortage of medical professionals and the physical condition of many public hospitals are in a dire state. Much of public healthcare infrastructure is run down and dysfunctional due to, underfunding, mismanagement, and neglect. All these factors place the provision of public education and healthcare under extreme pressure.

The education and health sectors are catalysts for human and economic development. Therefore, efficient spending on these sectors contributes to a vibrant, healthy and literate society. As a result, in 2017/18, the nine South African provinces spent 73 per cent of their budgets of R570.3 billion on primary and secondary education (40 per cent) and healthcare (33 per cent). The sectors respectively comprised 7 and 6 per cent of Gross Domestic Product. Despite this, the general quality of outcomes in both sectors is poor and provinces are inefficient in the use of the allocated funds. This warrants a scientific investigation into the technical efficiency of the public education and healthcare systems.

This study uses Data Envelopment Analysis to assess the technical efficiency of the provincial education and health sectors. The methodology is a comparative efficiency benchmarking tool using various inputs to produce multiple outputs to measure the technical efficiency scores of firms operating in homogenous conditions. Within a studied sample, firms with scores of 100 per cent are technically efficient and those with scores lower than 100 per cent are technically inefficient. Therefore, they need input or output improvements to reach the technical efficiency benchmark. The scores that are closer to 100 per cent, show the higher levels of efficiency and the opposite is also true. The study considers six models in each sector, using the 2017/18 learner-to-educator ratio, total education expenditure, health spending and staff as inputs and the reduced infant mortality rate and the number of public secondary schools attaining

the National Senior Certificate results of 60 per cent or greater as outputs. The first three models assume the constant returns to scale while the last three use the variable returns to scale, both with input-minimisation objectives.

In the education sector, the study found the mean pure technical efficiency scores ranging from 46 to 98 per cent between the Education Models 1 and 6; implying a reduction in the use of inputs of between 2 and 54 per cent. The significant efficiency improvements across all the tested models were recorded between Models 3 to 6 (the variable returns to scale models) due to their ability to tightly enclose the studied inputs and outputs. In 2017/18, KwaZulu-Natal, Limpopo and the Northern Cape were respectively the most efficient provinces and others were inefficient. Using the results of the Education Model 6, the study found that the six inefficient provinces had to reduce total education expenditure inefficiency by R24.7 billion and the learner-to-educator ratio by 6 per cent, by appointing additional 9 684 teachers. Therefore, the technically inefficient provinces experienced teacher shortages and used more funding compared to their efficient peers. The potential efficiency gains could be used by the inefficient provinces to appoint and adequately train the required teachers, especially in specialised areas. This could result in small class sizes and improvements in learning outcomes.

As it pertains to the health sector, the study observed the mean pure technical efficiency scores ranging from 36 to 87 per cent between the Health Models 1 and 6. This means a reduction in the use of inputs of between 13 and 64 per cent by all the inefficient provinces; with significant efficiency improvements noted between Models 3 to 6. The Gauteng province was efficient in all the models. The North West Province was second and the other four provinces only performed well under the variable returns to scale. The remaining three provinces were inefficient. The results of the Health Model 6 showed that these three provinces wasted R26.1 million in health spending and had 6 940 excess health staff. Therefore, the inefficient provinces had more employees and used slightly more expenditure than their efficient peers; needing input reductions to improve their efficiency. The potential efficiency gains could be used to appoint and retrain core health professionals. This could also assist to address the significant medical-legal claims for professional negligence, refurbish the existing and build more hospitals to reduce overcrowding.

KEYWORDS

Constant returns to scale, Data envelopment analysis, Decision making unit, Education, Efficiency, Expenditure, Health, Inputs, Outputs, Provinces, Technical efficiency, Variable returns to scale.

LIST OF ACRONYMS AND ABBREVIATIONS

AIDS	Acquired Immunodeficiency Syndrome
BCC	Banker, Charnes and Cooper
BPPGA	Borrowing Powers of Provincial Governments Act
BS	Basic Services Component
C	Correction Component
CCR	Charnes, Cooper and Rhodes
CRS	Constant Returns to Scale
D	Development Component
DEA	Data Envelopment Analysis
DMU	Decision-Making Unit
DRS	Decreasing Returns to Scale
DoRA	Division of Revenue Act
DoRB	Division of Revenue Bill
EU	European Union
FFC	Financial and Fiscal Commission
FDH	Free Disposable Hull
GDP	Gross Domestic Product
HALE	Health Adjusted Life Expectancy
HDI	Human Development Index
HIV	Human Immunodeficiency Virus
I	Institutional Component
IRS	Increasing Returns to Scale
LER	Learner-to-Educator Ratio
LGES	Local Government Equitable Share
MEC	Member of the Executive Council

MFMA	Municipal Finance Management Act
MIG	Municipal Infrastructure Grant
MFPFA	Municipal Fiscal Powers and Functions Act
MPSS	Most Productive Scale Size
MTEF	Medium-Term Expenditure Framework
MDB	Municipal Demarcation Board
NA	National Assembly
NCOP	National Council of Provinces
NHI	National Health Insurance
NSC	National Senior Certificate
NRF	National Revenue Fund
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
PRF	Provincial Revenue Fund
PTRPA	Provincial Tax Regulation Process Act
PSNSC with a pass rate ≥ 60 per cent	Public Secondary Schools with the National Senior Certificate pass rate of 60 per cent or more
PFMA	Public Finance Management Act
RAF	Road Accident Fund
RIMR	Reduced Infant Mortality Rate
RRC	Revenue Raising Correction
SALGA	South African Local Government Association
SFA	Stochastic Frontier Analysis
STI	Sexually Transmitted Infections

TEE	Total Education Expenditure
TFP	Total Factor Productivity
THE	Total Health Expenditure
TOPS	Technically Optimal Production Scale
TOPSIS	Technique for Order Preference by Similarity to The Ideal Solution
TB	Tuberculosis
UHC	Universal Health Care
VRS	Variable Returns to Scale

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CHAPTER 1

INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

In the year 2000, South Africa’s former Minister of Finance, Trevor Manuel (2000) stated the following:

> “Assigning new taxes to provinces does not guarantee greater accountability and efficiency in spending. For this reason, the Budget Council endorsed a gradual approach to extending provincial taxing powers while, in the meantime, allowing provinces to concentrate on improving their spending efficiency.”

This policy is known as the policy of gradualism and is relevant to achieve the intended objectives of this study of assessing and measuring the technical efficiency of provincial education and healthcare sectors in South Africa. In the context of the present study, provinces refer to the second-tier or sphere of government that is described in Chapter 2. Efficiency and technical efficiency are central themes of the research and are discussed in detail in Chapter 3. Briefly, Aristovnik (2011) defines efficiency as the use of minimum inputs to obtain a given level of output. Technical efficiency is defined by Fried et al. (2008) as the comparison of the quality of the actual use of inputs and achieved outputs with scientifically determined best optimum. It simply compares the observed input and output variables with the optimal level of inputs and outputs.

South Africa, is faced with evolving democracy, economic development, population growth and increased service delivery obligations. These and dwindling general government revenue, prompt a discussion on the technical efficiency of government spending. According to Statistics South Africa (2016a), in 2016, 22 years after the enthronement of democracy, the population was 55.6 million. Coupled with a high unemployment rate, high levels of poverty and inequality, the majority of the population relied heavily on public services. Given a very small number of taxpayers as a proportion of the entire population, this puts public institutions under extreme pressure to ensure the efficient usage of public resources. Therefore, the efficient delivery of public services is a prominent issue in the fiscal policy discourse in South Africa.

The National Treasury (2018a), (2018b), (2018c), (2018d), (2018e), (2018g), (2018h), (2018i) and 2018(j) show that, in 2017/18, the actual provincial spending on education and healthcare respectively constituted 40 and 33 per cent of the aggregated provincial budgets of R570.3 billion. Therefore, these are core areas of provincial spending in South Africa. Coovadia et al. (2009), Mayosi and Benatar (2014), Modisaotsile (2012) and Donohue and Bornman (2014) report that, despite the substantial investment in these sectors, health and education outcomes remain poor. Therefore, substantial expenditure on these two sectors is not being matched by good results. This warrants for a scientific evaluation of the technical efficiency of the education and healthcare sectors in South Africa.

1.2 PURPOSE OF THE RESEARCH

The main purpose of the study is to measure and assess the technical efficiency (and by implication the technical inefficiency) levels of provincial education and healthcare sectors and to determine how individual provinces can benchmark against peers to improve their performance.

1.3 PROBLEM STATEMENT

The Presidency of the Republic of South Africa (2009) states that, despite the real substantial financial investment in education and healthcare sectors, the quality of outcomes is deteriorating. The Financial and Fiscal Commission (FFC) (2013a) states that these sectors continued to record the poorest outcomes of all the provincial sector departments. Modisaotsile (2012) and Donohue and Bornman (2014) add that the general quality of public sector education is poor, with many signs of a crisis and increasingly poor Grade 12 or National Senior Certificate (NSC) results. The majority of learners who passed the NSC did not meet the minimum requirements to enrol for a bachelor’s degree. Coovadia et al. (2009) and the Presidency of the Republic of South Africa (2009) report that, South Africa’s Human Immunodeficiency Virus (HIV)/Acquired Immunodeficiency Syndrome (AIDS), tuberculosis (TB), life expectancy, maternal and child mortality rates were worse than in many other countries.

The FFC (2013b) reports that efficient social spending through education and health contributes to the formation of human capital which, in turn, positively contributes to economic growth and development. Therefore, given their importance and budget size, the technical efficiency of the education and healthcare sectors is critical. The Auditor General (2018) states that government cannot afford to continue losing money due to inefficiencies in the provision of education and healthcare services. Therefore, there is an urgent need for interventions to prevent their collapse. Despite the reported inefficiencies in provincial education and healthcare sectors, studies measuring their technical efficiency are very limited. The Health Systems Trust (2016) states that while it is important to improve the technical efficiency of existing resources, there is limited information available for efficiency determination. Given the limited government funding and increasing public education and healthcare expenditure requirements, the use of scientific methods to evaluate their technical efficiency is inevitable and critical in reshaping healthcare policy in South Africa. This study fulfils this purpose.

1.4 RESEARCH OBJECTIVES AND QUESTIONS

The main research questions are based on the problem statement that is outlined in the previous section. Therefore, the study addresses the following research questions: ***What are the prevailing provincial technical efficiency and inefficiency levels in the provision of education and healthcare services in South Africa and how can these be improved?*** The principal objective of this study is to estimate and assess the technical efficiency of provincial education and healthcare sectors in South Africa. This is achieved by determining the relative individual provincial technical efficiency scores for benchmarking and determination of best practices amongst the nine provinces. The secondary objective is to provide suggestions for reforms to provinces and policy makers to ensure that value for money is derived in the delivery of education and healthcare services. The present study uses Data Envelopment Analysis (DEA) to determine the technical efficiency of provincial education and healthcare sectors in South Africa.

1.5 STUDY CONTRIBUTION

Despite the substantial financial investment in the provision of provincial education and healthcare services and widely reported inefficiencies in these sectors in South Africa, there are few international studies that focus on their technical efficiency. The uniqueness of the present study is by filling this research gap in quantifying and assessing the 2017/18 provincial technical efficiency of the education and healthcare sectors. Therefore, this study does not focus on the technical efficiency of the entire public service in South Africa. It only focuses on the technical efficiency of provinces due to the large scale of funding that is dedicated to the provincial education and health sectors and the reported associated inefficiencies.

The existing few technical efficiency determination studies in these sectors involving South Africa were conducted by Kim and Kang (2014), Prasetyo and Zuhdi (2013), Benneyan et al. (2007), Taylor and Harris (2004), Kirigia et al. (2001) and Kirigia et al. (2000). The first three studies only include South Africa as a decision-making unit (DMU) in comparison with other countries. That is, they are cross-country technical efficiency analytical studies rather than inter-provincial benchmarking studies. These studies are not clear in terms of the studied level of government's education and healthcare systems. Therefore, they do not specifically focus on intricate provincial technical efficiency details of the education and health sectors.

The last two studies were conducted in South Africa and they analysed the technical efficiency of public clinics and hospitals only in one province, KwaZulu-Natal. Despite these studies applying the same methodology as the current study, neither of them used expenditure as an input in the production process. They all used non-financial variables. Despite this study not discussing individual schools and hospitals, the provincial technical efficiency results could be good indicators of which provinces have the most efficient or inefficient schools and hospitals. The study by Taylor and Harris (2004) focused on technical efficiency of South African universities. The current study focuses on relative technical efficiency between South African provinces and could present solutions that are implementable domestically; including opportunities for benchmarking amongst the efficient and inefficient provinces. The present study is a maiden technical efficiency analytical research in the field of primary and secondary education at the provincial level. Through the DEA methodology, it could present the exact levels of provincial technical efficiencies and inefficiencies in South Africa, thereby providing recommendations for fiscal policy reforms in the education and health sectors. Due to its individual and inter-provincial focus, the current study could be devoid of the problem of generalising the technical efficiency results as most cross-country studies do, thereby presenting more scope for lessons and reforms.

1.6 RESEARCH METHODOLOGY AND DATA

As reported earlier, the present study uses DEA methodology to determine and analyse the technical efficiency levels of provincial education and healthcare sectors. DEA is a mathematical programming method specially designed to quantitatively estimate the technical efficiency of DMUs that use multiple inputs to produce multiple outputs. It also enables the identification of the most technically efficient and the less technically efficient DMUs. Therefore, DEA can identify targets for improvement and the best practices required to help particular institutions to enhance their overall technical efficiency. It does so, by relating the technical efficiency scores of all the units in the sample to the scores of the most technically efficient units. Thereafter, it shows the relative level of existing inefficiencies in the use of the production technology needed to be addressed to produce a given level of outputs.

For the present study, technical efficiency is determined from an input-minimisation orientation using the constant returns to scale (CRS) and the variable returns to scale (VRS) DEA models. As reflected earlier, the study uses the financial and non-financial variables of the education and health sectors as inputs to determine their technical efficiency. All the physical input (except the education input) and output data are derived from the audited annual reports of the nine provinces for the 2017/18 financial year. The expenditure or financial inputs for both sectors are derived from the 2017/18 provincial expenditure and revenue budget publications of the National Treasury. The Department of Basic Education's publications are used to source the input data of the education sector. Throughout this research, the study samples nine provinces. Based on the technical efficiency literature review, data availability and its appropriateness; the study uses total health expenditure (THE) and total health staff (THS) as inputs of the health production functions while the reduced infant mortality rate (RIMR) is adopted as an output variable. Total education expenditure (TEE) and the learner-to-educator ratio (LER) are used as input variables for the education sector's technical efficiency frontiers. The number of public secondary schools with the NSC pass rate of 60 per cent or more (PSNSC with a pass rate ≥ 60 per cent) is included as an output measure. Based on the review of the literature of technical efficiency, DEA is the most appropriate method to analyse the technical efficiency of the provincial education and health sectors particularly in the context of benchmarking. DEA's assumptions are less restrictive and the methodology captures multiple inputs and outputs. DEA could also provide policy makers with valuable information on determining and improving provincial technical efficiency in the education and health sectors, which is the focus of this research. Therefore, DEA is a conducive tool to achieve the objectives of this study.

1.7 STRUCTURE OF DISSERTATION

Table 1.1: Study outline

Chapter 1: Introduction and background	Chapter 1 is an introductory and background chapter to the entire study. It presents the research problem and the rationale for conducting the study. It details the importance of measuring the technical efficiency of provincial education and healthcare in South Africa. This chapter also outlines the objectives of the study and the relevant non-parametric instrument used to achieve them.
Chapter 2: Fiscal arrangements in South Africa	Chapter 2 presents fiscal arrangements in South Africa. It discusses the relevant fiscal statutes and the structure of intergovernmental relations. The chapter also outlines the structure of government and the manner in which each level of government fits within the fiscal decentralisation landscape.
Chapter 3: Measuring provincial technical efficiency	This chapter presents a comprehensive review of the literature of technical efficiency measurement. It defines different forms of efficiency and presents different parametric and non-parametric technical efficiency analytical tools, with their advantages and disadvantages. This is a very important chapter as it presents information that motivates for the selection of the relevant education and healthcare input and output variables and DEA as an appropriate technical efficiency measurement instrument.
Chapter 4: Methodology	Chapter 4 presents the research methodology. It summarises the context of the study in terms of budget features of the health and education sectors. It presents the CRS and VRS DEA methodologies used to assess the technical efficiency of provinces in South Africa. It basically specifies the appropriate technical efficiency measurement model. It also presents data to be used in the study and the justification for their selection.
Chapter 5: Empirical analysis	This chapter analyses in detail the modelled technical efficiency scores for each province. It presents the in-depth analysis of the technical efficiency results for each DEA model.

Chapter 6: Conclusions and Recommendations	Chapter 6 is the last chapter of the study and provides conclusions based on empirical findings. It formulates policy recommendations from the results and presents the contributions of the study, its limitations and suggestions for areas of future research.

CHAPTER 2

FISCAL ARRANGEMENTS IN SOUTH AFRICA

2.1 INTRODUCTION

This chapter discusses the status of fiscal decentralisation in South Africa and further provides context for the analysis of the technical efficiency of provincial education and health sectors. Fiscal decentralisation refers to the assignment of spending and taxing powers from national government to elected subnational governments (levels below national government). In South Africa, subnational governments refer to provinces and municipalities. Smoke (2015), Bahl (2008), Smoke (2003) and Work (2002) generally agree that expenditure and tax assignment, borrowing powers and intergovernmental transfers are the four pillars of fiscal decentralisation. Fiscal arrangements and powers and functions cannot be understood outside the constitutional and legal frameworks. As a result, Section 2.2 outlines the legislative framework for fiscal decentralisation in South Africa. The four pillars of fiscal decentralisation are discussed in Sections 2.3 and 2.4.

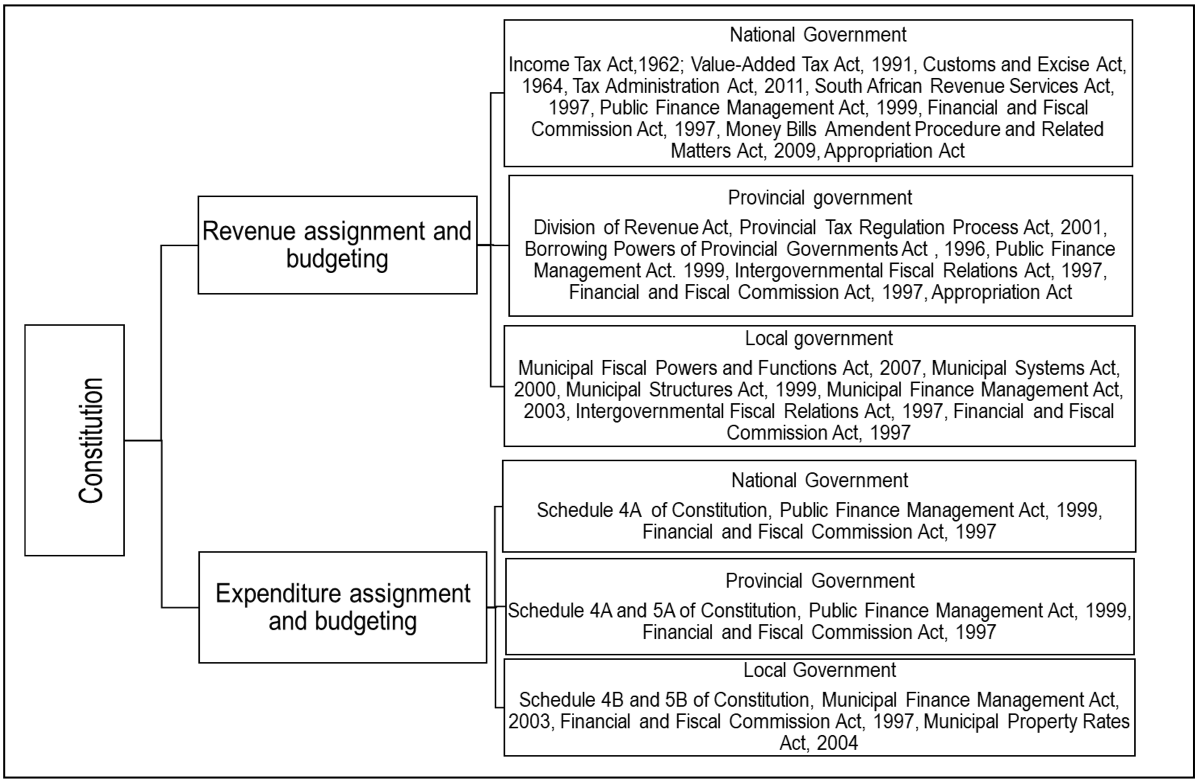
This chapter outlines fiscal decentralisation in the tenure of the democratic government, from 1994 onwards. It does not address the aspects of fiscal decentralisation during the Apartheid[1] era. Despite this, some pre-1994 aspects are discussed where the context and evolution of fiscal decentralisation warrants. For many years, the Apartheid system segregated approximately 89 per cent of the entire population. However, according to Statistics South Africa (2016a), by 2016, the democratic government adopted an all-inclusive approach catering for 55.6 million people. According to the Department of Finance (1996) and National Treasury (2016), this also increased overall public spending from R154.3 billion in 1996 to R1.38 trillion in 2016.

[1]The FFC (2003) defines Apartheid as a system of minority government that racially segregated different racial groups in South Africa.

2.2 CONSTITUTIONAL AND LEGAL FRAMEWORK OF FISCAL DECENTRALISATION IN SOUTH AFRICA

There are many fiscal statutes that are listed in Figure 2.1 facilitating fiscal decentralisation in South Africa. These statutes are given effect by the Constitution of the Republic of South Africa, 1996 (hereinafter "the Constitution"). They assign fiscal powers and functions amongst the spheres (i.e., levels) of government and govern budgetary practices.

Figure 2.1: Constitutional and legislative framework for fiscal decentralisation



Source: Author's diagram.

Section 77 of the Constitution defines Money Bills as national bills that appropriate money, abolish, reduce or exempt the imposition of national taxes, levies, duties or surcharges. They also authorise direct charges against the National Revenue Fund (NRF). Whereas, section 120 deals with provincial Money Bills. They have the same functions as national Money Bills, except that they authorise direct charges against a Provincial Revenue Fund (PRF). Section 1 of the Constitution states that the Republic of South Africa is a unitary[2], sovereign and democratic state which requires cooperative governance amongst all spheres of government. The three spheres (national, provincial and local) are distinctive, inter-dependent and interrelated. Ile (2010), Rao (2003) and Momoniat (2002) mention that the spheres are highly decentralised, with each having its powers and functions but are still expected to consult and cooperate with one another. They are also prohibited by the Constitution from assuming any powers or functions that are not constitutionally assigned to them.

From the perspective of cooperative governance, Boadway and Shah (2009) state that, there are three forms of cooperative governance: inter-dependent, marble-cake and independent spheres. In the case of the first form, the central government determines fiscal policy and subnational governments act as its implementing agents. In the case of the marble-cake approach, spheres of government are treated as equal partners and they share overlapping responsibilities. As it relates to the last form, all levels of government enjoy autonomy and equal status in the coordination of their fiscal policies. When applying these governance approaches to the South African context, it is noted that Sections 40 and 41 of the Constitution commit South Africa to an inter-dependent form of co-operative federalism. The cooperation arrangements amongst the spheres of government in South Africa are regulated by the Intergovernmental Relations Framework Act (Act No.13 of 2005), henceforth the IGRFA, which is an Act that is developed in line with Section 41(2) of the Constitution.

Section 42 of the Constitution recognises Parliament (comprising of the National Assembly and the National Council of Provinces) as the legislative authority of national government. Section 43 of the Constitution lists public consultation and representation, the passing of legislation and executive oversight as the main functions of the National Assembly (NA). Section 42(4) of the Constitution indicates that the National Council of Provinces (NCOP) represents the interests of provincial governments in the NA. Section 163 of the Constitution provides for the establishment of national and provincial government organisations representing the interests of local government. Currently, this role is performed by the South African Local Government Association

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[2] A unitary government is described by Agarwal (2012) as a form of government that has all its powers vested in a single central government with no limitations to its authority. In a unitary setting, subnational governments operate like administrative agencies of the central government through delegation.

(SALGA). Therefore, all the spheres of government are directly or indirectly represented in Parliament. As an ultimate law-making body, Parliament is an important institution for developing and passing statutes, including fiscal statutes. Section 91 of the Constitution states that the Cabinet consists of the President (who is the head of the Cabinet), the Deputy President and portfolio Ministers who form the Executive. The Cabinet drives the service delivery programmes of government within designated sectors. The Cabinet members are given authority by Section 100 of the Constitution to intervene in provincial government administration, in instances of gross failure in service delivery, subject to the approval of the NCOP.

Section 103(1) of the Constitution recognises nine provincial governments. They are the Eastern Cape, Free State, Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga, Northern Cape, North West and Western Cape. The provinces account to the Provincial Legislatures as stated in section 104 of the Constitution. The Provincial Legislatures have legislative powers within provincial boundaries and may assign them to Municipal Councils within their jurisdiction. Section 125(1) of the Constitution vests the executive authority of provinces in a Premier. Section 125(2) of the Constitution states that, together with the Members of the Executive Council (MECs), the Premier implements provincial legislation and all national legislation pertaining to the functions assigned to provinces as listed in Parts A of Schedules 4 and 5 of the Constitution. These schedules are discussed in detail in Section 2.3. The provincial executive is granted powers by Section 139(1) of the Constitution to intervene in municipalities in cases of material failure in service provision, subject to approval by the MEC for local government.

Section 151(1) of the Constitution describes the local sphere of government to consist of municipalities whose legislative authority is vested in Municipal Councils. Municipal Councils have the legislative authority to govern the local affairs of communities, subject to national and provincial government's legislation. This section further states that national and provincial governments may not compromise or impede a municipality's ability or right to exercise its powers or perform its functions. Section 152 of the Constitution lists the objectives of local government, with the most prominent being the sustainable provision of basic services and to promote social and economic development. Section 154 of the Constitution states that in the spirit of cooperative governance, national and provincial governments must, by legislative or other measures, support and strengthen the capacity of municipalities to manage, exercise and perform their powers and functions.

Section 156 of the Constitution requires national legislation to define the different types of municipalities that may exist within categories of municipalities. This legislation is the Local Government: Municipal Structures Act (Act No.117 of 1998). It defines the criteria to determine when an area should have a Category A-metropolitan, B-local and C-district municipalities[3]. Subject to Section 229 of the Constitution, the Municipal Structures Act details the powers and functions of municipalities. It also makes provision for the appropriate division of powers and functions between local and district municipalities within the same area. The same clause of the Constitution mandates a national statute to establish criteria and procedures to determine municipal boundaries by an independent authority, the Municipal Demarcation Board (MDB). The said statute is the Local Government: Municipal Demarcation Act (Act No.27 of 1998). Rao (2003) reports that, before 1994, there were many municipalities that were reorganised into 843 transitional municipalities in terms of the Local Government Transition Act (Act No.209 of 1993). The FFC (2003) mentions that, following the restructuring of local government in 2000, South Africa had 284 municipalities. In 2011, another restructuring occurred, resulting in 278 municipalities. Gordhan (2016) states that the 2016 municipal demarcation process resulted in a further reduction in the number of municipalities to 257 (eight metropolitan municipalities, 205 local municipalities and 44 district municipalities). Section 156(1) of the Constitution states that a municipality has the executive authority in respect of the administration of local government matters, that are listed in Parts B of Schedules 4 and 5 of the Constitution. These schedules are discussed in detail in Section 2.3. Section 156(4) of the Constitution mentions that national and provincial governments may assign to capacitated municipalities, by agreement, the administration of national or provincial government legislative authority relating to local government.

[3] Section 155(1) of the Constitution defines a Category A municipality as having an exclusive municipal executive and legislative authority in its area. It further defines a Category B municipality as sharing executive and legislative authority in its area with a Category C municipality within whose authority it falls. A Category C municipality is reported to have municipal and executive authority in an area that includes more than one municipality.

2.3 OVERVIEW OF NATIONAL, PROVINCIAL AND MUNICIPAL REVENUE BUDGETS

2.3.1 Intergovernmental fiscal institutions and revenue instruments

Chapter 13 of the Constitution outlines South Africa's budgetary framework. Section 213(1) of the Constitution states that the NRF is used to deposit all financial receipts of national government. The NRF is commonly referred to as the *fiscus*. Section 213(2) of the Constitution maintains that public funds may only be withdrawn from the NRF in terms of an appropriation by an Act of Parliament or as a direct charge against the NRF. The said Act of Parliament is the Appropriation Act (Money Bill). The national Appropriation Act only appropriates funds to national departments. Provinces are appropriated funds through the Provincial Appropriation Acts and together with the municipalities through the Division of Revenue Act[4] (DoRA). Section 214 of the Constitution regulates the equitable sharing of nationally-raised revenue amongst the three spheres of government. Another important fiscal law that is linked to the DoRA is the Intergovernmental Fiscal Relations Act[5] (Act No.97 of 1997). The purpose of this statute is to promote cooperation between the three spheres on fiscal, budgetary and financial matters. The revenue-sharing process in South Africa is enshrined in Section 214 of the Constitution and associated legislation listed in Figure 2.1.

Section 215(1) of the Constitution provides the legal basis for budgets of the three spheres of government. It requires their budgetary processes to promote transparency, accountability and effective financial management in the public sector. Section 215(2) of the Constitution requires national legislation to prescribe the budget

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[4] Section 214(1) of the Constitution states that an Act of Parliament must (i) provide for the equitable division of the nationally-raised revenue amongst national, provincial and local government, (ii) determine each provincial government's equitable share of the total share of that revenue to provincial governments and (iii) other allocations to provincial and local government from national government's share of that revenue and impose any conditions on which those allocations can be made. That is, this Act must outline the vertical division of revenue amongst the three spheres of government and the horizontal division of revenue amongst provincial governments themselves and amongst municipalities. Section 214(2) of the Constitution adds that the DoRA may be enacted only after provincial governments, organised local government and the FFC have been consulted, and any recommendations of the FFC have been considered.

[5] The IGFRA (1997) prescribes the process for determining the equitable shares and other allocations from nationally generated revenue. Sections 5 and 6 of this Act establish two important forums, the Budget Council and Budget Forum. The former serves as a consultation platform between national and provincial governments on mutual budget-related matters. The latter mandates similar engagements between national and local government. The other key aspects of this legislation are stipulated in Sections 9 and 10 of the Act, which set out the revenue-sharing process in South Africa amongst the three spheres of government as well as conditional grants that are assigned to them.

formats of the spheres of government. Section 215(3) of the Constitution requires their budgets to contain the estimates of revenue and expenditure, deficit financing proposals and borrowing implications. The said legislation is the Public Finance Management Act (Act No.29 of 1999, henceforth the PFMA). The PFMA only applies to provinces, national government and their entities. The equivalent of the PFMA at a local government level is the Local Government: Municipal Finance Management Act (Act No.56 of 2003, henceforth the MFMA).

There are two important institutions that are established by the Constitution to play prominent roles in budgetary matters in South Africa, the National Treasury and the FFC. Section 216 of the Constitution mandates the PFMA to establish the National Treasury to manage the budget of the country. Section 6 of the PFMA lists the functions of the National Treasury, most notably the formulation and management of fiscal policy, including the facilitation of the DoRA. Section 220(1) of the Constitution gives legal effect to the FFC whose role is to make recommendations on general fiscal matters. The Constitution recognises the FFC as an independent and impartial fiscal institution that is only subject to the Constitution and the rule of law and, whose operations are regulated by the Financial and Fiscal Commission Act[6] (Act No.99 of 1997). A critical role of the FFC is to make fiscal recommendations on the annual Division of Revenue Bill (DoRB) before it is enacted into the DoRA. Wehner (2003) maintains that the FFC was created by the drafters of the Constitution to guide the revenue-sharing[7] process in South Africa. Rao (2003) reports the objective of the FFC as to contribute to the creation and maintenance of effective, equitable, and

[6] The purpose of the FFC Act is to give effect to the constitutional requirements of the FFC. Section 3(1) of the FFC Act states that the Commission acts as a consultative body which makes recommendations and provides advice to organs of state in national, provincial and local spheres of government on financial and fiscal matters. Furthermore, Section 3(2) of the FFC Act states that the FFC may perform the functions stated above by its own volition or on request by an organ of state. The FFC must be consulted on all matters pertaining to the alteration of fiscal powers and functions of spheres of government and it must reply within 180 days upon the receipt of the request or notification. There should be proof that the recommendations of the FFC have been considered, otherwise the amendments to fiscal powers and functions have no legal effect. If the FFC does not respond to fiscal requests, the affected parties after consultation with the National Treasury may proceed with their plans. Section 3(2)(6) of the FFC Act legislates that the FFC must submit for tabling copies of all its recommendations made in terms of a provision of the Constitution to both Houses of Parliament and to the provincial legislatures.

[7] Revenue-sharing is defined by Martinez-Vazquez (2008) as a method where provincial and local governments are given a predetermined share of revenue that is generated from a given national tax base. In this case, provinces and local governments are not assigned any of aspects of the national tax. The central government determines the tax base and rate structure (tax policy) and by implication also administers the tax. Under revenue-sharing schemes, provincial and local governments do not have a direct role in the rate structure and administration of taxes as they do under tax-sharing schemes, therefore, revenue-sharing could be considered just as another form of transfers.

sustainable system of intergovernmental fiscal relations. The FFC Act requires effort to be made by the initiators of any fiscal reforms or amendments to the fiscal framework to incorporate the FFC's recommendations. The FFC's recommendations are not legally binding, but, since they are tabled in legislatures, it is normative to consider them in fiscal legislative processes.

The revenue of the three spheres of government is summarised in Table 2.1. It is observed that, of the consolidated government revenue of R1.5 trillion in 2017/18, the national, provincial and local governments shares were respectively, 80, 1 and 19 per cent. The FFC (2003) states that, in line with the Constitution, all taxes with broad bases, such as income, corporate and value-added taxes are assigned to national government. The primary legislation that is used for the administration of income taxes in South Africa is the Income Tax Act (Act No.58 of 1962)[8]. The value-added tax is administered through the Value-Added Tax Act (Act No.89 of 1991). This Act provides for taxation on the supply of goods and services and on the importation of goods. Taxes on international trade and other taxes with macroeconomic implications are imposed in terms of the Customs and Excise Act (Act No.91 of 1964)[9]. All these statutes are Money Bills. Simeon and Murray (2001) claim that the monopolisation of all the major sources of revenue by national government, grants it a lion's share of overall tax revenue as compared to provinces and municipalities.

The National Treasury (2019) reports that, for 2017/18, taxes on income and profits made up 57 per cent of total national government revenue. 39 per cent was attributed to personal income tax and corporate income tax accounted for 18 per cent. Domestic taxes on goods and services[10] were collectively the second largest tax revenue budget items. These taxes collectively contributed to 35 per cent of total national government

[8] The Income Tax Act (1962) aims to consolidate the law relating to the taxation of incomes and donations. It also provides for the recovery of taxes on persons and for deduction of their tax liabilities by employers. It also deals with payments into the NRF of portions of normal income taxes, interest and other charges.

[9] The Customs and Excise Act (1964) provides for levying of customs and excise duties, surcharge, fuel levies, Road Accident Fund (RAF) levies, air passenger taxes and environmental levies. It also provides for the prohibition and control of importation, exportation, manufacturing or use of certain goods.

[10] The National Treasury (2019) state that taxes on goods and services include value-added tax, excise duties, general fuel levy, electricity levy and other taxes like the plastic bag levy.

tax revenue, of which 25 per cent was the value-added tax. The general fuel levy was 6 per cent while other indirect taxes made up the remainder.

Table 2.1: Consolidated government revenue

Level of government	2017/18	% of total revenue
National government	1 196 399 000	80%
Provincial governments	19 513 093	1%
Local government	278 550 383	19%
Total	1 494 462 476	100%

Sources: Author's table based on National Treasury (2019), National Treasury (2018k), (2018l). Notes: All figures except percentages are in R'000. Provincial and municipal revenue exclude all forms of grants.

In terms of provincial revenue, Section 226(1) of the Constitution states that, all provincial receipts are deposited into a PRF for each province. As with the NRF, monies from the PRF may only be withdrawn by a Provincial Appropriation Act (Money Bill). Moreover, in terms of section 226(3) of the Constitution, revenue allocated by provinces to local governments within their jurisdiction in terms of Section 214(1) of the Constitution is a direct charge against the PRF. Provincial taxing powers are regulated by the Provincial Tax Regulation Process Act (Act No.53 of 2001) (PTRPA). Section 228(1)(a) of the Constitution allows provincial legislatures to impose taxes other than income, value-added, general sales, property and custom taxes. These taxes have already been assigned to national government, with the exception of property rates which are an exclusive competence of local government. Section 228(1)(b) of the Constitution allows provinces to impose a flat-rate surcharge on tax bases of any taxes, levies or duties imposed by national legislation.

Section 230(1) of the Constitution establishes the Borrowing Powers of Provincial Governments Act (Act No.48 of 1996) (BPPGA), to allow provinces to raise operational and capital loans. The BPPGA imposes fiscal rules for provincial borrowing, such as conditions for financial disclosure and prohibition of loan repayment guarantees to provinces for short-term borrowing or on loan agreements denominated in foreign currency. Despite having borrowing powers, provinces rarely use them as they are largely funded through intergovernmental grants. As a result, provincial borrowing is virtually non-existent.

Josie et al. (2006) report that provincial own revenue is categorised into tax and non-tax receipts[11]. The splits of provincial own revenue for 2017/18 were not readily available. However, National Treasury (2014) states that, in 2013/14, 65 per cent of total provincial revenue was attributed to tax receipts. Motor vehicle licences were the largest own-tax revenue budget item at 50 per cent for the same year, followed by casino taxes at 13 per cent. Horse racing taxes and liquor licences made up 2 per cent. The non-tax receipts were 36 per cent of provincial own revenue. The sales of goods and services was 20 per cent of non-tax receipts, with dividends and interest on land and financial transactions at 8 and 5 per cent respectively. Table 2.2 shows that provinces with large urban conurbation, such as Gauteng, KwaZulu-Natal and the Western Cape are able to generate sizable own revenue amounts compared to other provinces. Their consolidated revenue accounted for 64 per cent of total provincial own revenue. The other six predominantly rural provinces generate minimal amounts, ranging between 2 and 9 per cent.

Table 2.2: Provincial own revenue

Province	2017/18	% of total own revenue	% of population
Eastern Cape	1 713 346	9%	13%
Free State	1 062 377	5%	5%
Gauteng	6 087 032	31%	24%
KwaZulu-Natal	3 322 246	17%	20%
Limpopo	1 308 253	7%	10%
Mpumalanga	1 328 475	7%	8%
Northern Cape	351 801	2%	2%
North West	1 228 797	6%	7%
Western Cape	3 110 766	16%	11%
Total	19 513 093	100%	100%

Sources: National Treasury (2018k) and Statistics South Africa Census (2011). Notes: All figures except percentages are in R'000. Provincial and municipal revenue exclude grants.

[11] Josie et al. (2006) state that tax-receipts are derived mainly from taxes or levies on motor vehicle licences and gambling (casino licences and horse racing fees). On the other hand, non-tax revenue is derived from the sales of non-capital goods and services (such as hospital and patient fees), interest income and from other various insignificant fees, penalties and fines.

For municipalities, Sections 229(1)(a) and 229(1)(b) of the Constitution allow them to impose rates on property and surcharges on charges for municipal services. The Municipal Fiscal Powers and Function Act (Act No.12 of 2007) (MFPFA), authorises municipalities to impose other taxes that are appropriate for local government. However, municipalities are prohibited from imposing income, value-added, general sales and custom taxes. Most municipalities rely on user charges for operational sustainability. The National Treasury (2011) states that, the fiscal framework was deliberately designed to strike a balance between municipal revenue and customer's service delivery interests to enhance accountability. Municipal service charges are set in terms of the Local Government: Municipal Systems Act (Act No.32 of 2000) which also provides the framework for effective administration of municipalities. Table 2.1 depicts that, in 2017/18, municipal own revenue was 19 per cent of consolidated government revenue. This was largely comprised of revenue generated from electricity, water, sanitation and refuse removal charges.

Table 2.3: Municipal own revenue

Revenue source	2017/18	% of own-revenue
Property rates	60 286 864	22%
Electricity	114 250 485	41%
Water and sanitation	53 048 248	19%
Refuse	10 974 008	4%
Other revenue	39 990 778	14%
Total	278 550 383	100%

Source: National Treasury (2018k). Notes: All figures except percentages are in R'000. Municipal own-revenue, exclude all forms of grants.

Table 2.3 indicates that service charges and property rates collectively accounted for 86 per cent of total municipal own revenue in 2017/18. The electricity service charges were a dominant contributor followed by the water and sanitation charges and other miscellaneous revenue items. Therefore, municipalities who do not run their electricity and water and sanitation businesses efficiently are likely to generate low levels of own revenue, leading to poor service delivery. In terms of municipal borrowing, Section 230A(1)(a) of the Constitution allows municipalities to raise capital and operational loans; in accordance with national legislation-the MFMA. In terms of borrowing rules, the same principles that are applicable to provinces are also applicable to municipalities. Section 50 of the MFMA does not allow municipalities to issue any guarantees for any commitments, unless such guarantees are for municipal entities and are within the limits set in the approved municipal budgets. Section 51 of the MFMA prohibits national and provincial governments from guaranteeing any municipal borrowing. That is, there is no “bail-out” policy for municipal debt in South Africa.

Chitiga-Mabugu and Monkam (2013) submit that, in contrast to provincial borrowing, municipal borrowing levels differ markedly amongst municipalities in South Africa. This is due to different municipalities having varying revenue generation and debt repayment capacities. The National Treasury (2018k) states that, in 2018, of the 257 municipalities, 110 had no loans. Momoniat (2002) states that municipalities traditionally borrowed to finance capital infrastructure. However, given the poor state of local government finances in recent times; long-term borrowing has significantly decreased. Additionally, the National Treasury (2011) maintains that, due to national government not providing any guarantees for municipal borrowing, municipalities are compelled to borrow on the strength of their balance sheets. Therefore, their capacity to borrow is a function of sound and prudent financial management. The National Treasury (2018k) further reports that by the end of the 2017/18 municipal financial year (end June 2018), the total municipal borrowing balance was R62.5 billion. This included long-term loans of R43.6 billion and long-term marketable bonds of R18.6 billion.

2.3.2 Intergovernmental transfers

Blochlinger and Charbit (2008) define intergovernmental transfers as the transfer of national revenue to subnational governments to offset differences in their fiscal capacity and to subsidise service provision. Ebel and Yilmaz (2002) define horizontal equity as the extent to which subnational governments have the capacity to deliver an equivalent level of services. Therefore, where horizontal equity is not achieved, horizontal fiscal imbalance[12] exists (HFI). Equity also focuses on intergovernmental redistribution and equalisation between the different levels of government to enable them to meet their obligations. This is termed vertical equity. So, where vertical equity does not exist, there is vertical fiscal imbalance[13] (VFI).

Section 227(1)(a) of the Constitution states that each province is entitled to an equitable share of nationally raised revenue to enable the provision of basic services, such as education, health and social development. Schedule 2 of the annual DoRA outlines the horizontal division of the provincial equitable share grant; this is summarised in Table 2.4. Due to the high degree of autonomy the provincial equitable share gives to provinces, it is often considered part of provincial own revenue. The National Treasury (2014) explains that the equitable share is largely determined by regional demographics and is redistributive towards poorer provinces with large populations. In 2017/18; 97 per cent of provincial revenue was generated from intergovernmental transfers and 3 per cent from provincial own revenue. The majority of this revenue was derived from the unconditional provincial equitable share grant. This grant had an average contribution of 80 per cent to total provincial own revenue budgets. This implies that 17 per cent was related to conditional grants.

Table 2.4 shows that, the top five provinces receiving the majority of the equitable share allocations had a large population. These provinces accounted for 78 per cent

[12] Bahl and Bird (2008) define HFI as a phenomenon that arises when tax base endowments of different provincial and local governments vary, resulting in different levels of revenue being raised by these governments. *De facto*, wealthier regions would raise more revenue from their tax bases than their poorer counterparts, triggering fiscal equalisation.

[13] Blochlinger and Charbit (2008) define VFI as the difference between own tax revenue and expenditure of provincial or local governments. It is the fiscal gap that exists after the process of expenditure and tax assignment and before any fiscal equalisation is made. Bahl and Bird (2008) says that VFI is inherently embedded in the fact that most taxes with broad bases are assigned to the central governments in excess of their expenditure responsibilities, while residual tax instruments with narrow tax bases are assigned to provincial and local governments short of their expenditure responsibilities.

of the entire population and they received 77 per cent of the total equitable share allocations in 2017/18. The National Treasury (2014) explains that the provincial equitable share consists of six components. The education component is 48 per cent of the total equitable share allocation while the health component is 27 per cent. That is, 75 per cent of the provincial equitable share is directed towards the funding of these two key priorities of government. The basic component is 16 per cent and is derived from each province's proportion of the national population. The fourth is the institutional component (5 per cent); it contributes towards the defrayment of operational costs associated with administrative aspects of running provinces. The fifth component is the poverty component; it is 3 per cent of the equitable share and it provides a redistributive element to poorer provinces (falling into the lowest 40 per cent of household incomes). The last element is the economic activity component; a proxy of provincial government's tax capacity. It is the smallest of all the components at 1 per cent.

Table 2.4: Horizontal division of provincial equitable shares

Province	2017/18	% of total equitable share	% of population
Eastern Cape	61 969 363	14%	13%
Free State	24 590 994	6%	5%
Gauteng	86 412 496	20%	24%
KwaZulu-Natal	94 051 218	21%	20%
Limpopo	52 086 555	12%	10%
Mpumalanga	36 207 867	8%	8%
Northern Cape	11 733 117	3%	7%
North West	30 361 426	7%	2%
Western Cape	44 418 086	10%	11%
Total	441 831 122	100%	100%

Sources: Division of Revenue Act (2018) and Statistic South Africa (2011). Notes: All numbers except percentages are in R'000. Percentages might not add up due to rounding.

The FFC (2010) reports that, conditional grants were introduced in the 1998/99 financial year to standardise countrywide service provision and to achieve national policy objectives. They also provide funding to eradicate economic and social infrastructure backlogs. They enable the recipients to address spillovers resulting from the provision of certain service. Section 227(1)(b) of the Constitution states that local and provincial governments may conditionally or unconditionally receive other allocations from national government's revenue. In South Africa, conditional grants are classified into direct and indirect. The former are direct allocations to provinces and municipalities. The latter refers to allocations that are controlled by national government and are not directly allocated to the recipients. However, indirect grants are still spent on provincial and municipal functions with national spillovers.

The 2018 DoRA shows that provincial conditional grants are divided into Schedule 4A, 5A and 6A. The schedule 4A grants are allocations to provinces to supplement the funding of functions funded largely from provincial own revenue. The Schedule 5A DoRA grants are allocated to provinces for specific purposes. The Schedule 6A grants are special allocations to provinces for special or dedicated programmes. Table 2.5 shows that nine sectors received all these grants in 2017/18. These grants amounted to R100.8 billion in the same year. The health sector received 39 per cent, followed by education and human settlements sectors at 20 per cent each. The transport sector comprised 16 per cent of these allocations. Collectively, these four sectors accounted for 95 per cent of all conditional grants to provinces. The human settlements grant was the single largest conditional allocation to the provinces.

Table 2.5: Provincial conditional grants

Grants	2017/18	% of total Schedule 4A, 5A and 6A DoRA grants
Agriculture, Forestry and Fisheries	**2 240 689**	**2%**
of which the Comprehensive Agricultural Support Programme Grant (5A)	1 645 946	2%
Programme Grant: Poverty Relief and Infrastructure Development	594 743	1%
Arts and Culture	**1 419 960**	**1%**
of which the Community Library Services Grant (5A)	1 419 960	1%
Basic Education	**19 749 026**	**20%**
of which the Education Infrastructure Grant (4A)	*10 045 562*	10%
of which the National School Nutrition Grant (5A)	*6 426 313*	6%
the Learners with Profound Intellectual Disabilities Grant (5A)	*317 308*	0%
of which the Maths, Science and Technology Grant (5A)	*365 145*	0%
of which the School Infrastructure Backlogs Grant (6A)	*2 594 698*	3%
Health	**39 183 429**	**39%**
of which the Comprehensive HIV,AIDS and TB Grant (5A)	*17 557 903*	17%
of which the National Tertiary Services Grant (4A)	*11 676 145*	12%
of which the Health Professions Training and Development Grant (4A)	*2 631 849*	3%
of which the Health Facility Revitalisation Grant (5A)	*5 654 495*	6%
of which the National Health Insurance Indirect Grant (6A)	*1 663 037*	2%
Human Settlements	**19 969 343**	**20%**
of which the Human Settlements Development Grant (5A)	*19 969 343*	20%
Public Works	**781 162**	**1%**
of which the Social Sector Expanded Public Works Programme Incentive Grant for Provinces(5A)	*385 583*	0%
of which the Expanded Public Works Programme Integrated Grant for Provinces(5A)	*395 579*	0%
Transport	**16 296 535**	**16%**
of which the Provincial Roads Maintenance Grant (4A)	*10 573 664*	10%
of which the Public Transport Operations Grant (4A)	*5 722 871*	6%
Social development	**556 392**	**1%**
of which the Social Worker Employment Grant (4A)	*181 830*	0%
of which the Early Childhood Development Grant (5A)	*317 612*	0%
of which Substance Abuse Treatment Grant (5A)	*56 950*	0%
Sports and Recreation	***585 828***	**1%**
of which the Mass Participation and Sport Development Grant (5A)	*585 828*	1%
Total Schedule 4A, 5A and 6A provincial grants	**100 782 364**	**100%**

Source: Division of Revenue Act (2018). Note: all figures except percentages are in R'000.

In respect of local government grants, the local government equitable share (LGES) is the largest component of municipal operational revenue (not total revenue). The FFC (2010) states that it provides budgetary support to municipalities with no strings attached. The LGES aims to augment municipal own revenue for the provision of basic services. However, it grants the recipient municipalities the discretion to allocate funds amongst their expenditure priorities. Schedule 3 of the annual DoRA outlines the individual equitable share allocations to all municipalities. The DoRA (2018) shows that, in 2017/18, the LGES allocation was R57 billion. This was 17 per cent of total municipal own revenue in the same year. The FFC (2010) reports that the majority of the LGES was directed towards the provision of basic services and other operational support functions. The LGES allocations are guaranteed 100 per cent in the first year of the Medium-Term Expenditure Framework (MTEF), 90 per cent in the middle year and are not guaranteed in the third year.

The municipal conditional grants are also divided into direct and indirect allocations and are listed respectively in Schedules 5B and 6B of the DoRA each year. Schedule 5B grants are direct grants to municipalities, they link with municipal expenditure assignments that are contained in Part B of Schedules 4 and 5 of the Constitution. As reflected in Table 2.6, direct conditional grants are the largest form of conditional grants to local government. They amounted to R30.1 billion in 2017/18 while indirect conditional grants amounted to R7.3 billion. The Municipal Infrastructure Grant (MIG) was the single largest direct municipal conditional grant allocation, amounting to 53 per cent of all direct grants. The MIG provides funding for municipal infrastructure to extend access to water and sanitation to poor households.

Table 2.6: Municipal conditional grants

Municipal conditional grants	2017/18	% of total
Direct conditional grants		
Municipal Infrastructure Grant	15 891 252	53%
Public Transport Infrastructure Grant	6 159 599	20%
Integrated National Electrification Programme	2 087 048	7%
Water services infrastructure Grant	3 329 464	11%
Regional Bulk Infrastructure Grant	1 865 000	6%
Other direct grants	770 659	3%
Total direct	30 103 022	100%
Indirect conditional grants		
Regional Bulk Infrastructure Grant	2 773 539	38%
Water Services Infrastructure Grant	587 122	8%
Integrated National Electrification Programme (Eskom)	3 846 154	52%
Other indirect grants	130 993	2%
Total indirect grants	7 337 808	100%

Source: Division of Revenue Act (2018). Note: all figures except percentages are in R'000.

2.4 EXPENDITURE ASSIGNMENT

As reported earlier, Part A of Schedule 4 of the Constitution outlines the concurrent functions of national and provincial governments. This means that South Africa also follows the marble-cake approach of cooperative federalism that was defined in Chapter 1. There is a list of 32 concurrent functions that are contained in Part A of Schedule 4 of the Constitution (Annexure 1). The concurrent functions include agriculture, education, health, housing and public transport. They also include welfare services, casinos, racing, gambling, road traffic regulation and vehicle licencing services. On the other hand, the Constitution explicitly separates some exclusive national functions within the ambit of concurrent functions. For example, the functional areas of education are shared, except tertiary education, as it is a sole competency of national government. From the concurrent functions that are in Part A of Schedule 4 of the Constitution, all functions that are excluded from the concurrency list are *de facto* functions of exclusive national competence. These include higher education, national defence, parks, botanical gardens and marine resources. National policing, transportation, public works, roads, foreign and home affairs are also of functional areas of national competence. The other exclusive national government functions are national libraries, museums, archiving systems and regulation of veterinary services. In the last column on Annexure 1, this study lists 18 functions that are exclusive national functions.

Part A of Schedule 5 of the Constitution lists functional areas of exclusive provincial legislative competence. They include abattoirs, ambulance services, archives, libraries and liquor licences. Provincial museums, sport and recreation amenities, roads and traffic, veterinary services, planning and cultural matters also fall into this category. The roads and traffic function is a major function of exclusive provincial competence. The other major service delivery related functions with huge budgets are education and healthcare, however, they are concurrent functions.

As it pertains to municipal functional areas, there are no concurrent functions that are listed in the Constitution. Overall, the extent of expenditure decentralisation in South Africa is determined by the share of provincial and local governments' expenditure as a proportion of the aggregated government expenditure. Table 2.7 shows that provinces and municipalities accounted for 55 per cent of total government expenditure in 2017/18. It is clear that, within the context of fiscal decentralisation, the target area where huge potential efficiency gains could be realised is on the provincial expenditure side. However, this should not be interpreted that national government and municipalities do not have inefficiencies.

Table 2.7: 2017/18 consolidated spending

Sphere	Expenditure	% of total
National	781 536 602	45%
Provinces	570 358 442	33%
Local	373 781 072	22%
Total	1 725 676 116	100%

Sources: National Treasury (2018a), (2018b), (2018c), (2018d), (2018e), (2018g), (2018h), (2018i), (2018j), (2018k) (2018l). Notes: Expenditure is in R'000. The consolidated expenditure excludes all direct charges against the NRF. The subnational government expenditure includes, provincial and municipal own revenue and intergovernmental transfers.

2.4.1 National government spending

In 2017/18, national government spent a total of R781.5 billion. Table 2.8 shows the top 14 departments with expenditure of R10 billion and above. These departments' expenditure amounted to 89 per cent of total national government's expenditure. Social development comprised 21 per cent, while spending on national healthcare, basic and tertiary education collectively accounted for 14 per cent. 34 per cent was shared amongst the police, transport, cooperative governance and traditional affairs and the defence and military veteran's departments. The remaining 26 departments recorded expenditure of less than R10 billion or 11 per cent of the entire national government expenditure in 2017/18.

Table 2.8: National expenditure by department

Expenditure	2017/18	% of total expenditure
Cooperative Governance and Traditional Affairs	78 463 890	10%
Basic Education	22 993 620	3%
Correctional Services	22 814 593	3%
Defence and Military Veterans	48 999 560	6%
Health	42 645 557	5%
Higher Education and Training	52 307 639	7%
Human Settlements	33 477 701	4%
Justice and Constitutional Development	16 786 788	2%
National Treasury	40 484 306	5%
Police	86 761 128	11%
Rural Development and Land Reform	10 184 240	1%
Social Development	160 357 768	21%
Transport	59 795 180	8%
Water and Sanitation	15 607 449	2%
Other departments	89 857 183	11%
Total	781 536 602	100%

Sources: National Treasury (2018m). Notes: all figures, except percentages are in R'000. Percentages might not add up due to rounding.

2.4.2 Provincial expenditure

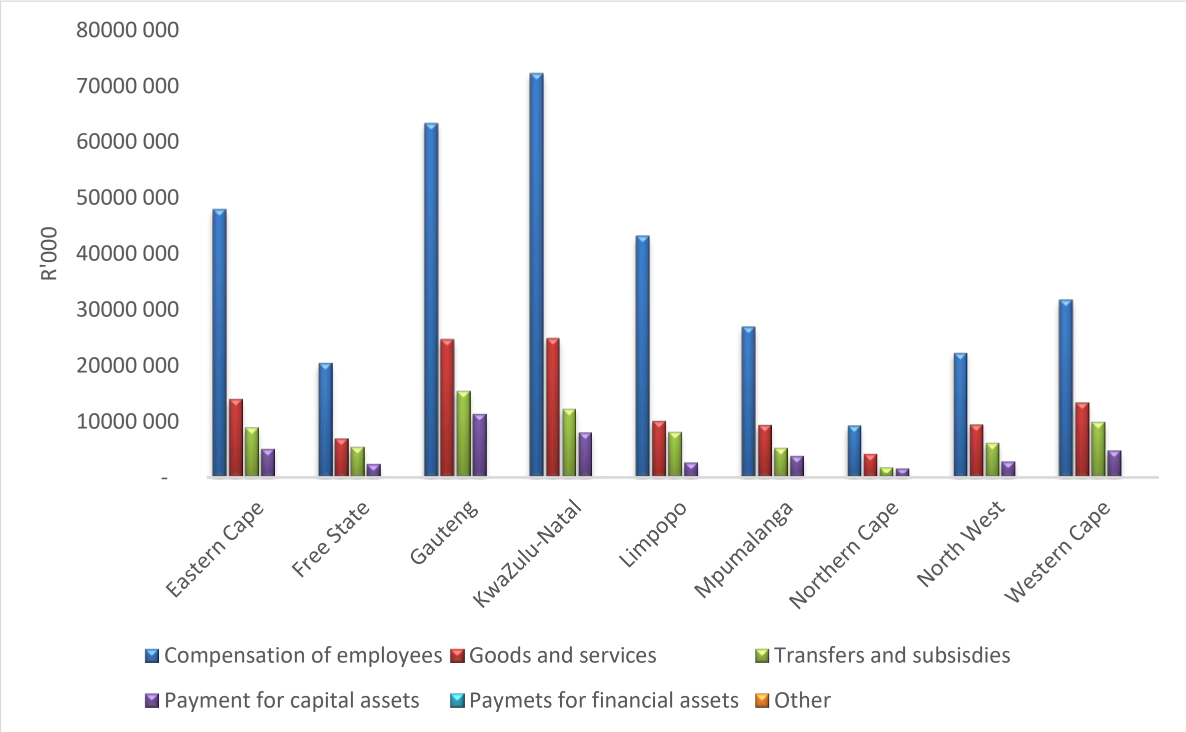
Table 2.9 reflects that provinces spent R570.3 billion in 2017/18. The expenditure on primary and secondary education, healthcare and social development portfolios was 76 per cent of this amount. The other sectors accounted for 24 per cent. The Eastern Cape, Gauteng, KwaZulu-Natal, Limpopo and the Western Cape respectively represented 76 per cent of total provincial expenditure in the same year. The departments of education and health were responsible for 73 per cent of consolidated provincial budgets. However, despite their substantial budget allocations, they continue to record poor outcomes. Therefore, any attempt to assess the technical efficiency of provincial service provision cannot ignore the education and health sectors. Figure 2.2 shows that the compensation of employees' budget was the leading provincial expenditure item, comprising 59 per cent of total provincial expenditure. Spending on goods and services and transfers and subsidies were respectively at 21 and 13 per cent.

Table 2.9: Provincial expenditure by function: 2017/18

Department	Eatern Cape	Free State	Gauteng	KwaZulu-Natal	Limpopo	Mpumalanga	Northern Cape	North West	Western Cape	Total expenditure	% of total expenditure
Cooperative Governance and Traditional Affairs	1 100 680	426 218	479 041	1 667 463	1 137 098	515 044	240 060	582 249	359 713	6 507 566	1%
and Tourism	1 112 281	529 224	1 425 973	2 788 507	1 694 971	1 127 725	455 716	555 624	961 064	10 651 085	2%
Education	33 344 643	13 534 735	41 786 542	48 286 416	29 255 925	19 535 077	6 069 346	15 107 481	20 722 693	227 642 858	40%
Health	22 771 139	9 795 191	44 132 368	40 430 163	19 522 743	12 445 693	4 722 157	11 420 212	21 671 137	186 910 803	33%
Human Settlements	2 686 965	1 437 190	6 255 557	4 066 734	1 530 744	1 739 988	504 594	2 466 496	2 693 318	23 381 586	4%
Office of the Premier	696 111	1 004 374	641 354	763 471	405 060	311 694	251 526	779 271	1 398 124	6 250 985	1%
Provincial Legislature	557 956	238 800	674 898	617 808	397 370	333 593	209 223	553 938	137 715	3 721 301	1%
Provincial Treasury	622 824	327 890	654 907	619 187	434 462	289 945	312 754	467 005	287 713	4 016 687	1%
Public Works and/or infrastructure development	2 167 788	2 474 454	3 024 461	1 542 817	3 428 053	1 117 062	1 844 602	3 098 403	2160316	20 857 956	4%
Rural Development And Agrarian Reform	2 204 218	776 641	971 896	2 210 644	1 864 207	1 143 801	617 394	1 401 161	877 648	12 067 610	2%
Safety and Liaison	94 892	517 538	738 844	204 486	103 713	1 194 121	109 088	350 079	301 739	3 614 500	1%
Social Development	2 643 128	1 163 976	4 585 919	2 947 202	1 828 814	1 509 438	870 316	1 525 356	2 110 521	19 184 670	3%
Sports, Recreation Arts And Culture	904 277	687 295	912 943	1 302 767	466 009	471 156	390 531	736 487	727 333	6 598 798	1%
Roads and Transport	5 002 272	2 289 693	6 957 676	10 165 666	1 990 645	3 660 073	308 458	1 728 222	5 388 272	37 490 977	7%
E-government	-	-	1 461 060	-	-	-	-	-	-	1 461 060	0%
Total provincial expenditure	75 909 174	35 203 219	114 703 439	117 613 331	64 059 814	45 394 410	16 905 765	40 771 984	59 797 306	570 358 442	100%
% of total provincial expenditure	13%	6%	20%	21%	11%	8%	3%	7%	10%	100%	

Sources: National Treasury (2018a), (2018b), (2018c), (2018d), (2018e), (2018g), (2018h), (2018i), (2018j). Note: all figures, except percentages are in R'000. Percentages might not add up due to rounding.

Figure 2.2: Provincial expenditure by economic classification: 2017/18



Sources: National Treasury (2018a), (2018b), (2018c), (2018d), (2018e), (2018g), (2018h), (2018i), (2018j).

2.4.3 Municipal expenditure

In terms of local government expenditure, Table 2.10 shows that, in 2017/18, all municipalities spent R373.8 billion of which R315 billion or 84 per cent was on operational expenditure and 16 per cent or R58.8 billion on capital expenditure. 57 per cent of the consolidated local government spending was concentrated in metropolitan municipalities while local and district municipalities respectively accounted for 36 and 7 per cent.

Table 2.10: Municipal expenditure 2017/18

Municipality	Operating expenditure	Capital expenditure	Total expenditure	% of total expenditure
Metropolitan	187 074 284	26 311 897	213 386 181	57%
Local	110 688 924	25 381 906	136 070 830	36%
District	17 262 304	7 061 758	24 324 062	7%
Total	315 025 512	58 755 561	373 781 073	100%

Source: National Treasury (2018k). Note: Expenditure is in R'000.

Table 2.11 shows that, in 2017/18, all municipalities spent 27 per cent of their consolidated budgets on the compensation of councillors and employees. They also spent a significant portion on goods and services, largely on water and electricity bulk purchases, other materials and contracted services (consultants). Municipalities also spent a significant portion of their budgets on capital expenditure for the provision of basic services infrastructure.

Table 2.11: Municipal expenditure by economic classification

Economic classification	Expenditure	% of total expenditure
Compensation of employees and councillors	102 489 621	27%
purchases and other materials and contracted services	138 019 306	37%
Payment for capital assets	58 755 561	16%
Transfers and subsidies	3 921 004	1%
Debt impairment, depreciation	49 185 091	13%
Other expenditure	21 410 490	6%
Total	373 781 073	100%

Source: National Treasury (2018k). Note: Expenditure is in R'000.

The National Treasury (2018k) reports that the R373.8 billion municipal expenditure in 2017/18 was 89 per cent of the total adjusted municipal budgets of R418 billion. Therefore, all municipalities underspent by R44.2 billion or 11 per cent. The Auditor General (2017) states that, in terms of service delivery efficiency, municipalities are faced with a plethora of challenges particularly in the development and maintenance of infrastructure. These include budget underspending, especially on the conditional grant allocations, delays in the completion of projects, poor quality workmanship and contract management. Although funding and support are generally available from national government for the development and maintenance of municipal infrastructure, the non-delivery in some municipalities negatively impacts on communities. In general, municipalities report challenges related to vacancies, instability in key positions and inadequate skills in technical and political spheres. This results in increased use of consultants and eventually leads to poor oversight by the councils. They also claim political infighting and interference in technical work. Insufficient performance, financial and record management systems and the lack of consequence management for transgressions are the other cited reasons. Moreover, in some municipalities there is a blatant disregard for controls and non-compliance with key legislation. This creates a fertile environment for corruption. The same issues are said to be ubiquitous in provinces.

2.5 CONCLUSION

South Africa has a very strong legal framework of fiscal decentralisation that is engraved in the Constitution and relevant fiscal and institutional legislation. This chapter indicated that the three spheres of government are expected to cooperate with each other. By legislative imperative and/or by structural design, there are many institutions participating in the fiscal decentralisation arena. These institutions are expected to abide by the applicable fiscal decentralisation frameworks. Provinces are heavily reliant on intergovernmental transfers for financial sustainability as they have limited own revenue-raising powers. Municipalities have substantial revenue generating powers. In terms of expenditure assignment, provinces mostly provide social services, like health, education and social development. Municipalities provide basic services, such as electricity, water and sanitation and refuse removal. There are reported inefficiencies in provinces and municipalities in the execution of their mandates which warrant further empirical investigation. As reported earlier, the present study only evaluates the technical efficiency of provincial education and healthcare sectors due to their budget and socio-economic significance.

CHAPTER 3

MEASURING PROVINCIAL TECHNICAL EFFICIENCY

3.1 INTRODUCTION

Table 2.7 in Chapter 2 reflects the actual consolidated public sector spending of R1.7 trillion in 2017/18. It also shows that provinces were responsible for R570.4 billion or 33 per cent of the aggregated government spending in the same year. Table 2.9 shows that the education and healthcare sectors accounted for R414.5 billion or 73 per cent of total provincial expenditure in 2017/18. The education sector alone accounted for 40 per cent of this amount while the health sector accounted for 33 per cent. Chapters 1 and 2 provide information suggesting the existence of provincial technical inefficiency. However, this information is largely qualitative in nature and inadequate to quantify and assess which provinces are more or less efficient. Therefore, the application of tried and tested scientific technical efficiency measurement methods are necessary for this purpose. However, to select an appropriate technical efficiency measurement tool, it is necessary to review the precursor technical efficiency analytical studies in the education and healthcare sectors. As a result, Section 3.2 reviews the theoretical efficiency concepts, Section 3.3 outlines different scientific methods of measuring technical efficiency. It also reviews the empirical public sector technical efficiency measurement literature and Section 3.4 concludes the discussions of Chapter 3.

3.2 REVIEW OF THEORETICAL TECHNICAL EFFICIENCY LITERATURE

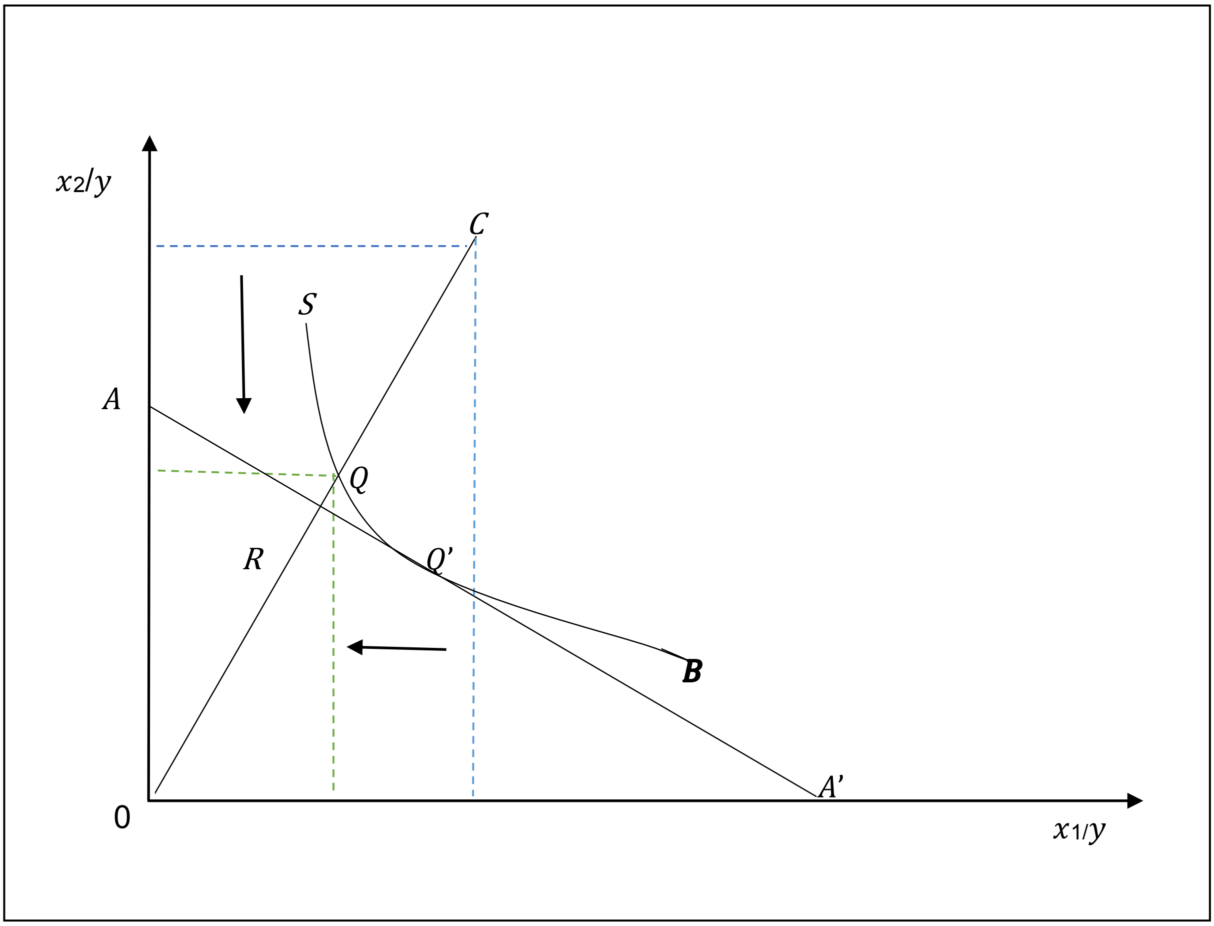
The term efficiency is often used in public finance discourse and in economic literature. González and Trujillo (2009) submit that efficiency is often confused with productivity, effectiveness and performance. These terms are related but do not necessarily mean the same thing. The concept of efficiency is the Economists' *raison d'être*. Simplistically, it refers to the use of resources in a less wasteful way. By definition, Economics is a study of how best to use scarce and limited resources. Therefore, efficiency is a central theme in economic literature. There are three broad categories of efficiency: technical, allocative and economic. Afonso et al. (2010) state that the technical efficiency determination process involves the comparison of actual and estimated costs and outputs. Therefore, technical efficiency refers to the comparison of actual production input and output variables with the estimated unknown optimal production functions. Hence Fried et al. (2008) maintain that technical efficiency compares the quality of the actual usage of inputs and achieved outputs with the scientifically determined optimum. Therefore, technical efficiency is a comparative benchmarking process. In contrast to technical efficiency, allocative efficiency refers to the dispersal of factors of production or input resources amongst competing government priorities at prevailing prices to derive the optimal production technologies. De facto, cost benefit analysis is a central feature of allocative efficiency measurement while it is not necessary in the determination of technical efficiency. Collectively, allocative and technical efficiency determine the extent of economic or cost efficiency. That is, economic efficiency is obtaining the maximum outputs at the lowest possible cost by employing inputs in an optimal manner amongst competing priorities.

Figure 3.1 was adopted from Alrwis and Francis (2013) and Worthington (2000). It graphically explains technical, allocative and economic efficiency. It uses a simple production technology that involves two inputs, $x1$ and $x2$, that are used to produce a single output, y, under the assumption of CRS, which is explained in detail in Section 3.3.1. The production technology is represented by an isoquant SS' showing all combinations of inputs x_1 and x_2 to produce an output, y. Any production combination that is located on the isoquant SS' is efficient. Point C, represents an input inefficient production bundle of a firm as it is not located on the efficient isoquant to produce a unit of output, y.

In terms of the production process, technical efficiency can be determined from two perspectives. It can be assessed from an input perspective to determine whether the same level of outputs could be attained with the lower quantity of inputs. This is commonly referred to as input-minimisation orientation. It could also be appraised from an output dimension to determine if higher levels of outputs could be attained with the same quantity of inputs (output-maximisation orientation). In Figure 3.1, technical efficiency is defined by the ratio OQ/OC, which is the proportional contraction in inputs that could be attained without any reduction in output levels. Therefore, this example determines technical efficiency from an input-minimisation perspective. Hence, technical efficiency is the reduction in the inputs that were used to produce an inefficient bundle C, to produce the same output at Point Q, shown by the shift from a blue hyphenated line to a green hyphenated line. Point Q, is technically efficient, as it is firmly located on the efficient isoquant.

Parida and Kumar (2009) report that technical efficiency is the distance between the quantity of inputs and outputs that define a productivity frontier. So, the distance between the inefficient production bundle (OC) and the efficient bundle (OQ) is a measure of technical efficiency. It should be observed that no price information is alluded to in the explanation of technical efficiency. However, if the input price ratio AA' is known, then allocative efficiency at point C, is the ratio OR/OQ where the distance RQ is the reduction in production costs if production occurred at Q. The total economic efficiency is the ratio OR/OC, with cost reduction being the distance RC. Total economic efficiency is given by product of technical and allocative efficiency, $EE = TE * AE, OQ/OC * OR/OQ \ = \ OR/OC$. The graphical illustration of economic and technical efficiencies in Figure 3.1 shows that cost efficiency is easily computed if reliable input, output and price or cost data is available while the computation of technical efficiency just requires input and output data. This is the reason that Balaguer-Coll et al. (2007) report that any researcher should first assess data availability prior to choosing the type of efficiency to be determined as data unavailability could restrict the nature of efficiency determination.

Figure 3.1: Technical, allocative and economic efficiency



Sources: Worthington (2000), Alrwis and Francis (2013).

Having defined, technical, allocative and economic efficiency, it is appropriate to discuss the other economic concepts that are related to efficiency. Mandl et al. (2008) mention that effectiveness compares the use of inputs against the impact of macroeconomic outcomes that are generated by the outputs. For example, if an increase in public expenditure exerts a positive impact on set socio-economic objectives, then such expenditure is effective. Therefore, this study does not consider techniques to determine effectiveness. Another closely related concept to efficiency is productivity. Tangen (2005) defines productivity as the quantum or magnitude of the production process given the factors of production. It is clear that an efficient production process would have a positive impact on productivity while an inefficient one would not. Therefore, the wastage of resources or inefficiency is the opposite of what productivity symbolises. Kamau (2011) and González and Trujillo (2009) hint that productivity can be measured by the partial-factor productivity ratio or the total factor productivity (TFP) ratio. The former is the ratio of an output to any selected input. The partial-factor productivity ratio applies specific measures to some fundamental measurement aggregate. For example, personnel expenses as a percentage of total expenditure. The latter refers to the ratio of overall outputs to inputs. Therefore, the TFP estimates the overall productivity of a production process by reflecting the global contribution of all inputs that are relevant for obtaining all output variables. Therefore, efficiency and productivity are conjoined concepts since the technical efficiency score is also a weighted ratio of inputs to outputs.

Parida and Kumar (2009) mention that the measures of technical efficiency are more accurate and reliable than measures of productivity. The efficiency measures involve the comparison of the unit's performance against the best optimum. Therefore, technical efficiency is the measure of the quality of the productivity ratio; it measures how well input resources are used to produce outputs. In simple terms, technical efficiency determination is about which productivity level is optimal or best. So, efficiency is about value creation or value-for-money that is obtained from a production process. Hence Nieswand and Seifert (2011) emphasise that technical efficiency assessments are essentially performance benchmarking techniques to identify the best practice production technologies for achieving higher productivity levels. As with the productivity ratio, Afonso et al. (2010) report that technical efficiency analysis uses macro (aggregated) or micro (individual) composite indicators. The former estimates the technical efficiency of the selected inputs to obtain the selected outputs. The micro composite indicators relate the selected inputs and outputs to a particular selected budgetary function or sector. In this case, the technical efficiency of public sector spending can only be assessed for expenditure that is related to specific individual function. The macro composite indicators measure efficiency for the entire spectrum of expenditure for all the government functions under consideration.

The determination of technical efficiency is a very complex methodological and empirical undertaking. It requires the accurate selection of inputs, outputs and analytical tools to achieve the identified objectives. In terms of measurement tools, Owusu-Ansah et al. (2010) state that there are parametric (econometric) and non-parametric (mathematical programming) scientific methods of analysing technical efficiency. Murillo-Zamorano (2004) adds that the technical efficiency measurement process can use either one of these methods. The choice of the relevant and appropriate technical efficiency estimation method is a long-standing debate in public finance discourse. González and Trujillo (2009) submit that some scholars prefer parametric approaches while others opt for non-parametric approaches. However, none of these methods is superior to the other; each have strengths and weaknesses. Hence, Owusu-Ansah et al. (2010) recommend that the use of parametric over the non-parametric methods and vice-versa depends on the unique objectives of the study under consideration. It also relies on data availability and the adeptness of a particular method to achieve the objectives of a particular study. Therefore, an appropriate method of technical efficiency estimation is the one that is fit-for-purpose, as its selection cannot be a subjective or arbitrary exercise. Section 3.2.1 and 3.2.2 respectively outline parametric and non-parametric measures of determining efficiency.

3.2.1. Parametric measures of efficiency

The parametric estimation methods are explained by Coelli et al. (2005) as statistical efficiency measurement instruments that apply statistical parameters to explain the efficiency or inefficiency levels of the studied DMUs. That is, they involve the appraisal of econometric parameters to determine the location of the studied firms on the efficiency frontiers. The parametric measures are comprised of the Least Squares Regression and Stochastic Frontier Analysis (SFA). Greene (2008) states that the econometric estimation of frontier functions are based on certain theoretical economic propositions. That is, these statistical methods limit the studied firms to operate within a specified economic theoretical constraint. As such, efficiency measurement is a scientific assessment of the extent to which the studied DMUs achieve or fail to achieve predetermined theoretical ideals. Owusu-Ansah et al. (2010) state that the econometric approaches specify upfront the functional form of a production frontier. They also make statistical assumptions about the distribution of inefficiencies and random errors. González and Trujillo (2009) maintain that the econometric approaches are statistically testable (stochastic in nature) and can easily distinguish the effects of statistical noise from the effects of inefficiency. They also consider random noise and thus separate measurement errors from the considered efficiency estimates. According to Owusu-Ansah et al. (2010), the limitations of these estimation methods include possible reading and interpretation of badly formulated or specified models as inefficiency. Therefore, their major drawback is the imposition of a certain functional form on the efficiency frontier which might be invalid, leading to incorrect results, statistical analysis and extrapolations.

According to Afonso and Fernandes (2008), the main purpose of the econometric models is to determine the impact of random or exogenous environmental variables on the efficiency of the studied units. They provide a framework for the inclusion of non-discretionary inputs to explain their bearing on efficiency scores. Therefore, statistical efficiency determinants are fit-for-purpose when a study intends to parametrically measure the influence of external factors on the internal performance of studied units. McWilliams et al. (2005) mention that the parametric efficiency estimation methods are only conducive to estimating the average efficiency relationships than determining comparative and extreme efficiency performance. That is, they are only suitable for deriving the average input-output relationships as opposed to identifying best-practice production technologies within a benchmarking context. Therefore, these techniques are not appropriate for efficiency benchmarking as they generalise the observed efficiency scores. There are two types of parametric methods that are discussed in the following paragraphs, the least squares econometric production method and SFA.

De Borger and Karstens (1996) state that the idea of the least squares method could be explained by using a cost function $C\ (yi, wi;\ \beta),$ which defines a relationship between expenditure C, needed to produce a given vector of outputs y, given input price w, with parameter vector β, to be estimated. It assumes that any deviation of the observed cost Ci, from frontier C' is attributed to inefficiency. Assuming a multiplicative disturbance term u, the model is stated as follows: $Ci = C\ (yi, wi;\ \beta)\ exp\ (ui)$, where $ui\ \geq\ 0$. Bonds and Hughes (2007) add that the error term has a one-sided distribution. Moreover, De Borger and Karstens (1996) maintain that a typical least squares regression consists of deterministic and random noise components. To estimate efficiency using the ordinary least squares (OLS) method, the first step is to calculate β to obtain the optimal frontier by shifting down the constant term so that all residuals are positive and at least one is zero. Greene (2008) and Auci and Mundula (2012) report that the OLS passes a function through the middle of myriad points to derive ideal estimated parameters of holistic production technology as opposed to the individual deviation from the ideal production function. Therefore, its limitation is the representation of average rather than best-practice relationship between the inputs and outputs in a particular data sample.

According to Nedelea et al. (2010), the mostly used and famous efficiency analytical parametric approach is the SFA. It was developed independently by Aigner et al. in 1977 and Meeusen and van den Broeck in the same year. Hasan et al. (2012) and Frohloff (2007) report that the SFA allows for the representation of the efficiency frontier deviations into a random error term that captures statistical noise and a one-sided error term that measures inefficiency. The first component measures the firm's efficiency. The one-sided error term has an independent and identical distribution across the observations and it captures technical inefficiencies across all the production units. So, the SFA allows the researcher to control for the unobserved random heterogeneity amongst the firms. The inefficiencies are assumed to follow an asymmetric distribution curve, usually a half normal, while the random errors are assumed to follow a symmetric standard normal distribution. Vierstraete (2012) and Greene (2008) emphasise that stochastic parametric frontiers are based on composite error models which allow differentiation between inefficiency and other stochastic influences. The SFA postulates that any departures from the efficient production frontier could be linked to other factors outside the control of the studied units. The SFA holds that some external factors have an effect on efficiency and if not considered in the efficiency analysis model, they may appear to a researcher as inefficiency while they are not. Therefore, the SFA adjusts the model for random exogenous factors and treats them as such, instead of interpreting them as inefficiency. This is one of the most valuable traits of the SFA.

Gebregziabher et al. (2012) claim that a stochastic frontier is defined as follows: $Yi = f(Xi, \beta)\ \exp(Vi - Ui), I = 1, \dots, N.$ Yi is the output produced by unit i, Xi is the vector of inputs used on unit i and β is the vector of parameters to be estimated. A symmetric component $Vi,$ captures disturbance in econometrics and a one-sided error term $Ui.$ De Borger and Karstens (1996) state that $+Ui,$ represents cost inefficiency components while $-Ui$ represents technical inefficiency. Nisrane et.al. (2011) supplement that Vi is assumed to be independently and identically distributed and is a component that represents random factors that are beyond the control of studied firms and other explanatory variables not included in the study. Vi is distributed $N\ (0,\sigma 2v)$.

Charoenrat and Harvie (2013) mention that the SFA only makes assumptions about the functional form of the efficiency production functions based on solid economic theory. Hinging on this theoretical basis, the SFA assumes that the form of the production function is known. It should be clear that the SFA does not make any upfront assumptions about the internal operations or efficiency of firms under consideration. It only makes assumptions about the nature and distribution of the two types of error terms that were explained earlier. Mustapha (2011) amplifies the view that statistical random errors generated by the estimation process are used to measure efficiency. The SFA, according to Grigoli (2014), is different from DEA which only considers endogenous factors that are linked to the efficiency of the studied firms within a sample. Grigoli and Kapsoli (2018) submit that a fundamental property of the SFA compared with non-statistical techniques is its ability to statistically capture, handle and contemporaneously control the large number of variables that can influence the efficiency results. Moreover, Malighetti et.al (2010) hint that the SFA is a better choice for considering efficiency where input and output determinant factors differ markedly across a studied sample, but with all of them having to be captured in the estimation of the efficiency scores. Therefore, this method is able to capture the effects of exogenous shocks or non-discretionary factors which are not inputs or outputs to the studied production process but which nonetheless influence the efficiency of producers. Liu (2006) maintains that the SFA enables simultaneous measurement of efficiency and consideration of other factors that affect the model. That is, the SFA has the ability to estimate the magnitude of the effects of exogenous factors on output levels. This is an idiosyncratic property which non-parametric measures do not possess.

The study now outlines the disadvantages of stochastic frontier analysis. The SFA heavily relies on economic theory to specify the correct form of the efficiency frontier. As a result, Nedelea et al. (2010) suggest that the SFA is rigid and imposes theoretically limiting norms on the functional form of the production frontier. This could cause misspecification which could eventually result in challenges in the interpretation of the evaluated efficiency scores. The assumption that the form of the production function is known based on theoretical postulations is questionable. It means that the SFA relies on the proficiency of researchers and their familiarity with the relevant economic and statistical theories. As a result, the selection of a distributional form for the inefficiency effects may be random - another potential source of efficiency model misspecification. Alrwis and Francis (2013) report that while it is possible under the SFA to include a large number of inputs and to control for stochastic influences, a major drawback is its inability to deal with multiple intra-model input-output technology. The technique is actually limited to efficiency measurement of single output production functions. Given the statistical grounding of the SFA and other regression-based approaches, it is sometimes cumbersome to use them to determine efficiency due to statistically insignificant relationship that could exist between inputs and outputs and due to potential wrong specification of the functional form of the efficiency frontier.

Cullinane and Song (2006) state that another criticism of the SFA is the required assumption that input variables or regressors and the production inefficiency elements are independent. It is contended that, in line with economic theory of rational expectations, any firm that encounters inefficiency is likely to make decisions that would attempt to address such weaknesses to become efficient. That is, inputs could be changed to reduce or realise efficiency. Therefore, the assumption of an independent relationship between regressors and the inefficiency component could be unrealistic. Moreover, due to the SFA containing elements of statistical noise (or random factors) and productive inefficiency, these trigger a requirement to make specific assumptions about the distributions and properties of these components. Of particular interest is the statistical noise component that is assumed to have a normal distribution, implying that this parameter is the same for all firms within the studied sample. McWilliams et al. (2005) state that, in practice, different parameter estimates have idiosyncratic statistical properties. Therefore, the assumption that this parameter has the same properties for all the firms is probably also unrealistic.

3.2.2. Non-parametric measures of efficiency

According to McWilliams et al. (2005), non-parametric methods (as opposed to parametric estimates) determine the best efficiency sample performance of the analysed firms instead of average performance. So, non-parametric approaches are critical when a study is interested in identifying individual firm's efficiency position and best practice benchmarks within the ambit of the studied sample. Owusu-Ansah et al. (2010) and Afonso and Fernandez (2008) maintain that these methods are tailor-made to assess the efficiency of individual firms relative to all the firms within the selected sample. That is, they measure relative efficiency instead of generalised efficiency to find the most efficient firms. Given that the parametric measures also exude the average efficiency scores of the entire sample, it could be said that they do what parametric measures do but with an added advantage of providing efficiency information about specific firms.

The adeptness of the non-parametric efficiency evaluation techniques is also found in their ability to uncover associations that are not possible to determine with the application of other methodologies, such as calculation of returns to scale. Coelli et al. (2005) state that non-parametric methods are comprised of DEA and the Free Disposable Hull (FDH). Unlike statistical models, these mathematical programs make assumptions about the internal operations and efficiency of the studied firms based on data that is used in efficiency analysis. For example, they consider whether or not the size of firms could affect the efficiency results. Moreover, non-parametric models do not involve any econometric estimation of parametric frontiers. Salazar Cuéllar (2014) and Rosko and Mutter (2011) report that the difference between DEA and the FDH is that the latter does not assume any convex combination of inputs and outputs while the DEA adopts a convex relationship that envelops the observed production technology to produce an estimated ideal technology. The DEA and the FDH are discussed in depth in the following section.

Since the mathematical programming procedures are not based on statistical parameters, Greene (2008) proffers that the traits of their efficiency vector estimates are vague and, at worst, unknown. Moreover, the accuracy of the efficiency scores estimated through these methods mostly depends on the quality and appropriateness of data. The efficiency estimators that are extrapolated from mathematical programs do not inherently produce standard errors for efficiency coefficients, forcing inference to be precluded. Given that linear programming approaches are not stochastic in nature, González and Trujillo (2009) state that they collectively interpret the effects of statistical noise and inefficiency all together as inefficiency. Therefore, the quality of the estimated frontier or the efficiency results could easily be distorted by the presence of random noise. Furthermore, parametric efficiency estimates do not allow for hypothesis testing as they do not make assumptions about the distributional form of the error term. They also do not confuse the effects of a bad frontier functional form specification and inefficiency as inefficiency. They do not specify functional forms but econometric approaches do. Therefore, they are less sensitive to, and even devoid of, this type of error. Their main strength is their effortless ability to handle multiple input-output production technologies in terms of factors of production that are used by firms for efficiency determination. However, Grigoli and Kapsoli (2018) advise that, to create the best-practice production frontier, the efficiency results of non-parametric models depend on the presence of performance extremities or outliers in the studied sample. The non-parametric models are also conducive to analyse homogenous firms who operate in the same environment bearing similar conditions. Their main disadvantage is that their efficiency results could be affected by the presence of heterogeneous firms and their operational conditions. At this juncture, the study discusses DEA and FDH in detail.

Adler et al. (2002) state that DEA was conceived by Farrell in 1957 in his seminal work, but was made famous by Charnes et al. in 1978 (henceforth referred to as the CCR) by changing a fractional linear efficiency estimate into a linear programming format. Cooper et al. (2007) and McWilliams et al. (2005) report that the terminology “envelopment” refers to the ability of the efficiency production frontier to tightly enclose the production technology. DEA was developed in a microeconomic setting and applied to firms to convert inputs into outputs. However, in efficiency determination, the term “firm” is sometimes replaced by the more encompassing DMU, the term coined by CCR. DEA is an appropriate method to compute and analyse the efficiency of public sector institutions, as they employ multiple inputs to produce multiple outputs. DEA was developed in a public sector environment where market-based input and output prices may not be available. In this situation, DEA provides a solution by computing ‘shadow’ prices to enable the determination of cost efficiency. Greene

(2008) states that DEA is an a-theoretical efficiency determination method which does not base the production technology frontier on any fixed economic theory. Therefore, DEA estimated frontiers do not specify any functional form that is related to the production technology and makes no assumptions about the technology. That is, DEA does not rely on economic theory to formulate any efficiency measurement parameters. It only applies the assumptions of microeconomic production functions, such as convexity, returns to scale and output and input efficiency dimensions in the efficiency measurement exercise.

According to Taylor and Harris (2004), DEA is a comparative efficiency measurement tool that evaluates the efficiency of homogeneous DMUs, where there is no known relationship between the conversion of inputs and outputs. The unknown relationship between the studied variables implies that the efficiency frontier is also not known, but can be determined by comparing the deviation between the actual and estimated best performance of DMUs within the same sample. According to Wang and Alvi (2011), DEA measures the distance or derivatives of the production functions to determine the extent of DMUs efficiency deviation to the optimal position. It classifies DMUs into extremely efficient performers versus inefficient performers. In DEA analysis, efficient performers are then given a rating of one hundred per cent which is then compared with calculated efficiency scores of the other units. That is, efficiency is measured by a ratio that is between zero and one hundred per cent and a ratio value of one hundred per cent means a firm is fully efficient. Aristovnik (2012) states that, in a DEA dispensation, inefficiencies are degrees of deviance from the efficiency frontier. As reflected in Figure 3.1, input-oriented inefficiencies show the degree to which the input variables should be scaled back in order for the inefficient DMUs to lie on the efficient practice frontier. On the other hand, the output-oriented efficiencies are increases in outputs needed for a DMU to become more efficient by using similar or fewer inputs.

Therefore, DEA compares similar DMUs that are described by a common set of multiple technological attributes operating in homogeneous conditions to calculate the relative efficiency of a set of DMUs. Wang and Alvi (2011) state that the relative efficiency of similar DMUs implies that DEA is a transformation of multiple-variable production technologies of various DMUs into a single best optimum production technology; serving as an ideal efficiency yardstick for all DMUs. As explained in Section 3.2.1, Coelli et al. (2005) define a measure of efficiency as the ratio of the weighted sum of outputs divided by the weighted sum of inputs. DEA computes separate weights for each DMU and each of the weights are assumed to be positive. That is, each DMU is assumed to use at least some level of inputs to produce outputs. Wang and Alvi (2011) maintain that DEA's optimal efficiency benchmark is compared with the efficiency of other DMUs in the same study. That is, DEA uses only the information of a particular study to determine efficiency and does not take into consideration exogenous factors.

Marschall and Flessa (2009) report that DEA uses linear programming to construct convex efficiency frontiers that are defined by multiple sub-functions requiring little or no modification to determine the efficiency of DMUs. As reflected earlier, DEA is premised on the tenets and properties of convex production frontiers. Fried et al. (2008) and Coelli et al. (2005) maintain that DEA envelops a dataset subject to conditions and properties of a convex production frontier. A production function shows all the production possibilities of a firm, given particular input variables. To explain a convex production frontier, the following example is adopted. Take a situation where a DMU uses N inputs to produce a single output q. The technological possibilities of such a firm can be summarised by using a production function, $q = f(x)$. That is, output is a function of inputs. Where x = (x_1, x_2.........x_N).The main properties of this convex production frontier are that $f(x)$ input values are positive finite real numbers. This implies that there is a limited number of inputs, indicating a resource constraint and that all input variables are positive real numbers or $f(x) \geq 0$; this is called the non-negativity condition. The second condition is that of weak essentiality, meaning that the production of a positive output is impossible without the use of at least one input variable. Intuitively, outputs cannot be produced without using some inputs. The third condition is that of monotonicity: additional units of an input will not decrease the output; therefore, the marginal products are non-negative. This implies that decreasing returns to scale (DRS) that will be explained shortly is not part of the optimal efficiency frontiers. The fourth major condition is the concave nature of inputs, that is, all marginal products are non-increasing. That is, for efficiency to prevail, there should be no increasing returns to scale (IRS).

Aristovnik (2012) maintains that, depending on the problem at hand, there are various types of DEA models that can be used to measure the efficiency of DMUs. The various

DEA models can be distinguished by the scale and orientation of the model under consideration. For example, if the objective is to adjust outputs before inputs, then an output-maximisation-oriented DEA rather than an input-minimisation oriented model would be appropriate to measure efficiency. Martić et al. (2009) state that the input-minimisation orientation determines the quantity of the required inputs that could be curtailed without reducing the prevailing level of outputs to make DMUs efficient. On the other end, the output-maximisation oriented DEA expands outputs of DMUs until the combination of inputs and outputs reach the production possibility frontier while holding the levels of inputs constant. The two DEA orientations provide the same results under the CRS assumption for input or output orientated models but give different values under the VRS assumption.

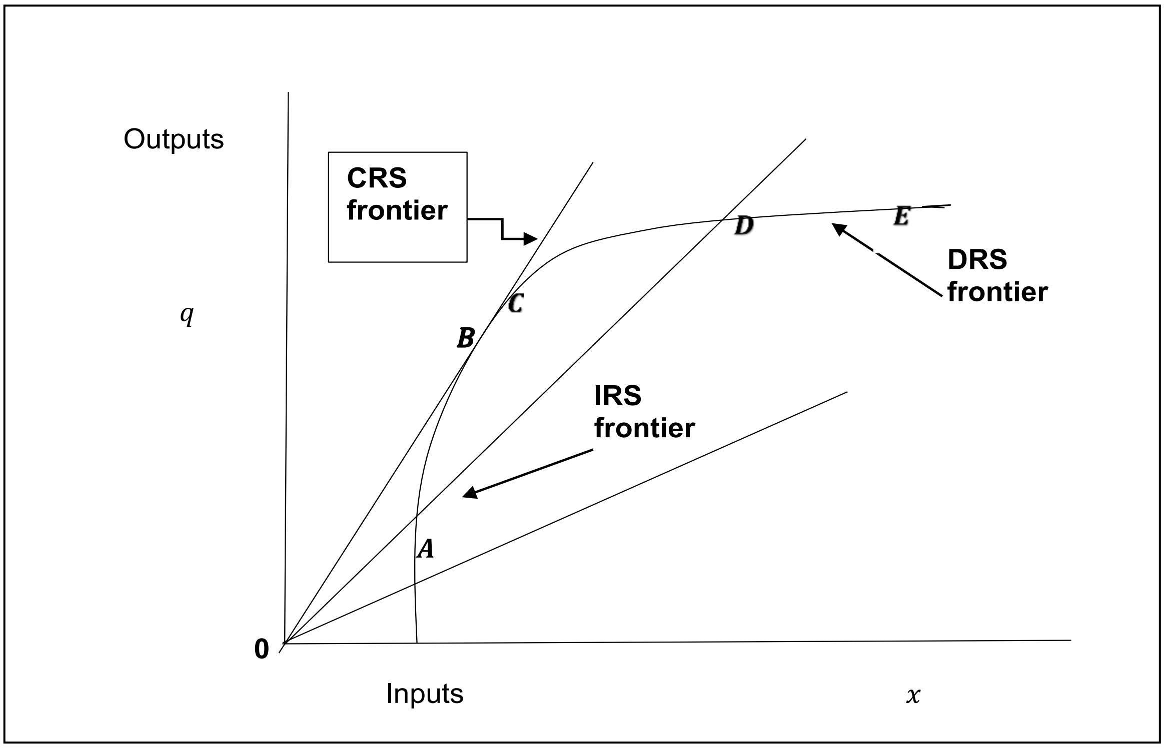
In explaining the different orientations, it is important to re-emphasise that DEA operates under the context of distance functions. Coelli et al. (2005) state that the distance functions under which DEA operates involve radial (divergent rays from the origin) contractions and expansions. The input distance function characterises a production technology by considering the minimal proportional contraction of input vectors, given output vectors. An output distance function considers the maximal proportional expansion of output vectors, given input vectors. Marschall and Flessa (2009), Gannon (2005) and Adler et al. (2002) report that radial movements are input contractions or output expansions that are required for a firm to become efficient. They represent the level of inefficiency that DMUs should address to become efficient. Moreover, in cases where DMUs remain inefficient post radial movements, additional input reductions and/or output expansions, called slack variables are required to make them efficient. In other words, slack variables represent either input excesses or output shortfalls or both. Avkiran (2001) submits that under the input-minimisation approach, the potential efficiency improvements indicated by DEA may further suggest increasing one or more outputs while further lowering inputs. Such slacks depict under-produced outputs and overused inputs. Similarly, under the output-maximisation DEA model, the results may further suggest raising outputs and reducing inputs. Tongzon (2001) states that radial and slack movements are only applicable to inefficient DMUs as efficient DMUs do not encounter any radial and slack movements; where they do, it reflects weak efficiency levels.

Aristovnik (2012) maintains that, in terms of scale, if one cannot assume the existence of the CRS, then a VRS type of DEA model is an appropriate choice for calculating efficiency. Afonso and St Aubyn (2004) define the CRS as the level of output change given a constant proportional change in input factors of production. That is, if output increases or decreases by the same proportional change in inputs, then the CRS prevails. Avkiran (2001) adds that the CRS postulates no significant relationship between DMUs operational scale and efficiency. That is, it assumes that large DMUs attain the same levels of efficiency as small DMUs in transforming inputs to outputs. Therefore, under the CRS, DMU size is not relevant when assessing efficiency. Gannon (2005) cautions that if it is likely that the size of a DMU will have a bearing on its ability to produce services more efficiently, then CRS assumption would not be valid for use. The VRS would, as it allows the use of inputs to outputs to change with the size DMUs. Avkiran (2001) explains that the VRS implies that an increase in inputs is anticipated to cause an unequal rise in outputs or a decrease in inputs could cause a disproportionate decrease in outputs. The VRS is favoured when a strong link exists between DMU size and efficiency.

Avrikan (2001) reports that the CRS efficiency scores represent technical efficiency. On the other hand, the VRS efficiency scores represent pure technical efficiency. Fried et al. (2008) provide intuition that the efficiency results that are calculated through the VRS are always higher than those calculated using the CRS. This is because the best VRS efficiency frontier is only formed by the convex efficient combinations of inputs and outputs. As a result, the VRS model envelops data tighter than the CCR model. Moreover, the VRS model also generates the CRS efficiency scores and has an added benefit of calculating scale efficiency. Therefore, the VRS provides more information about the technical efficiency of DMUs than the CRS. The VRS is useful if there is a variation in the conditions within which DMUs operate while the CRS requires similar operational conditions. However, where both the CRS and the VRS are used to measure technical efficiency scores, if the compared efficiency results of most of the DMUs in the sample are varied, then the VRS is an appropriate model to adopt. In instances where the scores of most of DMUs are the same (not varied), then the CRS can be adopted. However, data and study context is always important in selecting an appropriate DEA model.

The study uses Figure 3.2 adopted from Coelli et al. (2005) to explain the CRS and the VRS. All DMUs that are located at points A, B and C are technically efficient. They operate on the efficient production frontier. However, these DMUs are notably not equally productive. The productivity of each of the three DMUs is the ratio of outputs to inputs or q/x or Y/X, an expression that is equivalent to the slope of a ray drawn from origin through data point (x, y). A DMU on point A, operates on the VRS (IRS) as it could become more productive by increasing scale operations to point B. That is, a small increase in inputs can lead to a larger increase in outputs. A DMU on point E, functions on a VRS (DRS) as an increase in inputs causes a decrease in outputs. Actually, a DMU on point E becomes more efficient by decreasing scale operations to point D. Therefore, DMUs A and E operate on the VRS. A firm on point B is operating at most productive scale size ($MPSS$) or technically optimal productive scale ($TOPS$), a point where the ray from origin is tangent to the production frontier. This DMU operates on a CRS. Mathematically the $Tops = max\, Y|X\ (x, y) \in S$. This discussion implies that the CRS frontier is the $TOPS$ point. Prasetyo and Zuhdi (2013) state that the CRS efficient frontier estimates the maximum output-input slope from the original point while the VRS efficient frontier sorts the slopes starting from a DMU which has the minimum input such as Point A to the one that has the maximum input such as Point E. Therefore, the VRS frontier is a comprehensive efficiency solution as it captures the efficiency performance of all the DMUs, including the DMUs that are already on the CRS frontier as well as those on the VRS efficiency frontier. It is important to note that both DMUs B and C, are efficient under the CRS and the VRS methods but DMUs A, D and E are efficient under the VRS but not under the CRS.

Figure 3.2: Technical and scale efficiency, CRS and VRS



Sources: Prasetyo and Zuhdi (2013), Coelli et. al (2005).

Coelli et al. (2005) state that the basic DEA model was developed by CCR, who proposed a model that is input-oriented and assumed CRS. Hence the CRS, is often referred to as the CCR model. Under the input-minimisation oriented CRS model, if there are M different number of inputs and P different number of outputs for N DMU, these quantities are represented by column vectors xij (i = 1, 2, 3, …M, j = 1,2,3 …N) and qrj (r = 1, 2, 3, …P, j = 1,2,3 …N). The $M\ x\ N$ input matrix, X and $P\ x\ N$ output matrix, Q represent the production technology for all the N number of DMUs. For each DMU, the ratio of all the output variables over all the input variables is represented by u'qrj/v'xij. Where u $= P\ x\ 1$ vector output weights and v $= M\ x\ 1$ vector input weights. As explained earlier, the optimal weights or efficiency estimates are obtained by solving a mathematical problem. The model is stated as follows:

Tops = $\max_{u,v}$ (u'qrj/v'xij)

$St.$

u'qrj/v'xij ≤ 1 (3.1)

u, v ≥ 0

Equation 3.1 shows the original linear program, called the primal. It aims to maximise the efficiency score represented by the ratio of all weighted outputs to inputs, subject to ($St.$) the efficiency score not exceeding 1, with all inputs and outputs being positive. Equation 3.1 has an infinite number of solutions, if (u'v') is a solution, so is αu', αv'. To avoid this, one can impose a constraint v'x$ij = 1$, which produces Equation 3.2.

maxu,v (u'qrj)

$St.$

v'xij =1 (3.2)

u'qrj - v'xij ≤ 0

u, v ≥ 0

Wang and Alvi (2011) assert that an equivalent envelopment problem can be developed for the problem in Equation 3.2, using the duality in linear programming. The dual for maxu,v (u'qrj) is $min\theta, \lambda\theta$. The value of θ is the efficiency score, it satisfies the condition $\theta \leq 1$; it is the scalar measure. λ is $NX1$ vector of all constants, the value of λ is Farrell's radial technical efficiency measure which provides initial performance evaluations for each DMU. This results in Equation 3.3 which represents the CCR CRS model.

$Min\theta, \lambda\theta$

$St.$

-qrj + $Q\lambda \geq 0$ (3.3)

θxij - $X\lambda \geq 0$

$\lambda \geq 0$

Gavurova et al. (2017) report that, in 1984, Banker et al. generalised the CCR formulation to allow for testing of the VRS assumption; this is called the BCC model. As reported earlier, this model is appropriate for application where DMUs do not operate at their optimal size. Lavado and Domingo (2015) state that, in practice, there is a plethora of factors like financial constraints, that may result in DMUs not operating at optimal scale, hence the introduction of the BCC model. Marschall and Flessa (2009) maintain that the CCR and BCC models only differ in the manner in which the latter includes convexity constraints. As reflected earlier, the CCR model only measures the overall technical efficiency without considering scale effects and the BCC model measures pure technical efficiency, since it factors in scale effects. Yawe (2014) submits that the CRS linear programming problem can be modified to account for the VRS by adding the convexity constraint: $N1'\lambda = 1$ to Equation 3.3 to formulate Equation 3.4. Where $N1$ is an $Nx1$ vector of ones. Equation 3.4 represents the BBC VRS model with an input minimisation orientation.

$$Min\theta, \lambda\theta$$

$$St.$$

$$-qrj + Q\lambda \geq 0, \qquad (3.4)$$

$$\theta xij - X\lambda \geq 0,$$

$$N1'\lambda = 1,$$

$$\lambda \geq 0$$

As explained earlier, a DEA model calculates slacks for inefficient DMUs. The model of this study accounts for slacks in Equation 5. Gavurova et al. (2017) say that Sr^{+} and Si^{-} are respectively the output and input slacks that are calculated with θ and λn. ε, is the non-Archimedean constant. Gavurova et al. (2017) state that if slack variables are not equal to zero and the efficiency score is lower than unity, then it is necessary to perform a non-radial shift expressed by slack variables to achieve efficiency. But if the slack variables are non-zero and the efficiency score is at unity, there is "weak-efficiency". Therefore, radial and slack movements are not similar and should not be used synonymously. Ramirez-Hassan (2008) states that slack variables are not radial to the efficiency frontier; they are parallel. Therefore, in Equation 3.5, slacks determine the optimum level of inputs that the inefficient DMUs would further reduce above their original input usage and outputs they would produce to become efficient. Given that the model of this study is VRS based, the restriction $\sum_{j=1}^{N} \lambda j = 1$ is introduced. If the restriction is not there, it would imply a CRS model. The slacks are calculated for all the inefficient DMUs using Equation 3.5.

$$\text{Min } \theta, \lambda j, Sr^{+}, Si^{-}$$

$$\theta - \varepsilon \left[\sum_{i=1}^{M} Si^{-} + \sum_{r=1}^{P} Si^{+} \right]$$

$$St.$$

$$\theta x i_0 - \sum_{j=1}^{N} x ij \, \lambda j - Si^{-} = 0, \qquad \sum_{j=1}^{N} x ij \, \lambda j = X\lambda \tag{3.5}$$

$$\theta q r_0 = \sum_{j=1}^{N} q r j \, \lambda j - Sr^{+} = 0, \qquad \sum_{j=1}^{N} q r j \, \lambda j = Q\lambda$$

$$\sum_{j=1}^{N} \lambda j = 1$$

$$\lambda j, Sr^{+}, Si^{-} > 0$$

Marschall and Flessa (2009) report that some DEA applications use a single-stage approach by only measuring efficiency and not extending the model to consider exogenous random variables. At the other end, some DEA methods adopt a two-stage methodology in which regression analysis is used to explain the variation in efficiency scores that are generated by the first-stage DEA. That is, the second-stage DEA co-opts parametric techniques to explain factors that affect the efficiency scores. The use of the second-stage regression analysis identifies drivers of gross efficiency or inefficiency and computes the net efficiency scores from the residuals of the regression. Since the second-stage analysis predominantly employs regression, according to Nieswand and Seifert (2011), it imposes strong statistical assumptions and requires correct model specification. Therefore, depending on the objectives of a particular study, a researcher may opt to use a single-stage or two-stage DEA. To conclude the discussion on the background of DEA methodology, it is essential to note the efficiency measurement norm. Akazili et al. (2008) mentions the norm as using the minimum amount of resources for a given level of output or producing the maximum amount of output with the same or lower resources. Therefore, the efficiency criterion refers to the elimination of wastage in the use of resources of a production process. As a result, if more inputs than necessary are used to produce outputs, then the efficiency criterion would be violated.

Having outlined the DEA methodology, the research shifts to detailing its advantages and disadvantages. Tongzon (2001) states that as a mathematical efficiency evaluation program, DEA offers an alternative to classical statistics. Kuosmanen and Johnson (2010) indicate that DEA only relies on the general axioms of production theory, such as monotonicity, convexity, and homogeneity to determine the efficiency of DMUs relative to best estimated production technology. Bray et al. (2015) add that, as opposed to parametric models, DEA does not make any assumptions about the form or shape of the efficiency frontier or the production technology of the DMUs under consideration. Buljan et al. (2017) assert that DEA is a flexible efficiency analytical tool which does not impose any functional form on the frontier. Therefore, DEA recognises inherent differences in the production processes of the studied DMUs. This is a deficiency that is found in econometric estimation methods like the SFA which assume that production processes of varying DMUs are the same which, in practice, are not. Given that DEA does not require a predetermined production function, its main advantage is simplicity in application. It simply takes output-input data and transforms it to define the efficiency of DMUs.

Bray et al. (2015) state that DEA's efficiency weights do not use *a priori* determination to fix the weights in advance. Unlike the SFA, DEA extracts information from the sampled observations to determine efficiency and makes no assumptions about inefficiencies and random errors. As a result, Gannon (2005) states that DEA is favoured when measurement error is an unlikely threat and where the assumptions of neoclassical production theory are questionable. Cook et al. (2014) and Afonso et al. (2010) maintain that, due to the lack of any requirement to specify the functional form of a production function, DEA is also not subject to sample size statistical measurement requirements. It is a benchmarking tool that focuses on individual DMU performance relative to peers irrespective of sample size. However, a caveat is that DEA's sample size depends on the number of inputs and outputs that are used in a production process.

Johnes and Li (2008) state that DEA assigns the best weights to chosen inputs and outputs so that each DMU is represented by its best efficiency score and appear to its best advantage compared with its peers. Tongzon (2001) mentions that DEA optimises the performance of each DMU to an extent that even the worst performing DMUs are represented by their optimal score. It is a measure of "best of the best" within the context of the sample that is under examination. Hence Martić et al. (2009) describe DEA as a methodological process of extremities that only measures the positive extreme performance of DMUs as opposed to techniques that focus on central tendencies or average performance. As a result, Moore et al. (2005) report that DEA programmes yield a unified efficiency score. Afonso et al. (2010) assert that it provides information regarding the prevailing input and output targets that inefficient DMUs can use for efficiency improvement and benchmarking purposes. Helmig and Lapsey (2001) state that DEA's popularity stems from its strongest and idiosyncratic advantage of determining efficiency within the environment of multivariate functions where multiple outputs and inputs are considered. Alhassan et al. (2015) and Johnes and Li (2008) maintain that DEA is proficient in handling multiple inputs and outputs while using a single measure of efficiency. In fact, DEA is one amongst the few known efficiency estimation approaches suitable for measuring relative efficiency in this context. The input-output coefficients used in parametric models are not suitable for estimating efficiency in the multi-variable production technology environment as stated earlier.

In terms of disadvantages, Bray et al. (2015) noted that, in as much as DEA is versatile in measuring relative efficiency in datasets that define multiple production technologies; its limitation is its heavy reliance on data accuracy. The quality of data used in DEA applications determine the quality of efficiency scores. Therefore: garbage in equals garbage out. Since DEA focuses on frontiers, small changes in data can significantly change characteristics of the efficiency frontiers. That is, DEA is a data-sensitive method and, to apply it successfully, accurate data measurement is necessary. DEA can also be sensitive to the number of inputs, outputs and DMUs that are included in efficiency analysis. As a result, Marschall and Flessa (2009), Cook et al. (2014) and Nieswand and Seifert (2011) advise on the need to avoid the inappropriate ratio between the number of DMUs and variables used in DEA models. They further suggest that the number of DMUs should at least be double or triple the aggregated number of inputs and outputs. If the number of inputs and outputs used in efficiency analysis are relatively higher than the number of DMU observations, DEA may lead to substantial overestimates of the efficiency scores. The opposite is also true, as fewer inputs than necessary could yield very low efficiency scores.

Grigoli and Kapsoli (2018) maintain that when a large number of inputs are used relative to a small number of DMUs, a high percentage of observations can be classified as efficient while they are not. This could make it difficult to rank the DMUs in terms of efficiency. Ramirez-Hassan (2008) reports that DEA achieves the efficiency outcomes that are less stable than those obtained with regression analysis, if comparative analysis for each DMU is done in a small sample. However, this problem can be addressed by restricting a study to a single input or to most relevant inputs and outputs such as those related to mandatory tasks of DMUs. It can also be addressed by applying the golden rule that was alluded to earlier. Nieswand and Seifert (2011) and Johnes and Li (2008) state that DEA frontiers are also sensitive to extreme or outlier values of input and output variables as DEA has a problem of always enveloping outliers with certainty. When DMUs affected by data outliers are identified as peers, they can directly influence the efficiency scores to yield biased efficiency results. Therefore, it is essential to conduct data sensitivity checks when using the DEA applications.

Nieswand and Seifert (2011) submit that another criticism of the technique is the computation of relative efficiency scores with a slow convergence rate to the global optimum. The convergence rate measures how fast an estimator converges to the true and unknown parameter subject to the number of observations. De Witte and Geys (2011) say that despite its low rate of convergence, DEA is more consistent compared with parametric models that could be wrongly specified. Osei et al. (2005) state that another limitation of DEA is its deterministic non-parametric nature, disabling it from performing statistical hypothesis testing in efficiency analysis. Johnes and Li (2008) assert that DEA does not allow for the adjustment of measurement errors and makes no assumptions about the distribution of errors of a production function. That is, statistical inference cannot be drawn from DEA results. Due to this, Marschall and Flessa (2009) warns that DEA may suffer from the omitted variable bias or randomness in the process of estimating the efficiency frontiers. Buljan et al. (2017) caution that stochastic errors caused by the omitted variables and input and output measurement errors could be incorporated into efficiency scores and interpreted as inefficiency, while practically they are just effects of random exogenous factors.

That is, DEA does not account for all the possible exogenous macroeconomic and environmental factors that could negatively affect the efficiency outcomes and this could result in biased efficiency results. However, the underlying DEA rationale is that inputs directly determine outputs without interference from any external influences. This is a direct antithesis of SFA methodology. In this context, DEA does not generate general relationships for the identification of factors creating differences in efficiency. Other methods considering the influence of environmental factors are needed for this purpose. That is, DEA requires the use of parametric methods to demystify the effects of exogenous factors on the efficiency of DMUs.

Wang and Alvi (2011) submit that another challenge with DEA is that, to define the efficiency frontiers, it assumes at least some DMUs in the observed sample are efficient. That is, at least some DMUs will be given a score of one while in reality even the best-performing DMUs within the sample or study may not operate in a perfectly efficient manner. This is because Osei et al. (2005) noted that there could be best performers outside the realm of the studied sample. However, since DEA measures relative efficiency than absolute efficiency, comparison is with the best units in the observed sample. Zere et al. (2006) maintain that DMUs that are deemed to be efficient are indeed the most efficient in terms of relative efficiency. That is, they are the best benchmark within that sample. Moreover, each study has boundaries in data selection. Since DEA measures relative efficiency, other external samples and production technologies that could offer improved results do not matter as they are not part of the sample under consideration.

Due to DEA only dealing with relative efficiency within the studied sample, it is not able to compare how DMUs in one country fare relative to their counterparts in other countries. This especially, if the data is not adjusted to comply with homogeneity requirements. Therefore, most DEA applications involve multiple DMUs within the same setting. For DEA analysis to thrive, the DMUs should generally have the same procedures and policies and face roughly the same environmental conditions. So, the determination of relative efficiency of DMUs where they operate in completely different conditions is not possible with DEA approach.

Lastly, the study analyses the FDH methodology. Based on Alfonso and St. Aubyn (2004), the FDH is a non-parametric technique first proposed in 1984 by Deprins et al. As with DEA, the FDH was originally developed and applied in a microeconomic setting to firms that convert inputs into outputs. De Borger and Karstens (1996) state that, similarly to DEA, the FDH computes efficiency measures that can be input or output oriented. But, unlike DEA, the FDH does not tightly enclose the data. It places fewer restrictions on data and only assumes free-disposability of resources. Free-disposability implies that an increase in inputs never results in a decrease in outputs and that any reduction in outputs would remain producible with the same quantity of inputs. Afonso et al. (2010) report that the FDH is broadly based on the concept of X-efficiency[14] advanced in 1966 by Leibenstein. The central premise of the FDH is that a producer is relatively inefficient if another producer uses fewer or equal inputs to generate more or the same outputs. Alternatively put, a producer is relatively efficient if there is no other producer that uses fewer inputs to generate more outputs. Afonso and St Aubyn (2004) use the matrix below to explain the FDH methodology. It shows the production technologies of three DMUs, A, B and C given input quantities ranging

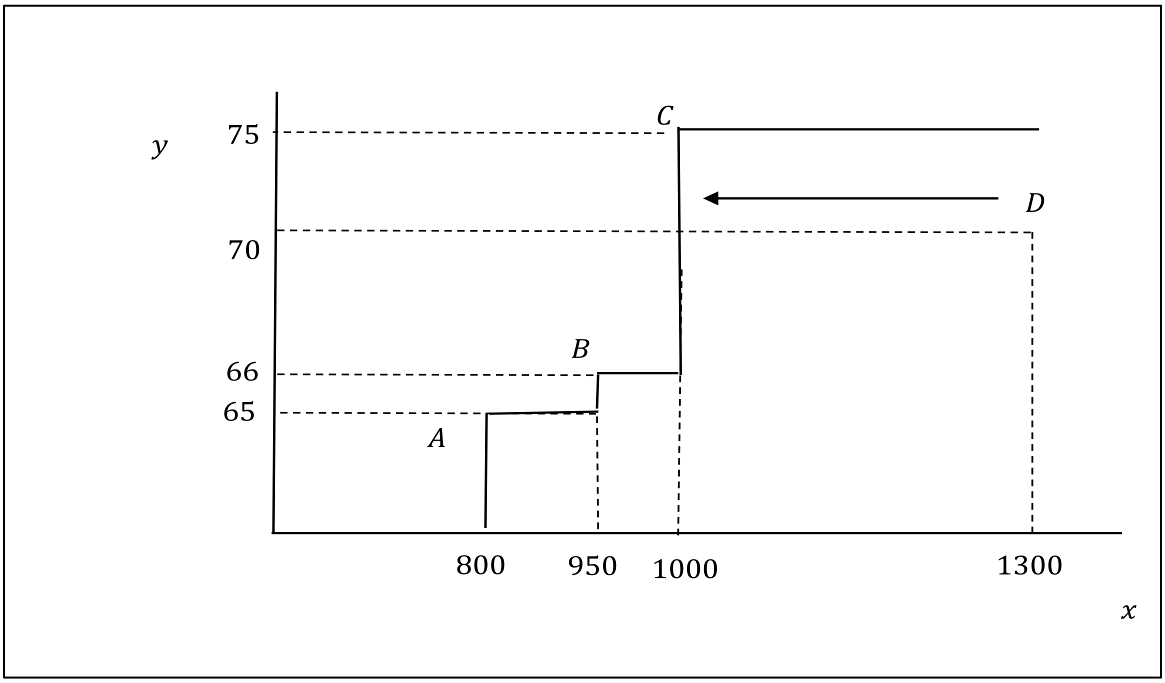
[14] Mahabir (2014) states that X-inefficiency occurs when certain decision-making units willingly use more inputs than required, which results in higher average costs than necessary. This usually occurs in a monopoly where the company has no incentive to cut unnecessary costs because it is already making supernormal profits.

from 65 to 1300. Suppose that, under efficient conditions, output is represented by indicator yi and inputs by xi. Therefore, output is represented by $yi = F(xi)$ and if $yi < F(xi)$, then $DMUi$ is said to be inefficient. The efficiency frontier is illustrated in Figure 3.3. Inefficiency may be measured as a vertical distance between $DMU\ D$'s performance and the efficiency frontier. $DMU\ D$, uses more resources and produces less output than $DMU\ C$. The efficiency loss is about 300 or 24 per cent (300/1300). However, to attain an indicator level of 70, it is not necessary to spend more than 1000 as shown by $DMU\ C$. $DMUs\ A$ and B operate under IRS conditions while $DMU\ D$, is on DRS.

$$yi < F(xi) = \begin{cases} 65 \leq x < 950 & A \\ 66 \leq x < 1000 & B \\ 75 \leq x < 1300 & C \end{cases}$$

Source: Afonso and St Aubyn (2004).

Figure 3.3: Free disposable hull frontier



Source: Afonso and St Aubyn (2004).

Grigoli and Kapsoli (2018) state that the FDH is a special case of DEA methodology with the difference being that the FDH uses a non-convex production technology. That is, the FDH's input-output combinations are not located on the convex production frontier. In other words, the input-output combination points connecting DEA vertices are not similar to the FDH's combination points. However, as with DEA, as a non-parametric tool, the FDH is extremely sensitive to presence of outliers which define the frontier. It also does not address the random variation in the data and measurement errors which become part of the inefficiency. Moreover, under the FDH method, multiple DMUs are on the frontier with each one being fully efficient due to the non-convex nature of the production frontier. On the other end, the convexity of the DEA's frontier means that only few DMUs are technically efficient, making it ideal for comparative analysis. The FDH enjoys the same benefits and drawbacks of the DEA since they are both form a taxonomy of non-parametric models.

3.3 REVIEW OF EMPIRICAL PUBLIC SECTOR EFFICIENCY STUDIES

The discussion on parametric and non-parametric efficiency estimation methods in Sections 3.2.1 and 3.2.2 provides intuition and insights about these tools and their relevance. Given the main objective of this thesis, DEA is fit for the job as it is able to determine the individual DMU's efficiency performance relative to its peers. Section 3.3 reviews the extant public education and health sector efficiency estimation studies that are based on the DEA methodology. Aristovnik (2012) states that DEA literature on public sector efficiency measurement is ubiquitous the world over. Therefore, this provides the current study with an opportunity to conduct a sound literature review. As reported earlier, DEA can be used in different ways to determine efficiency, depending on the interests and objectives of the researcher and the study.

The reviewed education and health sector DEA efficiency studies are summarised in Appendices 2 and 3 respectively. As reported earlier, DEA can be used to evaluate efficiency in a global way by covering all or at least several services that are provided by governments. On the other hand, there are DEA studies that evaluate only a particular service. When assessing the productive efficiency of the DMUs in the public service, most empirical studies in Appendices 2 and 3 use actual total expenditure as an input. These studies also use financial and non-financial inputs to measure the efficiency of the education and health sectors. The mostly used financial indicators in these sectors are the total education and health expenditure. In the education sector, the commonly used non-financial indicators include labour or personnel related indicators, such as the teacher-to-pupil ratio, the number of employed teachers, administrative staff and students per class. The capital related indicators, such as the number of classrooms, computers and average class size are also widely used as physical inputs. On the output front, the education output indicators include the school enrolment rate, quality of education results in maths and science and school completion rates. The analysed studies in Appendices 2 and 3 also use labour and capital related input variables for the health sector. In terms of the former, they include the number of staff employed in the health institutions such as doctors and nurses. The capital related indicators include surgical equipment, the number of beds, detention wards and staff working hours. The health output indicators include the number of inpatient and outpatient visits, antenatal and postnatal visits, baby deliveries and performed operations. The infant mortality rate, life expectancy, adult survival rate, hospital discharges, immunisation and disease prevalence or incidence are also used as output indicators.

3.3.1. Education sector efficiency studies

As reflected in Section 3.3, Appendices 2 and 3 summarise the essential features of the selected education and healthcare DEA studies. This study reviews 13 previous DEA studies that assessed the efficiency of the education sector. These studies are summarised in Appendix 2. The said studies outline aspects that provide important efficiency insights to enable the current study to achieve its intended objectives. Arias Ciro and Torres Garcia (2018) adopted a two-stage DEA methodology involving a three-input and two-output production technology. They assessed the efficiency of secondary education in 37 developing and developed countries between 2012 and 2015. They used a VRS model with output-maximisation orientation. The teacher-to-pupil ratio, government and private expenditure as a percentage of Gross Domestic Product (GDP) were used as inputs. The learner enrolment rates, and reading or literacy, mathematics and science results were selected as the output variables. The study used two models to control for possible input estimations. In the first model, private and government expenditure as percentage of GDP were used as inputs for all the selected output measures and the second model used the teacher-to-pupil ratio as a single input. In Model 1, nine per cent of the analysed countries emerged as efficient. In Model 2, eight countries were efficient. Inefficient developed and developing countries could increase the enrolment rates respectively by 21 and 22 per cent for Model 1 and 2 while maintaining the same input levels. This implied the average efficiency rates of 79 and 78 per cent respectively for both models. In the second stage, the study showed that the inclusion of an exogenous regressor variable (adult educational attainment) changed the efficiency scores that were obtained in the first stage.

In the same year, Halkiotis et al. (2018) used a single-stage DEA methodology to evaluate the efficiency of 23 high schools in Greece with data from 2015. They used three inputs: the teacher-to-student ratio, average number of students per class and average annual expenditure per pupil. They also included four outputs, percentage of students admitted to university and higher technology institutions, the number of students obtaining the best university entrance results and those not admitted to higher education institutions. Only eight of the 23 schools achieved the maximum technical efficiency level. The sample mean technical efficiency was 80 per cent, meaning the required reduction of inputs by 20 per cent. Another study by Gavurova et al. (2017) used a single-input and three-output production function to measure the technical efficiency of secondary education in 31 European (EU) countries for 2015. The secondary education expenditure as a percentage of GDP was the single input variable. The output variables were results for mathematics, science and reading disciplines. The authors used an output-maximisation model assuming VRS. The pure technical efficiency results showed an average score of 96 per cent with seven countries defining the pure technical efficiency frontier. Therefore, inefficient DMUs could increase their output levels by 4 per cent at the prevailing levels of expenditure as a proportion of GDP. In 2016, two additional studies by Lauro et al. (2016) and Yuan and Shan (2016) respectively assessed the efficiency of education in Brazil and China. The former study adopted a two-stage DEA considering 465 elementary Rio de Janeiro schools as DMUs using 2011 data. It selected four non-financial variables as inputs. The input variables were employed teachers, school staff, computers and classrooms. It also used the number of students served by schools, the average pass rate and standardised scores as three selected output measures. The study applied the VRS model with an output-maximisation orientation. It found that 30 schools achieved pure technical efficiency, 65 were purely technically efficient and 30 were scale efficient. 430 schools were under DRS and 5 were classified as IRS. In stage 2, the study used regression analysis to identify the variables that had an impact on efficiency.

Yuan and Shan (2016) used a single-stage DEA model to determine the efficiency of 17 Shanghai districts. They applied the CRS and the VRS models adopting the input-minimisation and output-maximisation approaches. Total budget per capita, equipment budget per capita and the teacher-to-pupil ratio were elected as inputs. The quota of students per school, per class and student density were used as outputs for a period between 2008 and 2012. The study adopted four DEA models, Model 1 was based on the input-minimisation approach using the CRS, Model 2 adopted an output-maximisation orientation using the CRS, Models 3 and 4 were under the assumption of the VRS based on the same orientations respectively. The mean efficiency scores for these models were 85, 85, 88 and 93 per cent respectively. The study concluded that five districts achieved technical efficiency in Models 1 and 2 and six were purely technically efficient in Models 3 and 4.

Two separate studies by Huguenin (2015) and Hussain et al. (2015) also applied DEA methodology to evaluate the efficiency of the education sector. The first study used a two-stage DEA methodology while the second one used a single-stage approach. The study by Huguenin (2015) analysed the efficiency of 90 primary schools in Switzerland from 2010 to 2011. It considered a six-variable efficiency frontier. The selected input variables were the number of full-time equivalent teaching staff, administrative staff and the overall school budget. The three output measures were grades 2, 4 and 6 results for French and mathematics. The VRS model with an input-minimisation orientation was assumed. The study revealed that, on average, each school could reduce its inputs by 7 per cent while maintaining the same quality of pupil performance. In the second stage, the efficiency scores were regressed with school characteristics and environmental variables; these were the external factors that were outside the control of the head teachers. The research by Hussain et al. (2015) assessed the efficiency of six rural and six urban schools for a period of 20 years using a five input-output production function. The inputs were the number of employed teachers and institutes and basic infrastructure (such as electricity, water, toilets, boundary walls and buildings). The two selected outputs were the school enrolment and student-teacher ratios. The study observed an average efficiency rate of 84 per cent under the CRS. The average pure technical efficiency score was 92 per cent under the VRS. Lavado and Domingo (2015) sampled 38 Asian countries for a period of seven years. They used a single input, education expenditure per capita and two-outputs, the percentage of pupils completing primary and secondary education to evaluate the efficiency of these countries. The study adopted the CRS and the VRS models with both the input-minimisation and output-maximisation orientations. The inefficient countries overspent by 27 per cent at prevailing output levels and they also had scope to raise their outputs by 6 per cent using the same levels of expenditure.

In 2014, Baciu and Bolezat (2014) used DEA to gauge the efficiency of public expenditure in 27 EU member states from 2000 to 2009. The study used the composite input and output indicators to aggregate the inputs and outputs of various sectors to calculate the efficiency of the public sector. In terms of the education sector, total education expenditure was the single input variable while the secondary school enrolment rate and mathematics and science results were used as outputs. The study used an input-minimisation orientation based on the CRS and the VRS models. The results indicated that from a sample of 27 countries, four were best performers and the remainder were at the bottom of the efficiency rankings. The average efficiency rate was 67 per cent, calling for a reduction in total education expenditure by 33 per cent. In the same year, Salazar Cuéllar (2014) appraised the efficiency of public spending in 15 Latin American countries using cross-country data between 2000 and 2009. A mixture of financial (public expenditure per student) and non-financial (percentage of teachers per student) inputs were employed. Three output variables were studied, the youth literacy, net student enrolment and completion rates. The study enabled efficiency assessment of each output indicator for primary and secondary education by applying the input-minimisation and output-maximisation orientations based on the VRS. The output-oriented results showed that inefficient countries could increase the primary education output indicators by 3 to 4 per cent with the same public spending per student at primary level. The input-minimisation results reflected that inefficient countries in the region wasted between 37 and 45 per cent of resources to achieve the prevailing output levels. In terms of secondary education, inefficient countries could, on average, increase the secondary school enrolment and its quality by 6 to 10 per cent, with the same public spending per student. In terms of inputs, inefficient countries wasted between 32 and 44 per cent to achieve the same output levels.

In terms of the 13 education studies that were reviewed in Section 3.3.1, the VRS DEA model featured prominently. Ten of these studies used education expenditure together with the other non-financial variables as inputs to the production process. This underscores the importance of this variable in education sector efficiency measurement. Four of 13 analysed education studies by Gavurova, et al. (2017), Lavado and Domingo (2015), Baciu and Bolezat (2014) and Aristovnik (2011) in Appendix 2 used expenditure as a single input. Therefore, in technical efficiency literature, the expenditure variable is mostly complemented by other variables when determining the technical efficiency of education provision. Seven of the 13 studies directly link with the purpose of the current study as they also adopt an input-minimisation orientation. The seven studies were conducted by Halkiotis et al. (2018), Yuan and Shan (2016), Huguenin (2015), Lavado and Domingo (2015), Baciu and Bolezat (2014), Salazar Cuéllar (2014) and Aristovnik (2011).

3.3.2. Health sector efficiency studies

Appendix 3 summarises 21 DEA health efficiency studies that are reviewed in this section. The first study in Appendix 3 was conducted by Campanella et al. (2017) who adopted a two-stage DEA to assess the technical efficiency of 50 Italian hospitals using three inputs and three outputs. The selected inputs were the number of beds, medical doctors and nurses per admitted patient. The 3 output variables were the levels of mortality rates related to pneumonia, heart failure and myocardial infarction. The CRS model was used. Therefore, the study disregarded scale by assuming that all hospitals were homogeneous in the provision of secondary healthcare. It also assumed the same with respect to the use of inputs and outputs. As a result, the VRS assumption was eliminated. The input-minimisation orientation was adopted for the study to determine how inputs could be contracted given the level of outputs. The results illustrated an average efficiency score of 77 per cent, meaning a requirement to reduce inputs by 23 per cent for inefficient DMUs to achieve efficiency. The study also analysed the other exogenous factors having a bearing on hospital efficiency.

Another study by Lo Storto and Goncharuk (2017) considered a seven variable production function. They used the number of practicing medical doctors, nurses, midwives and healthcare assistants and hospital beds as three inputs. The four output indicators were served population, infant mortality rate, number of healthy lives at birth and life expectancy. Data was collected over a period of four years from 2011 to 2014 for 32 EU countries. The study specified two models. Model 1 was based on the CRS with an input-minimisation orientation and it used the first three inputs and served population as an output. Model 2 was based on an output-maximisation orientation and it employed the ratio of infant mortality to population as an input and healthy life years and life expectancy as the outputs. The results for Model 1 ranged from 64 per cent in 2011 to 66 per cent in 2014 for the best performing DMUs. This meant that all inefficient DMUs could have reduced the use of inputs by 36 and 34 per cent between 2011 and 2014. The mean efficiency scores for Model 2 for the same period were 32 and 44 per cent respectively. The inefficient DMUs should increase outputs by 68 and 56 per cent respectively.

Alhassan et al. (2015) applied a two-stage DEA to assess the technical efficiency of 64 health facilities in Ghana. They used five variables as inputs of the health efficiency frontier. The inputs were the number of clinical staff, support staff, patient observations, detention wards and consulting rooms. The four selected outputs comprised of the number of baby deliveries, outpatient, family planning and child health visits. The study assumed the CRS in Model 1 and the VRS in Model 2 based on an input-minimisation orientation. The input-minimisation approach was considered because the DMUs had more control over the inputs than the outputs. The study found that 31 per cent of 64 health facilities were efficient relative to their peers and 44 or 69 per cent of the studied DMUs were inefficient. The DEA results also showed the average technical efficiency score of 65 and 85 per cent for Model 1 and 2, meaning reductions in the use of inputs by 35 and 15 per cent respectively for both models.

Jarjue et al. (2015) contributed to DEA efficiency literature in the African continent. They used a four variable production technology to determine the technical efficiency of 41 secondary healthcare centres in The Gambia. The inputs were the average number of full-time health staff and beds at each healthcare centre. They also used the number of admitted patients and outpatients from 2011 to 2012 as outputs. The study applied an output-maximisation BCC DEA model to consider scale effects in the production of health outputs. The mean efficiency score of the study was 65 per cent, meaning that inefficient DMUs could still maximise outputs by 35 per cent. The outcomes of the study showed that 22 per cent of the studied healthcare centres in The Gambia were efficient and 78 per cent were inefficient. 10 per cent of DMUs were scale efficient while 90 per cent were scale inefficient with a mean score of 87 per cent. Elsewhere, Asandului et al. (2014) analysed the efficiency of the health systems of 30 EU countries in 2010. They used three input variables, the number of doctors and hospital beds and public health expenditure as a percentage of GDP. On the output side, they used life expectancy at birth, health adjusted life expectancy (HALE) and infant mortality rates as outputs. They used an input-minimisation orientation for the CRS and the VRS methods. They also tested for the robustness of the results by dropping one variable in each model. In Model 1, they used the HALE and the infant mortality rates. The outputs of the second model were life expectancy and the infant mortality rates while employing aforementioned three input variables. The Model 1 results showed an average efficiency score of 74 per cent for the CRS and 75 per cent for the VRS. In this model, 20 per cent or six of the 30 countries were efficient. The results of Model 2, yielded a slightly different efficiency score of 81 per cent for the CRS approach and 77 per cent for the VRS and seven of the 30 countries were efficient.

Asandului and Fătulescu (2014) evaluated the efficiency of health systems of 27 EU countries using data collected in 2008. They used a four-variable production technology. Their choice of inputs was public health expenditure and the non-immunised rate. They employed the rate of Tuberculosis (TB) or its incidence and the adult survival rate as the two output indicators. An input-minimisation CRS-DEA model was adopted. The model identified five countries on the efficiency frontier. 14 countries had efficiency scores of below 50 per cent, needing to reduce their input usage by more than 50 per cent to be efficient. The remaining countries had the efficiency levels of above 50 per cent, with the most efficient in this category being Germany with an efficiency score of 0.95.

Another efficiency analysis study in the EU region was conducted by Baciu and Bolezat (2014) who assessed the health efficiency of 27 EU countries using data from 2000 to 2009. The study used a composite input and output indicator to aggregate the inputs and outputs of various sectors. In terms of the health sector, health expenditure was adopted as a single input variable while life expectancy and the infant survival rate were used as outputs. The study used an input-minimisation VRS-DEA model. The results showed four countries on the efficiency frontier. The average efficiency score was 60 per cent, showing more room by the inefficient DMUs to reduce the overall input usage by 40 per cent while maintaining the same output levels. Kim and Kang (2014) used DEA to consider four variables as inputs. The input variables were the average years of schooling for women over 15 years, total health expenditure, life expectancy at birth and mortality rate. This data was collected for 2007 and was used to analyse the efficiency of health care systems of 170 countries, including South Africa. The research adopted an input-minimisation CRS-DEA model which ascertained that only 17 per cent of the countries used inputs efficiently in the provision of healthcare. The Asian countries were the most efficient, South Africa was amongst the inefficient countries with an efficiency score of 84 per cent, wasting about 16 per cent of inputs. The high and upper middle-income countries had efficiency scores of over 70 per cent. The lower-middle income and lower income countries recorded average efficiency scores of 67 and 66 per cent respectively.

Anton (2013) measured the technical efficiency of 20 healthcare systems in Eastern and Central Europe. Three inputs, the number of hospital beds and physicians and total health expenditure per capita were considered. Two outputs were employed, infant deaths per life births and years of life expectancy at birth. The study adopted an output-maximisation BBC DEA model. It found the overall mean efficiency score of 98 per cent for life expectancy and 82 per cent for infant mortality for all the DMUs in the studied health systems. Another study by Prasetyo and Zuhdi (2013) investigated the efficiency of health provision in 81 countries, including South Africa from 2006 to 2010. The study adopted a four variable production technology comprising of the health subsidies, government expenditure per capita, other health transfers and life expectancy at birth as a measure of the Human Development Index (HDI). The study chose an input-minimisation orientation given the objective of comparing the expenditure efficiency of the selected DMUs. It adopted a VRS DEA model and it observed that 17 countries or 21 per cent of DMUs were efficient in using government expenditure to maximise the HDI. South Africa had an efficiency rate of 94 per cent.

Another study by Varabyova and Schreyögg (2013) applied a two-stage DEA to assess the efficiency of healthcare in 31 Organisation for Economic Co-operation and Development (OECD) countries using input and output data from 2000 to 2009. The study elected six non-financial variables: the number of hospital beds, hospital staff, physicians and employed nurses. Only two output variables were considered, the number of patient discharges and the mortality rate. The study used nine environmental variables to explain their impact on the efficiency results. The paper also used the input-minimisation and output-maximisation orientations based on the CRS. The mean efficiency score was over 70 per cent, indicating possible input contraction of 30 per cent or less and possible output expansions by the same proportions.

In another study, Chowdhury et al. (2010) analysed the technical efficiency of 113 acute care hospitals in Ontario, Canada from 2003 to 2006. The study used six input variables: staff working hours, nursing working hours, number of beds, medical costs for surgical supplies, nonsurgical supplies and total equipment cost. The number of inpatient days and the total number of outpatient visits were used as the output variables. A VRS-DEA method was used. The efficiency results showed that, over the period under consideration, most Ontario hospitals were not technically efficient, 65 per cent were subject to DRS, 10 per cent to IRS and 25 per cent were CRS efficient. Another study by Marschall and Flessa (2009) used an eight-variable production technology to compute the efficiency of 20 healthcare centres in Burkina Faso. 2004 data was used in the analysis. The selected inputs were health personnel costs, annual depreciation of health equipment, vaccination costs and building area. On the output front, the number of general consultations, baby deliveries, immunisation and special services and family planning, pre-natal and post-natal consultations were used as variables. The first stage DEA analysis was based on the CRS and the VRS output-maximisation measures. The CRS approach found that 14 healthcare centres were efficient. The mean efficiency score was 91 per cent. The VRS approach yielded the mean efficiency score of 94 per cent. The second stage DEA analysis showed that efficient DMUs were closely located to the villages. That is, distance had a bearing on the technical efficiency of healthcare centres in Burkina Faso.

Akazili et al. (2008) applied DEA to calculate the technical efficiency of 89 randomly sampled healthcare centres in Ghana using data for 2004. The study used the number of non-clinical staff, clinical staff, beds and cots and expenditure on drugs and supplies as inputs. The output measures were: the general number of outpatient visits, antenatal care visits, child deliveries, immunised children and family planning visits. The study employed an input-minimisation orientation. The findings showed grave inefficiency in healthcare delivery by public healthcare centres. 65 per cent of health centres were technically inefficient and they used the resources they did not need. Amongst the inefficient healthcare centres, 24 per cent had technical efficiency scores of less than 50 per cent. 27 per cent of DMUs had efficiency scores of between 50 and 74 per cent. The inefficient health centres had an average technical efficiency score of 57 per cent, implying that, on average, they could reduce the utilisation of all their inputs by about 43 per cent without reducing the prevailing output levels.

In another case, Benneyan et al. (2007) compared the efficiency of healthcare systems of 180 countries, including South Africa. The study used five inputs: the number of hospital beds and trained medical staff, total heath expenditure per capita, immunisation rate and median age. The exercise analysed six output variables:

healthy life expectancy at birth, adult mortality, infant mortality and TB prevalence rates, adverse event and equity. The study used the CRS and the VRS input-minimisation and output-maximisation approaches. It found that few countries were efficient, providing more opportunities for improvement through best practices. Countries that were inefficient, including South Africa accounted for 115 or 64 per cent. In Zambia, Masiye (2007) evaluated the efficiency of a sample of 30 hospitals using DEA model based on 2003 data. The study used the non-labour costs, number of medical doctors, administrative and non-administrative staff and nurses, laboratory technicians and pharmacists as inputs. The output measures were the number of performed operations, ambulatory visits, beds occupied by inpatients and baby deliveries. The study noted that the efficiency of hospitals was likely to be influenced by size and institutional or geographical constraints. As a result, the VRS model with an input-minimisation orientation was specified. The overall results showed that the Zambian hospitals operated at 67 per cent level of efficiency, implying that 33 per cent of input resources were being wasted. Only 40 per cent of hospitals were efficient in relative terms. The study further revealed that the size of hospitals was a major source of inefficiency.

In another case by Afonso and St Aubyn (2006) a two-stage DEA approach was used to compare the technical efficiency of health systems of 30 OECD countries for the period 2000 to 2003. The study used a seven-variable production function. In terms of inputs, the number of practicing physicians and nurses, beds and high-tech medical equipment were used. The output measures encompassed life expectancy at birth, the infant survival rate and potential years of lives not lost. The authors specified a VRS DEA model based on the output-maximisation orientation. They ascertained that seven countries were efficient and, on average, all inefficient countries could increase their efficiency by 40 percent. This study also showed that inefficiency in the health sector was strongly related to the variables that were beyond the control of governments. These variables were the GDP per capita, education level and unhealthy lifestyles. In Namibia, Zere et al. (2006) analysed the efficiency of 30 district hospitals using data from 1997 to 2001. The selected inputs were total recurrent health expenditure, the number of beds and nursing staff. The selected outputs were the number of outpatient visits and inpatient days. The study used the CRS and the VRS with an input-minimisation objective. The CRS results yielded efficiency scores ranging from 63 to 74 per cent over the period. The mean VRS efficiency scores ranged from 67 to 72 per cent for the same period. Less than half of the hospitals included in the study were located on the technically efficient frontier. IRS were a predominant form of scale inefficiency.

Another study by Gannon (2005), assessed the technical efficiency of 60 Irish hospitals using data covering six years. The average number of hospital beds and employed personnel per year were used as factors of production. The number of outpatient consultations per year and inpatient discharges were applied as outputs. The research adopted a CRS DEA model with an input-minimisation approach. The results showed the mean efficiency score of 96 per cent, thereby requiring the inefficient DMUs to curb input wastage by 4 per cent. In 2001, Kirigia, et al. (2001) analysed the efficiency of 155 public clinics in KwaZulu-Natal in South Africa using 1996 data. The study involved a 10-variable production function. The two selected inputs were the number of employed nurses and general staff. The eight outputs were the number of baby deliveries, antenatal care, child health care, dental care and family planning, psychiatry, sexually transmitted infections related care and TB related visits. The study used the CRS DEA and VRS DEA models based on the input-minimisation and the output-maximisation orientations. It ascertained that 47 clinics were technically efficient and 108 clinics were inefficient. The inefficient clinics had room to be efficient by reducing inputs and increasing outputs. The inefficient clinics should reduce the number of nurses by 417 and general staff by 457. These reductions represented 30.8 and 31.5 per cent inefficiency rates. The outputs should be increased by 115 534 antenatal care visits, 1 010 baby deliveries, 179 075 child health care visits, 5 702 dental care visits, 121 658 family planning visits, 56 068 psychiatry visits, 34 270 sexually transmitted infections related care visits: and 34 270 TB related visits. In the preceding year, Kirigia et al. (2000) analysed the efficiency of 55 provincial hospitals in KwaZulu-Natal. They used nine non-financial variables as inputs: the number of doctors, administration staff, nurses, general staff, provisioning staff, paramedics, technicians, other staff and beds. The four selected output variables were the number of inpatient days, outpatient visits, surgical operations and life births. The study used the input-minimisation orientation based on the VRS DEA model. The average technical efficiency rate was 91 per cent. All 22 DMUs that were inefficient needed to reduce the inputs as follows, 117 doctors: 295 administration staff, 2 709 nurses, 835 general staff, 1 191 provisioning staff: 61 paramedics, 58 technicians, 38 other staff members and 1 752 beds.

In terms of the 21 health studies that are in Appendix 3, both the CRS and/or the VRS are appropriate for analysing the efficiency of the health sector. The studies either used the CRS, the VRS or both. That is, in the analysis of the technical efficiency of the health sector, scale can be considered or ignored depending on the context of the study. Only six of the studies by Campanella et al. (2017), Lo Storto and Goncharuk (2017), Asandului et al. (2014b), Kim and Kang (2014), Varabyova and Schreyögg (2013) and Gannon (2005) considered only the CRS. Seven studies by Jarjue et al. (2015), Baciu and Bolezat (2014), Anton (2013), Prasetyo and Zuhdi (2013), Chowdhury et al. (2010), Masiye (2007), Afonso and St Aubyn (2006) considered the VRS. The other remaining eight studies by Alhassan et al. (2015), Asandului et al. (2014), Marschall and Flessa (2009), Akazili et al. (2008), Benneyan et al. (2007), Zere et al. (2006), Kirigia et al.(2001) and Kirigia et al. (2000) considered both the CRS and the VRS DEA models. Overall, 16 of these studies adopted an input-minimisation approach across various DEA models. Nine or 42.9 per cent of the 21 health studies used expenditure as one of the inputs of the production process together with the other non-financial inputs. The nine studies were conducted by Asandului et al.(2014), Asandului and Fătulescu (2014), Baciu and Bolezat (2014), Kim and Kang (2014), Prasetyo and Zuhdi (2013), Chowdhury et al. (2010), Marschall and Flessa (2009), Benneyan et al. (2007) and Masiye (2007). Only the study by Baciu and Bolezat (2014) used expenditure as a solitary input, this indicates the importance of other variables other than expenditure in calculating the efficiency of the health sector.

3.3.3. DEA model, data and orientation

Lauro et al. (2016) outline the important issues to be considered in model and data selection. A serious consideration for the selection variables for DEA technical efficiency analysis is the ability of DMUs to control those variables. For example, if DMUs do not have control over the output outcomes, the motivation for using an output-maximisation model is weakened. Despite provinces always striving to maximise education and healthcare outcomes, they do not always have control over those outcomes. The same is the case with inputs, depending on their nature education and health expenditure are commonly used inputs in technical efficiency analysis. Since the central theme of this study is to determine the technical efficiency of provincial education and health sectors, therefore, it cannot ignore selecting expenditure as one of the input variables. Moreover, once allocated, the education and health budgets are under the control of provinces. As with the extant studies, this study adopts an input-minimisation orientation. Given the wisdom to complement expenditure with other non-financial variables, the study will also elect non-financial variables in Chapter 4.

As reported in Chapter 2, education and health budgets are largely derived from the provincial equitable share formula. The formula allocates more funds to the education and healthcare sectors in provinces with large population densities. This information also shows that the size of the provinces and their socio-economic profile could also affect their technical efficiency levels. In other words, the VRS cannot be ignored. The technical efficiency literature that was discussed earlier advised researchers to complementary use the CRS and the VRS models for completeness. This is to also check the extent of the variability of the technical efficiency results and to control for potential over or under estimations of the efficiency outcomes. As a result, this study selects both the CRS and the VRS models with an input-minimisation orientation to assess the technical efficiency of provincial education and health sectors in South Africa. The current study measures relative provincial technical efficiency for benchmarking purposes rather than for determining causal-effect relationships between budget efficiency and output performance. As a result, it uses a single-stage DEA methodology which suffices to enable the study to achieve its intended objectives.

3.4 CONCLUSION

This chapter discussed and reviewed the different efficiency measurement methods of analysing technical efficiency. Given the objectives of this study and the multi-dimensional nature of selected variables, DEA is the appropriate method for measuring technical efficiency. The study also adopts a single-stage CRS and VRS DEA models whose details are outlined in Chapter 4. The present study is now equipped to select the input and output variables for efficiency measurement. However, the selection of the production technology is reserved for Chapter 4.

CHAPTER 4

METHODOLOGY

4.1 INTRODUCTION

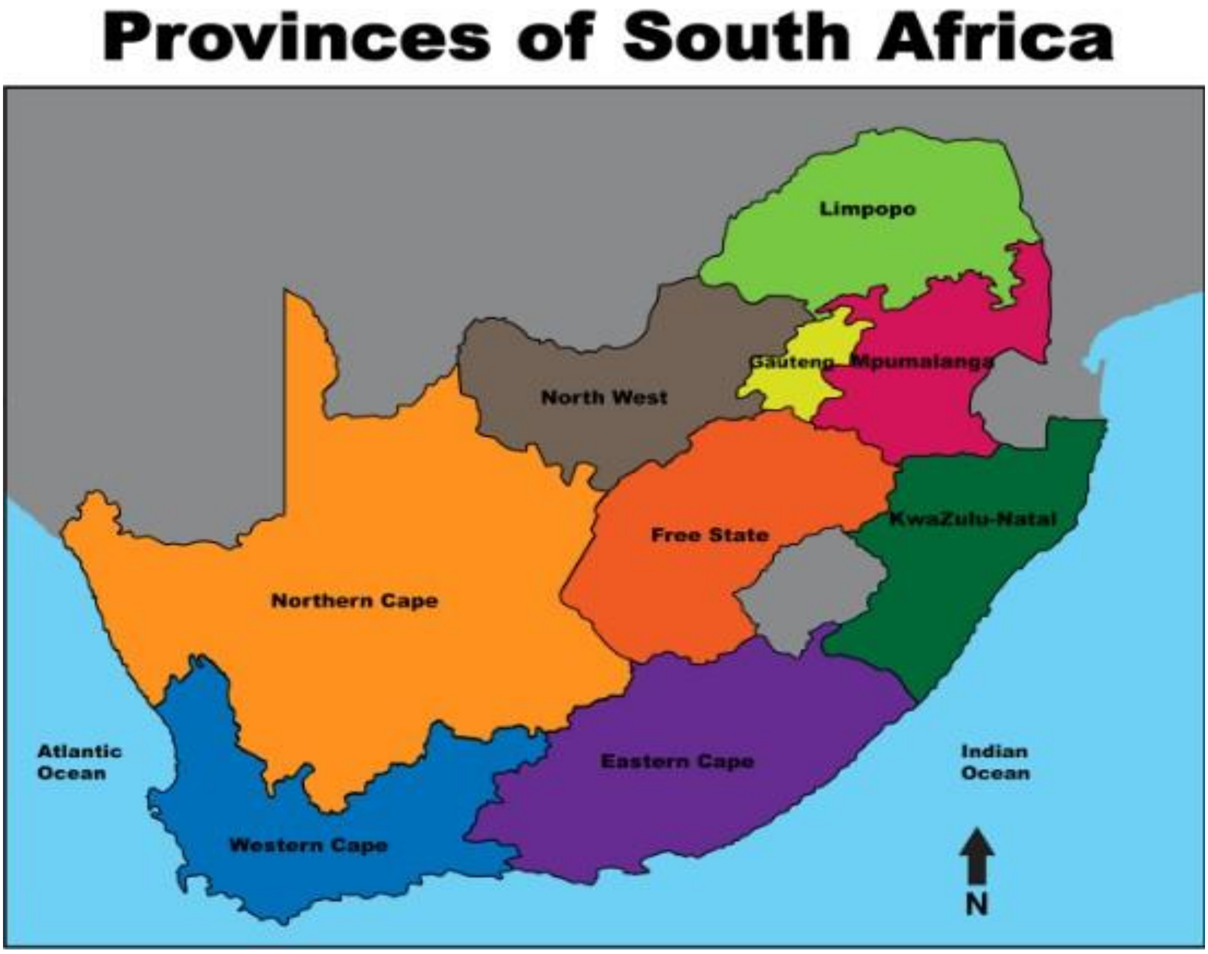
As reported in the previous chapters, the main purpose of this study is to determine and assess the technical efficiency of the provincial education and healthcare sectors in South Africa. As defined in Chapter 1, technical efficiency refers to optimal output that could be attained with minimum inputs. Therefore, for the education and health sectors, technical efficiency refers to optimal education and healthcare outputs that can be attained with the least possible inputs. Although there are several efficiency evaluation methods, based on the public sector technical efficiency literature that was reviewed in Chapter 3; this study adopted DEA to analyse the technical efficiency of the education and health sectors in South Africa. Through DEA, it is possible to determine technical efficiency from an input-minimisation and/or output-maximisation perspectives. For these orientations, technical efficiency can be considered through the CRS or/and the VRS. As already reflected in Chapter 3, the current study considers minimising the prevailing levels of education and health expenditure to the most efficient levels without reducing the current education and health output levels. This implies an input-minimisation orientation. Chapters 2 and 3 report that, given the varying size of provinces and their varied budgets, their technical efficiency is likely to be affected by scale effects. As a result, the current study assesses both technical and pure technical efficiencies. This can only be achieved methodologically through the CRS and the VRS DEA specifications respectively.

Chapter 4 discusses the current study's focus area and specifies the empirical DEA technical efficiency analytical model used to achieve the objectives of the study. Section 4.2 summarises the context of the education and health sectors within which DMUs or provinces operate. Section 4.3 outlines the DEA analytical framework and Section 4.4 specifies the DEA model to be used in Chapter 5 to measure the technical efficiency of provincial education and health sectors. Section 4.5 discusses data and its properties and presents justifications for input and output selection. Section 4.6 concludes on methodological issues and sets the tone for Chapter 5.

4.2 STUDY CONTEXT

As reported in Chapter 2, Section 103(1) of the Constitution recognises nine provinces. These are the Eastern Cape, Free State, Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga, Northern Cape, North West and Western Cape. These provinces are depicted in Figure 4.1.

Figure 4.1: The map of South Africa and its provinces



Source: Department of Cooperative Governance and Traditional Affairs (2019).

As reported in Chapters 1 and 2, the assessment of technical efficiency of education and healthcare systems is very important. Gavurova et al. (2017) note that these sectors contribute to economic and social well-being of individuals and nations. Educated people participate in the labour market while healthy people contribute to the country's positive health status and productivity. As a result, Afonso and St Aubyn (2006) and Afonso and Santos (2005) state that the technical efficiency of these sectors is expected to produce positive economic growth effects. Chapter 2 shows that provincial education and health sectors accounted for 73 per cent of total provincial expenditure of R570.3 billion in 2017/18. Table 4.1 shows their contributions to regional GDP.

Table 4.1: Gross domestic product, health and education contributions 2017/18

Provinces	GDP	% of GDP	Health spending % GDP	Education spending % GDP
Eastern Cape	247 040 000	8%	9%	13%
Free State	154 400 000	5%	6%	9%
Gauteng	1 080 800 000	35%	4%	4%
KwaZulu-Natal	494 080 000	16%	8%	10%
Limpopo	216 160 000	7%	9%	14%
Mpumalanga	216 160 000	7%	6%	9%
Northern Cape	61 760 000	2%	8%	10%
North West	185 280 000	6%	6%	8%
Western Cape	432 320 000	14%	5%	5%
Total	3 088 000 000	100%	6%	7%

Sources: Author's table based on Statistics South Africa (2017), National Treasury (2018a), (2018b), (2018c), (2018d), (2018e), (2018g), (2018h), (2018i), (2018j). Note: all figures except percentages are R'000.

4.2.1. Education sector

In terms of the education sector, Statistics South Africa (2016b) reports that the South African education system consists of three phases: primary (Grades R to 7, dealing with childhood development), secondary (Grades 8 to 12, preparing learners for tertiary education) and tertiary. Collectively, these phases have a duration of 12 years to complete. According to the Department of Basic Education (2018b), the South African education sector is divided into public and private components. Public education is largely funded by the state while private education is mostly funded by private payments. In 2018, the private education sector had 1 865 independent (private) schools with 589 348 learners and 38 660 educators, translating into an average LER of 15:1 per private school. Due to the high levels of unemployment and poverty in South Africa, most pupils are enrolled in public schools. As a result, this study focuses on the public sector component of the education system. Table 4.2 shows that, in 2018, South Africa had a total of 23 289 public schools in all provinces. Of these schools, 25 per cent or 5 849 were in KwaZulu-Natal, 22 per cent or 5 210 in the Eastern Cape, 17 per cent or 3 843 in Limpopo. These rural provinces accounted for 64 per cent of all public schools in South Africa. Gauteng had 2 077 public schools while the North West, Mpumalanga and the Western Cape collectively accounted for 5 765 or 25 per cent of all public schools, in slightly varying proportions. The Northern Cape had 2 per cent of total public schools. Table 4.2 also reflects that 12.2 million learners were enrolled in public schools in 2018. KwaZulu-Natal, Gauteng, Eastern Cape and Limpopo accounted for 69 per cent of these learners. These provinces together accounted for 68 per cent of the 398 789 teachers employed in public schools for the same period. The average LER in public schools was 31:1. Hofmeyer (2015) reports that the demand for teachers is based on learner enrolment rates and that the number of learners was expected to grow from 12.4 million in 2015 to 13.3 million in 2025 with 456 000 teachers by 2023.

Table 4.2: Number of public schools, learners and educators 2017/18

Province	Learners	% of Learners	Educators	% of Educators	Schools	% of Schools
Eastern Cape	1 775 602	15%	59 324	15%	5 210	22%
Free State	688 976	6%	22 640	6%	1 117	5%
Gauteng	2 109 890	17%	69 180	17%	2 077	9%
KwaZulu-Natal	2 773 823	23%	90 288	23%	5 849	25%
Limpopo	1 659 635	14%	51 640	13%	3 843	17%
Mpumalanga	1 026 151	8%	33 681	8%	1 751	8%
Northern Cape	291 461	2%	10 227	3%	545	2%
North West	820 545	7%	26 128	7%	1 454	6%
Western Cape	1 084 111	9%	35 681	9%	1 443	6%
Total	12 230 194	100%	398 789	100%	23 289	100%

Source: Department of Basic Education (2018b). Note: Percentages might not add up due to rounding.

Education expenditure is the single largest provincial expenditure budget item in South Africa. It accounts for 40 per cent of provincial budgets annually. Table 4.1 shows that spending in the provincial education sector accounted for 7 per cent of GDP in 2017/18. In the same year, provinces spent R227.6 billion on education. As reflected in Table 4.3, 79 per cent of this amount or R180.5 billion related to the public schools programme. The National Treasury (2018c) reported that this programme provides primary public schools with the required resources for Grades 1 to 7. It also provides secondary public schools with the required resources for Grades 8 to 12. The infrastructure development and administration segments collectively accounted for 12 per cent or R27.6 billion of provincial education spending. The infrastructure development programme provides for and maintains the administrative and infrastructure related educational facilities. The administration component provides support to core educational functions, the management, and the office of the MEC responsible for education. Table 4.3 also shows that, total current payments accounted for 88 per cent or R199.4 billion of public education expenditure in 2017/18. The compensation of employees' expenditure was 78 per cent or R178.5 billion of total current payments and goods and services spending for items such as books and stationery was 9 per cent or R20.8 billion. The transfers and subsidies to non-profit organisations to assist provinces to implement their programmes amounted to 15.3 billion. This was 7 per cent of total provincial budget on education in 2017/18.

Despite these high levels of education spending as a proportion of total provincial budgets, Bernstein (2011) states that, the South African education system was underperforming in the NSC examinations, particularly in mathematics and science learning disciplines. The Department of Basic Education (2018a) states that, of the 265 801 and 192 618 learners who respectively enrolled for mathematics and physical science in 2016, only 51 and 62 per cent passed. Moreover, only 34 and 40 per cent of these learners obtained pass rates of 40 per cent or more in these disciplines while 18 and 23 per cent of learners passed mathematics and science with pass rates between 30 and 39 per cent. According to Modisaotsile (2012) and Donohue and Bornman (2014), the general quality of the public sector education was poor and there were many signs of a crisis. The sector was marked by violence in schools, high learner enrolment rates alongside worrying dropout trends, high teenage pregnancy rates, and low high school completion rates coupled with increasingly poor grade 12 or NSC results. Statistics South Africa (2016b) states that the upper secondary school completion rate[15] was 55 per cent in 2016. The majority of learners who passed the NSC did not meet the minimum requirements to enrol for a bachelor's degree. The Department of Basic Education (2018a) shows that of the 610 178 learners who wrote

[15] Statistics South Africa (2016b) defines the upper secondary school completion rate is the percentage of students completing the last year of high school (Grade 12). It is calculated by taking the total number of students in Grade 12, divided by the total number of children of the official Grade 12 age.

the NSC in 2016, 442 672 passed (73 per cent) and 167 506 failed. Of the total NSC enrolment, 162 374 (27 per cent) qualified for a bachelor's degree, 179 619 (29 per cent) were eligible for a national diploma, 100 486 (17 per cent) qualified for a higher certificate programme and the rest were not eligible to be admitted to higher education. Despite the high NSC pass rate, the quality of the passes remained poor and the substantial expenditure on education was not being matched by the results. This statement implies the existence of expenditure inefficiencies in the education sector. Ramdass (2009) states that the main challenge is to improve the overall quality of education, however, this is a daunting task as schools were deprived of resources, facilities and qualified teachers. It is difficult to have efficiency, effectiveness and quality under these circumstances. One of the greatest challenge facing the South African education system is the inability to produce sufficient and competent teachers who can provide quality teaching for all school subjects and phases.

Table 4.3: Provincial education spending by function and economic classification: 2017/18

Provinces	Eastern Cape	Free State	Gauteng	KwaZulu-Natal	Limpopo	Mpumalanga	Northern Cape	North-West	Western Cape	Total	% of total
Administration	2 830 212	983 333	2 997 416	1 778 866	1 816 011	1 284 422	636 850	876 615	1 582 575	14 786 300	6%
Public ordinary school education	26 829 214	10 328 833	31 422 394	40 343 213	24 945 546	15 880 365	4 421 392	11 277 299	15 069 228	180 517 484	79%
Independent school subsidies	122 559	94 056	691 636	86 038	126 973	2 100	9 169	29 613	107 578	1 269 722	1%
Public special school education	743 562	517 404	2 411 902	1 112 083	484 368	297 430	142 428	579 668	1 247 693	7 536 538	3%
Early childhood development	626 226	153 537	765 459	999 780	189 281	281 253	95 002	561 760	551 337	4 223 635	2%
Infrastructure development	1 672 194	877 994	2 124 840	2 414 834	1 227 770	1 084 795	623 578	1 068 308	1 760 553	12 854 866	6%
activities	520 676	579 578	1 372 895	1 551 602	465 976	704 712	140 927	714 218	403 729	6 454 313	3%
Total	**33 344 643**	**13 534 735**	**41 786 542**	**48 286 416**	**29 255 925**	**19 535 077**	**6 069 346**	**15 107 481**	**20 722 693**	**227 642 858**	**100%**
Current payments	**29 030 383**	**11 293 067**	**35 761 988**	**44 596 525**	**25 873 183**	**17 213 924**	**5 047 985**	**12 843 280**	**17 696 591**	**199 356 926**	**88%**
Compensation of employees	25 964 676	10 396 889	31 401 688	40 498 770	23 226 074	15 504 849	4 651 988	11 603 213	15 258 313	178 506 460	**78%**
Goods and services	3 065 707	895 895	4 360 270	4 096 848	2 647 109	1 709 020	395 899	1 239 971	2 438 278	20 848 997	**9%**
Interest on land and rent	-	283	30	907	-	55	98	96	-	1 469	**0%**
Transfers and subsidies	**2 601 286**	**1 516 808**	**4 099 362**	**1 787 832**	**2 167 268**	**1 402 892**	**472 658**	**1 240 932**	**1 999 578**	**17 288 616**	**8%**
Departmental accounts and agencies	64 052	30 124	84 639	89 497	70 008	46 643	6 373	14 653	7 279	413 268	**0%**
Non-profit institutions	2 302 312	1 405 693	3 600 662	1 577 772	1 880 317	1 028 520	416 896	1 167 456	1 886 700	15 266 328	**7%**
Households	234 832	80 991	414 061	118 743	216 586	327 281	49 389	58 823	105 599	1 606 305	**1%**
Other transfers and subsidies	90	-	-	1 820	357	448	-	-	-	2 715	**0%**
Payments for capital assets	**1 712 974**	**717 403**	**1 912 412**	**1 870 166**	**1 215 474**	**918 261**	**548 703**	**1 023 269**	**1 021 083**	**10 939 745**	**5%**
Buildings and other fixed structures	1 479 346	674 114	1 736 152	1 835 438	1 156 373	911 447	504 787	985 144	962 345	10 245 146	**5%**
Machinery and equipment	216 641	35 289	127 693	29 990	59 101	6 814	28 265	38 125	58 723	600 641	**0%**
Other capital items	16 987	8 000	48 567	4 738	-	-	15 651	-	15	93 958	**0%**
Payments for financial assets	**-**	**7 457**	**12 780**	**31 893**					**5 441**	**57 571**	**0%**
Total economic classification	**33 344 643**	**13 534 735**	**41 786 542**	**48 286 416**	**29 255 925**	**19 535 077**	**6 069 346**	**15 107 481**	**20 722 693**	**227 642 858**	**100%**

Sources: National Treasury (2018a), (2018b), (2018c), (2018d), (2018e), (2018g), (2018h), (2018i), (2018j). Note: Expenditure is in R'000.

4.2.2. Health sector

Coovadia et al. (2009) and Mayosi and Benatar (2014) indicate that South Africa's health outcomes were worse than in many low-income countries. This was exacerbated by inadequate human resources to cater for a growing population amidst rising number of refugees and economic migrants. As a result, there is a growing concern about the state of the public health system, its efficiency and capability to provide sustainable services. The South African healthcare sector is also comprised of public and private segments that are deep-rooted in the past unjust policies of Apartheid, which caused disparities in healthcare access between black and white citizens. Marten et al. (2014) report inequitable access to health services between the poor majority and the rich minority in South Africa. This situation still persists. However, the current divides are generally between the rich and the poor, irrespective of race.

The Government of the Republic of South Africa (2018) states that, overall, the health sector had 813 hospitals with 133 387 beds for acute healthcare. The public sector accounted for 49.7 per cent or 404 of these hospitals and 69 per cent of total bed allocation. The private sector accounted for 409 or 50.3 per cent of these hospitals and 31 per cent of the total number of beds. These numbers clearly point to inequality between the private and public hospitals and may further hint at a shortage of public health infrastructure. These statistics translate into 81 188 people per public hospital per year with an average of 228 beds per public facility. The Competition Commission (2019) states that, in 2018, the vulnerable and poorly resourced public healthcare facilities served approximately 83 per cent of the population who were largely without medical insurance. The private healthcare facilities served 17 per cent of the population with private healthcare insurance.

According to the Government of the Republic of South Africa (2018), there is a substantial difference in resource availability between the public and private health sectors. More than half of the financial and human resources were allocated to the private sector. The public health sector is structured into five layers: primary healthcare (clinics), district; regional, provincial and central or tertiary (academic) hospitals. Mayosi and Benatar (2014) add that many state hospitals were in a dire state with much of public healthcare infrastructure run down and dysfunctional due to underfunding, mismanagement, and neglect. This compromised the quality of healthcare and often lead to earlier than required patient discharges. Moreover, the National Treasury (2018f) reports that the provincial health departments were faced with contingent liability risks associated with medical-legal claims due to negligence by health professionals. In 2017/18, this liability was estimated at R80 billion, up 32 per cent from 2016/17. Pay-outs against these claims amounted to R1.5 billion in 2017/18 and were projected to exceed R2 billion in 2018/19. On the other hand, the Government of Republic of South Africa (2018) reports that South Africa was working towards the provision of free publicly funded quality universal healthcare (UHC) or the National Health Insurance (NHI) by 2030. Therefore, the NHI could require additional financial and human resources prompting the efficient use of existing funding resources.

Marten, et al. (2014) indicate that, aside from the institutional structure of the healthcare system, inefficiencies and inadequate public health infrastructure, another Achilles heel was the absolute and chronic deficit of health workers in the country. Table 4.4 shows that healthcare workers were unevenly distributed along the health qualification categories and geographical areas. This uneven distribution of staff and skills, according to Coovadia et al. (2009), compromised the ability to deliver key programmes, notably for HIV and AIDS, TB, child, mental and maternal health. Mayosi and Benatar (2014) mention that nurses are central to healthcare, especially in rural areas where physicians are reluctant to practice. Table 4.4 also shows that, in 2018, the nursing personnel accounted for 143 264 or 63 per cent of total health personnel while medical practitioners, specialists and researchers accounted for 19 988 or 9 per cent. Despite medical doctors being a small component of total health workers, 70 per cent were employed in the private sector, implying shortages in the public sector. Moreover, Mayosi and Benatar (2014) state that government’s increased investment in the medical profession produced more doctors over the years, but a brain drain reversed these gains. South Africa incurred the highest costs for medical doctor education but in turn lost returns on investment as doctors migrated to Europe. 30 per cent of South African doctors have emigrated and 58 per cent were intending to emigrate to Western countries. 24 per cent or 54 180 of health personnel was attributed to community health workers and 4 per cent to other health personnel categories.

Table 4.4: Practicing health personnel by sector April 2018

Province	Pupil Auxiliary nurses	Student nurses	Enrolled nurses	Nursing assistants	Professional nurses	Medical practitioners	Medical researchers	Medical specialists	Other	Total	% of total
Eastern Cape	356	-	3 263	5 260	10 993	1 903	1	177	6 210	28 163	12%
Free State	76	-	939	1 972	2 295	664	5	293	2 954	9 198	4%
Gauteng	823	2 902	7 694	6 518	14 223	3 614	13	1 929	12 034	49 750	22%
KwaZulu-Natal	512	951	9 926	5 976	17 163	3 383	120	808	12 480	51 319	22%
Limpopo	64	470	4 085	4 731	9 409	1 248	12	60	12 389	32 468	14%
Mpumalanga	67	749	1 881	1 431	5 471	1 079	1	78	7 687	18 444	8%
Northern Cape	116	-	237	864	1 520	457	2	21	3 070	6 287	3%
North West	49	21	958	2 489	4 511	934	-	116	6 842	15 920	7%
Western Cape	225	-	2 608	4 152	5 314	1 719	6	1 345	5 622	20 991	9%
Total	2 288	5 093	31 591	33 393	70 899	15 001	160	4 827	64 965	228 217	100%

Source: Author's own table based on Health Systems Trust (2018). Note: other refers to clinical associates, community health workers, dental practitioners, therapists and specialists, environmental health workers, occupational therapists, pharmacists, physiotherapists, psychologists, radiographers and speech therapists and audiologists. The figures exclude national personnel. 83 per cent of the other category is community health workers.

The Health Systems Trust (2016) reports that another major challenge in the health sector was the high cost of providing medical care in South Africa. Moreover, the high public sector salaries and excessive administration costs; duplication of services and inefficiencies were a serious problem. Table 4.5 shows that health spending was concentrated in the same five provinces with high population statistics. Collectively, the Eastern Cape, Gauteng, KwaZulu-Natal, Limpopo and the Western Cape accounted for 80 per cent or R148.5 billion of total healthcare expenditure in 2017/18. In the same year, all provinces spent R186.9 billion on healthcare, of which 46 per cent or 86.2 billion was on the provision of district health services.

The National Treasury (2018a) states that the district health services include primary health care services for the prevention of illness and provision of basic curative health services, including the treatment of HIV, AIDS, Sexually Transmitted Infections (STIs), TB, maternal care, women's health and nutrition and control of communicable diseases. it also includes community and coroner services. The central and provincial hospital services were the second and third largest health spending components, respectively comprising 21 and 17 per cent of total health spending. Collectively, the district health services and the provincial and central hospital services accounted for 84 per cent or R157.2 billion of the entire provincial health spending. The National Treasury (2018c) states that hospital services include the district, regional and provincial hospitals catering for patients who require treatment by general practitioners or specialists. The central or tertiary hospitals are for sophisticated medical procedures at a national level and provide a platform for research and training of health workers.

In terms of spending by economic classification, Table 4.5 shows the provincial health sectors' current payments accounted for 91 per cent or R170.1 billion of total health spending in 2017/18, of which the compensation of employees was 61 per cent or R113.4 billion and goods and services such as medical supplies accounted for 30 per cent or R56.6 billion.

Table 4.5: Provincial health spending by function and economic classification: 2017/18

Provinces	Eastern Cape	Free State	Gauteng	KwaZulu-Natal	Limpopo	Mpumalanga	Northern Cape	North West	Western Cape	Total	% of total
Administration	663 403	273 065	1 025 754	882 614	310 271	410 294	229 329	371 787	703 526	4 870 043	3%
District health services	11 392 808	4 161 994	14 368 623	19 659 155	12 763 056	7 389 393	2 012 944	5 653 119	8 784 810	86 185 902	46%
Emergency medical services	1 359 928	757 200	1 495 093	1 403 117	728 879	379 810	330 635	319 477	1 034 293	7 808 432	4%
Provincial hospital services	3 276 014	1 268 346	8 033 715	10 728 960	2 423 542	1 347 606	348 750	1 692 362	3 420 957	32 540 252	17%
Central hospital services	3 816 133	2 303 073	15 837 183	4 755 928	1 779 857	1 177 393	1 021 272	1 654 902	6 082 824	38 428 565	21%
Health sciences and training	811 619	288 786	946 453	1 263 186	660 476	367 640	116 128	424 121	355 792	5 234 201	3%
Health care support services	119 235	155 017	279 529	221 476	154 490	212 276	100 456	436 616	456 212	2 135 307	1%
Health facilities management	1 331 999	587 710	2 146 018	1 515 727	702 172	1 161 281	562 643	867 828	832 723	9 708 101	5%
Total	**22 771 139**	**9 795 191**	**44 132 368**	**40 430 163**	**19 522 743**	**12 445 693**	**4 722 157**	**11 420 212**	**21 671 137**	**186 910 803**	**100%**
Current payments	**20 769 512**	**8 813 718**	**39 661 569**	**37 548 048**	**18 121 855**	**11 007 665**	**4 031 192**	**10 330 206**	**19 767 209**	**170 050 974**	**91%**
Compensation of employees	14 699 278	6 282 119	25 342 631	24 777 838	13 357 931	7 245 550	2 564 791	6 451 497	12 718 881	113 440 516	**61%**
Goods and services	6 067 691	2 530 434	14 318 938	12 767 311	4 763 924	3 761 843	1 463 550	3 877 100	7 048 328	56 599 119	**30%**
Interest on land and rent	2 543	1 165	-	2 899	-	272	2 851	1 609	-	11 339	**0%**
Transfers and subsidies	**692 108**	**248 072**	**1 921 204**	**1 194 477**	**748 951**	**388 046**	**169 086**	**247 357**	**1 202 753**	**6 812 054**	**4%**
Provinces and municipalities	4 181	1 089	739 104	225 894	25 046	519	7 373		520 679	1 523 885	**1%**
Non-profit institutions	6 596	72 095	698 608	142 226	421 398	193 466	114 445		459 340	2 108 174	**1%**
Households	670 318	100 274	451 619	807 083	279 048	187 178	47 265	227 404	202 644	2 972 833	**2%**
Other transfers and subsidies	11 013	74 614	31 873	19 274	23 459	6 883	3	19 953	20 090	207 162	**0%**
Payments: capital assets	**1 309 519**	**733 401**	**2 542 988**	**1 579 896**	**651 937**	**1 049 982**	**521 879**	**842 649**	**693 861**	**9 926 112**	**5%**
structures	610 535	498 816	1 191 599	972 667	184 609	851 531	324 941	717 106	287 948	5 639 752	**3%**
Machinery and equipment	698 984	218 175	1 351 389	607 229	467 328	198 451	196 938	125 543	397 398	4 261 435	**2%**
Other capital items	-	16 410	-	-	-	-	-	-	8 515	24 925	**0%**
Payments: financial assets	**-**	**-**	**6 607**	**107 742**	**-**	**-**	**-**	**-**	**7 314**	**121 663**	**0%**
Total economic classification	**22 771 139**	**9 795 191**	**44 132 368**	**40 430 163**	**19 522 743**	**12 445 693**	**4 722 157**	**11 420 212**	**21 671 137**	**186 910 803**	**100%**

Sources: National Treasury (2018a), (2018b), (2018c), (2018d), (2018e), (2018g), (2018h), (2018i), (2018j). Note: Expenditure is in R'000.

4.3 ANALYTICAL FRAMEWORK

Chapter 3 discusses parametric and non-parametric methods of production efficiency measurement. In the same chapter, their advantages and disadvantages are also presented. This chapter further discusses DEA, the most famous non-parametric method. DEA has its origins in the microeconomic production context, where it was applied to firms to convert inputs into outputs. Therefore, DEA is simply based on the tenets of the production theory of firms rather than on predetermined statistical or economic theory. So, DEA can assess technical efficiency where there is no known relationship between the studied variables. That is, DEA is adept at measuring technical efficiency even in the absence of information on correlation coefficients. DEA only requires the researcher to obtain the relevant input and output data, specify the technical efficiency estimation models to measure and present the technical efficiency results. Cook et al. (2014) and Nieswand and Seifert (2011) report that DEA is able to simultaneously handle multiple inputs and outputs provided that, the number of DMUs is at least double or triple the aggregated number of inputs and outputs. Therefore, DEA is a model for assessing many DMUs, inputs and outputs in the computation of relative technical efficiency. It measures radial and slack movements between the actual DMU performance and the ideal technical efficiency position. It provides information about which elements of the production technology are to be adjusted for reaching technical efficiency. DEA gives decision makers relevant information to improve their production processes. In the context of this study, through the application of DEA, it will be possible to determine which provinces are more or less efficient in the performance of the education and health functions.

As reflected in Chapter 3, DEA is based on two models, the CCR and the BCC models. There are various DEA models that can be distinguished by scale and by model orientation. The selection of an appropriate DEA model to measure technical efficiency depends on the objectives of the efficiency analysis. If a study intends to maximise the output production while holding the inputs constant, then an output-maximisation orientation is relevant. If the objective of a particular study is to minimise costs while maintaining the same level of outputs, then an input-minimisation orientation is appropriate. As reflected in Chapter 3, depending on the objectives of the study, if there are no concrete assumptions on whether or not to consider scale, the safe approach is to use both the CRS and the VRS to test for the variability of the efficiency results and to remove subjectivity in model selection and errors in specification. Suffice to indicate that the VRS method is the most comprehensive and accurate. It captures most technically efficient DMUs than the CRS dispensation.

4.3.1. Charnes, Cooper and Rhodes (CCR) Model

As reported in Chapter 3, Adler et al. (2002) report that DEA converts a fractional linear efficiency estimate into a linear program. Coelli et al. (2005) state that the CCR proposed a model that is input-oriented under the assumption of the CRS. Under this model, if there are M different number of inputs and P different number of outputs for N DMUs. These quantities are represented by column vectors x_{ij} (i = 1, 2, 3, …M, j = 1,2,3 …N) and q_{rj} (r = 1, 2, 3, …P, j = 1,2,3 …N) The $M \, x \, N$ input matrix, X and $P \, x \, N$ output matrix, Q represent the production technology for all the N number of DMUs. For each DMU, the ratio of all the output variables over all the input variables is represented by $u'q_{rj}/v'x_{ij}$. Where $u = P \, x \, 1$ vector output weights and $v = M \, x \, 1$ vector input weights. As explained earlier, the optimal weights or the efficiency estimates are obtained by solving a mathematical problem. In the context of the CRS, efficient DMUs operate at MPSS or TOPS. Hence, the optimal weights or efficiency estimates are obtained by solving a mathematical problem that is reflected in Equation 4.1.

$$Tops = \max_{u,v} (u'q_{rj}/v'x_{ij})$$

$$St.$$

$$u'q_{rj}/v'x_{ij} \leq 1 \qquad (4.1)$$

$$u, v \geq 0$$

Equation 4.1 shows the original linear program, called the primal. It aims to maximise the efficiency score, which is represented by the ratio of all weights of outputs to inputs, subject to the efficiency score not exceeding 1, with all inputs and outputs being positive. Equation 1, has an infinite number of solutions, if (u,v) is a solution, so is αv,αv. To avoid this, one can impose a constraint $v'x_{ij}$ =1, which produces Equation 4.2.

$max_{u,v}$ (u'qrj)

$St.$

v'xij =1 (4.2)

u'qrj - v'xij ≤ 0

u, v ≥ 0

An equivalent envelopment problem can be developed for the problem in Equation 4.2, using duality in linear programming. The dual for $max_{u,v}$ (u'qrj) is $min\theta, \lambda\theta$. The value of θ is the efficiency score; it satisfies the condition $\theta \leq 1$; it is the scalar measure. Lauro et al. (2016) say that λ is an $NX1$ vector of all constants representing intensity variables indicating necessary combinations of efficient entities or reference units (peers) for every inefficient DMU, it limits the efficiency of each DMU to be greater than 1. This results in Equation 4.3, which represents the CCR-CRS model with an input minimisation orientation.

$Min\theta, \lambda\theta$

$St.$

-qrj + $Q\lambda \geq 0$ (4.3)

θxi - $X\lambda \geq 0$

$\lambda \geq 0$

Avkiran (2001) states that the CRS postulates no significant relationship between the operational size and efficiency of DMUs. That is, the large DMUs attain the same levels of efficiency as small DMUs in transforming inputs to outputs. Therefore, the CRS assumption implies that the size of DMUs is not relevant when assessing technical efficiency.

4.3.2. Banker, Charnes and Cooper (BCC) Model

As reflected in Chapter 3, Gavurova et al. (2017) mention that in 1984, Banker et al. generalised the CCR formulation to allow for the VRS, this is called the BCC model. Lavado and Domingo (2015) argued that, in practice, there is a plethora of factors such as financial constraints that may result in the DMUs not operating at optimal scale. Aristovnik (2012) adds that, if one cannot assume the existence of the CRS, then a VRS type of DEA is an appropriate choice for computing efficiency. Gannon (2005) advises that the VRS should be used if it is likely that the size of a DMU will have a bearing on efficiency. As such, Yawe (2014) cautions that the use of the CRS specification when DMUs are not operating at an optimal scale results in a measure of technical efficiency which is confounded by scale effects. The solution is to use the VRS as it permits for the calculation of scale inefficiency. The CRS linear programming problem can be modified to account for the VRS by adding the convexity constraint: $N1'\lambda = 1$ to Equation 4.3, where $N1$ is an $Nx1$ vector of ones to formulate Equation 4.4. Equation 4.4 represents the BBC VRS model with an input-minimisation orientation. Therefore, Equations 4.1 to 4.3 represent the CRS models while Equation 4.4 represents the VRS models.

$Min\theta, \lambda\theta$

$St.$

-qrj + $Q\lambda \geq 0$ (4.4)

θxij - $X\lambda \geq 0$

$N1'\lambda = 1$

$\lambda \geq 0$

Lauro et al. (2016) and Yuan and Shan (2016) report that the CCR and the BCC models only differ in that the latter includes convexity constraints. The BCC is adept to calculate pure technical efficiency and inefficiency and when applied with the CCR model, it also measures scale inefficiency. Where, $\sum_{i=1}^{I} \lambda I = 1$, a DMU is on a CRS frontier, if $\sum_{i=1}^{I} \lambda I < 1$, the DMU is located on the IRS frontier and if $\sum_{i=1}^{I} \lambda I > 1$, there is DRS. This study has adopted both the CCR and the VRS with an input-minimisation orientation.

As explained in Chapter 3, a DEA model for the current study calculates the slack movements for the inefficient DMUs. These are considered in Equation 4.5. Gavurova et al. (2017) maintain that Sr^{+} and Si^{-} are respectively the output and input slacks that are calculated with θ and λn. ε, is the non-Archimedean constant. In Equation 4.5, slack movements determine the optimal level of inputs that the inefficient DMUs would further reduce if they are still inefficient after radial movements have occurred. If the model is VRS based, the restriction $\sum_{j=1}^{N} \lambda j = 1$ is introduced. If the restriction is not there, it would imply the CRS model.

$$\text{Min } \theta, \lambda j, Sr^{+}, Si^{-}$$

$$\theta - \varepsilon \left[\sum_{i=1}^{M} Si^{-} + \sum_{r=1}^{P} Si^{+} \right]$$

$St.$

$$\theta \text{x}i_0 - \sum_{j=1}^{N} \text{x}ij\, \lambda j - Si^{-} = 0, \qquad \sum_{j=1}^{N} \text{x}ij\, \lambda j = X\lambda \tag{4.5}$$

$$\theta \text{q}r_0 = \sum_{j=1}^{N} \text{q}rj\, \lambda j - Sr^{+} = 0, \qquad \sum_{j=1}^{N} \text{q}rj\, \lambda j = Q\lambda$$

$$\sum_{j=1}^{N} \lambda j = 1$$

$$\lambda j, Sr^{+}, Si^{-} > 0$$

4.4 MODEL SPECIFICATION

To specify the model for this study, there are nine provinces ($Pj,\ j = P1, P2 \ldots \ldots .. P9$) whose efficiency is to be evaluated using the CCR and the BCC models. If there are Z different number of inputs and Y different number of outputs for the 9 provinces. These variables are represented by column vectors xij (i = 1, 2, 3, …Z, j = P1,P2,P3 …P9) and qrj (r = 1, 2, 3, …Y, j = P1,P2 ,P3 …P9). The $Z\ x\ N$ input matrix, X and $Y\ x\ N$ output matrix, Q represents the entire input-output matrix combinations of all the nine provinces. For each province, the ratio of all the output variables over all the input variables is represented by u’qrj/v’xij. Where u $= Y\ x\ 1$ vector output weights and v $= Z\ x\ 1$ vector input weights.

For each province, the ratio of all outputs and inputs is denoted by u’qrj/v’xij. Given that the measure of technical efficiency is the weighted ratio of all outputs over all inputs in a sample, the primal equation of the model of this study is exactly similar to CCR-CRS specification that is represented by the Equation 4.1 in Section 4.3.1 except that the model to determine the technical efficiency of the nine provinces in South Africa has multiple inputs and a single output. So, the primal for the current study's model is adjusted to be represented by Equation 4.6. The technical efficiency (CRS) scores of the nine provinces are determined by Equations 4.6 to 4.8; while the pure technical efficiency scores are generated through Equation 4.9. Equation 4.10 calculates the input and output slack variables. All the variables contained in these equations are defined in Sections 4.3.1 and 4.3.2.

Tops = $\max_{u,v}$ (u'qrj/v'xij)

$St.$

u'qrj/v'xij ≤ 1 (4.6)

u, v ≥ 0

maxu,v (u'qrj)

$St.$

v'xij =1 (4.7)

u'qrj - v'xij ≤ 0

u, v ≥ 0

$Min\theta, \lambda\theta$

$St.$

-qrj + $Q\lambda \geq 0$ (4.8)

θxij - $X\lambda \geq 0$

$\lambda \geq 0$

$Min\theta, \lambda\theta$

$St.$

-qrj + $Q\lambda \geq 0$ (4.9)

θxij - $X\lambda \geq 0$

$N1'\lambda = 1$

$\lambda \geq 0$

$\text{Min } \theta, \lambda j, Sr^{+}, Si^{-}$

$$\theta - \varepsilon \left[\sum_{i=1}^{Z} Si^{-} + \sum_{r=1}^{Y} Sr^{+} \right]$$

$St.$

$$\theta \mathrm{x}i_0 - \sum_{j=\mathrm{P1}}^{P9} \mathrm{x}ij\, \lambda j - Si^{-} = 0, \qquad \sum_{j=\mathrm{P1}}^{P9} \mathrm{x}ij\, \lambda j = X\lambda \qquad (4.10)$$

$$\theta \mathrm{q}r_0 = \sum_{j=P1}^{P9} \mathrm{q}rj\, \lambda j - Sr^{+} = 0, \qquad \sum_{j=P1}^{P9} \mathrm{q}rj\, \lambda j = Q\lambda$$

$$\sum_{j=P1}^{P9} \lambda j = 1$$

$$\lambda j, Sr^{+}, Si^{-} > 0$$

4.5 INPUT AND OUTPUT DATA

Outputs are defined by Parida and Kumar (2009) as the actual products or services of a production process. Input variables are comprised of various resources, such as human resources (labour), capital assets (such as tools, plant and equipment) and financial inputs (expenditure) that are used to produce final products or services. The study selects financial and non-financial input variables for technical efficiency analysis. The 2017/18 provincial audited annual reports are the sources of information for non-financial inputs of the health sector. The non-financial education inputs are obtained from the Department of Basic Education (2018b). The financial inputs for both sectors are obtained from the 2017/18 estimates of provincial revenue and expenditure signed off by the accounting officers of these provinces and submitted to the National Treasury. The education and health outputs for all the sectors are derived from the 2017/18 annual reports. All the selected variables are the actual attained inputs and outputs, as Afonso et al. (2010) maintain that technical efficiency determination involves the comparison of actual and estimated inputs and outputs.

As reflected in Chapter 3, Afonso et al. (2010) note that it is very difficult to select the appropriate public sector inputs and outputs. However, it is necessary to choose the appropriate variables as the accuracy of their selection is important in public sector efficiency measurement. The reviewed technical efficiency literature for education and health sectors are benchmarks used by this study for selecting the relevant inputs and outputs. The literature permits the use of physical and financial inputs in technical efficiency measurement. However, Bray et al. (2015) warn that DEA is sensitive to the number of inputs, outputs and DMUs that are included in technical efficiency analytical model. Marschall and Flessa (2009) add that it is necessary to avoid the inappropriate ratio between these variables. As reported earlier, Cook et al. (2014) and Nieswand and Seifert (2011) recommend that the number of DMUs should be at least double or triple the aggregated number of inputs and outputs to prevent the overestimation of technical efficiency scores.

All the reviewed studies in Appendices 2 and 3 upheld the aforementioned golden rule. In their case, they mostly selected a large number of DMUs relative to the aggregated number of inputs and outputs. However, given the limitation of the sample size of the current study, in that there are only nine provinces in South Africa, this prompts for a decision to restrict the aggregated number of inputs and outputs in each sector to three. Given this reality, it is important to select the most representative and relevant inputs. As a result, a two-input and single-output production technology is selected for the education and health sectors. Asandului et al. (2014) maintain that, over the years, the technical efficiency of education and healthcare systems have become synonymous with expenditure. Therefore, increasing their expenditure technical efficiency is unavoidable. It is necessary to alleviate the burden of allocating additional funds to these sectors. Moreover, Appendices 2 and 3 reflect that education and health expenditure are commonly used input variables for technical efficiency determination in these sectors. Given the objective of the current study, these are the default variables.

In terms of the non-financial inputs, Appendix 3 shows that, for the health sector, personnel related input variables such as the total number of staff, doctors, nurses, practitioners, provisioning, general staff and hospital beds are prevalently used for technical efficiency determination. As it relates to the current study, the meaningful data that could be obtained consistently across the provincial audited annual reports are personnel variables: total number of staff, doctors, nurses and nursing assistants. However, to capture all staff categories, in addition to total health expenditure, the study resolves to select the total number of health sector staff as the second input variable. However, in Chapter 5, the health sector model will first be run with health expenditure as a single input, followed by total health staff and then a model that includes both. This will be done using the CRS and the VRS resulting in six health sector models. These various models are used to test for the variability of the technical efficiency results. Table 4.5 illustrates that the total health sector's compensation of employees' accounted for 61 per cent of total health spending in 2017/18. This compensation bill is directly linked to total number of health sector staff, therefore, THE and THS are relevant for analysing provincial health sector efficiency.

In terms of the education sector, the reviewed literature also shows that personnel or human resource variables such as the number of teachers and/or students are prevalently used in the education sector as input variables. There are some other capital or infrastructure related variables that are used in literature but are not as common as the personnel related variables. In addition to TEE, the study also selects the LER in public schools as the second education variable. This is ratio of total number of learners to teachers per school. As with the health sector, the education sector model will be run six times resulting in six models. Therefore, the study considers twelve models; six in each sector. As reflected in Table 4.3, the consolidated expenditure on public education was 79 per cent of total provincial expenditure. On the other end, the aggregated compensation of employees' expenditure accounted for 88 per cent of total provincial education expenditure in 2017/18. Therefore, the number of learners and educators are good proxies for all the provincial education inputs.

As it relates to health and education output indicators. Based on available data, the study selects the RIMR as an output variable for the health sector. The commonly used indicators such as inpatient admissions and outpatient consultations were not available consistently across the board. For the output of the education sector, the study selects a public secondary school results measure, represented by the number of PSNSC pass rate ≥ 60 per cent. This reflects the quality of the results that are obtained by each secondary public school. This output selection is also justified by the common use of the school completion and pass rates as outputs in the reviewed literature (Appendix 2) as well as its importance in education discourse in South Africa. The selected input and output variables are summarised in Table 4.6. Given that the study considers two sectors: education and health, each sector will go through the models separately. Moreover, the models will consider the CRS and the VRS specifications from an input minimisation perspective. The details of these models will be presented in Chapter 5.

Table 4.6: Selected inputs and outputs for health and education

Sector	Input variables	Description	Output variables	Description
Education	Total education expenditure (TEE): X1 = TEE	Total education expenditure measured in R'000	The number of public secondary schools with National Senior Certificate pass rate of ≥ 60 percent. PSNSC with pass rate ≥ 60 per cent =Y1.	Number of public secondary schools obtaining NSC results of 60 per cent or above.
	Learner to educator ratio: X2 = LER	public ordinary schools divided by the total number of educators employed in the same sector.		
Health	Total health expenditure (THE): H1 = THE	Total health expenditure measured in R'000.	Reduced Infant mortality rate (RIMR): Y2 = RIMR	The number of deaths per 1,000 live births of children under one year of age.
	Total number of staff in the health sector (THS): H2 = THS	Total number of people employed in the health sector.		

Source: Author's own table.

The numerical data for the aforementioned input and output variables are reflected in Table 4.7. The sample consists of nine provinces of South Africa. The high standard deviations in the data (except for the LER) reflects that their distributions are not normal and have marked variations. The LER has a standard normal distribution with a variance of 1. The education expenditure ranges from R6.1 billion for the Northern Cape to R48.3 billion for KwaZulu-Natal. There are slight variations in the number PSNSC with pass rate ≥ 60 per cent. KwaZulu-Natal records the maximum number of schools in this regard. High variations are also observed with respect to health expenditure across provinces. The minimum health expenditure of R4.7 billion is in the Northern Cape with Gauteng spending the sample maximum of R44.1 billion. There are also major variations in the number of total health staff per province.

Table 4.7: Efficiency input and output data and descriptive statistics

Provinces	Education inputs		Education output	Health inputs		Health output
	x1 (TEE)	*x2 (LER)*	*y1(SNSC)*	*x1 (THE)*	*x2 (THS)*	*y1(RIMR)*
Eastern Cape	33 344 643	30	523	22 771 139	40 424	14
Free State	13 534 735	30	312	9 795 191	17 301	11,8
Gauteng	41 786 542	30	835	44 132 368	66 124	10,1
KwaZulu-Natal	48 286 416	31	1243	40 430 163	68 125	12,4
Limpopo	29 255 925	32	814	19 522 743	33 848	12,4
Mpumalanga	19 535 077	30	445	12 445 693	20 421	9,7
Northern Cape	6 069 346	28	114	4 722 157	6 924	11,6
North West	15 107 481	31	364	11 420 212	17 536	8,1
Western Cape	20 722 693	30	413	21 671 137	31 549	9,3
Observations	9	9	9	9	9	9
Mean	25 293 651	30	563	20 767 867	33 584	11
Minimum	6 069 346	28	114	4 722 157	6 924	8
Maximum	48 286 416	32	1 243	44 132 368	68 125	14
Median	20 722 693	30	445	19 522 743	31 549	12
Standard deviation	13 110 046	1	323	12 794 907	20 302	2

Sources: Department of Basic Education (2018b), Department of Education of Province of KwaZulu-Natal (2018), Department of Education of Province of Mpumalanga (2018), Eastern Cape Education (2018), Free State Department of Education (2018), Free State Department of Health (2018), Gauteng Department of Education (2018), Gauteng Department of Health (2018), KwaZulu-Natal Department of Health (2018), Limpopo Department of Education (2018), Limpopo Department of Health (2018), Mpumalanga Department of Health (2018), Northern Cape Department of Education (2018), Northern Cape Department of Health (2018), North West Department of Education (2018), North West Department of Health (2018), Western Cape Government Education (2018), Western Cape Government Health. National Treasury (2018a), (2018b), (2018c), (2018d), (2018e), (2018g), (2018h), (2018i), (2018j). Notes: descriptive statistics are Author's calculation and total expenditure is measured in R'000.

4.6 CONCLUSION

This chapter presented the structure and challenges of the education and health sectors. It also provided justification for selecting THE, TEE, THS, the LER and the number of PSNSC with pass rate ≥ 60 per cent and the RIMR as the input and output variables of this study. It further motivated the use of the CRS and VRS DEA models to achieve the objectives of this study. Therefore, this chapter enables the study to determine and assess the technical, pure technical and scale efficiency of provincial education and health in South Africa in Chapter 5.

CHAPTER 5

EMPIRICAL ANALYSIS

5.1 INTRODUCTION

As reported in Chapter 4, the empirical technical efficiency analysis of this study is based on the input-minimisation orientation of the CRS and the VRS DEA models in the education and health sectors. Chapter 5 analyses TEE, LER, THE and THS that could potentially be minimised by the provinces to reach the optimal efficiency frontier; while holding the RIMR and PSNSC with a pass rate ≥ 60 per cent constant. In this chapter, technical, pure and scale efficiency for the education and health sectors are calculated using Data Envelopment Analysis Program (DEAP) Version 2.1 described by Coelli (1996). Given the chosen inputs for each sector, the 12 models alluded to in Chapter 4 are summarised in Table 5.1.

Table 5.1: Provincial education and health efficiency determination models

Model	DEA Model	Number of variables	Variable description
Education Model 1	CRS	2	Total education expenditure and PSNSC with a pass rate ≥ 60 per cent
Education Model 2	CRS	2	Learner-to-educator ratio and PSNSC with a pass rate ≥ 60 per cent
Education Model 3	CRS	3	Total education expenditure, learner-to-educator ratio and PSNSC with a pass rate ≥ 60 per cent
Education Model 4	VRS	2	Total education expenditure and PSNSC with a pass rate ≥ 60 per cent
Education Model 5	VRS	2	Learner-to-educator ratio and PSNSC with a pass rate ≥ 60 per cent
Education Model 6	VRS	3	Total education expenditure, learner-to-educator ratio and PSNSC with a pass rate ≥ 60 per cent
Health Model 1	CRS	2	Total health expenditure and reduced infant mortality rate
Health Model 2	CRS	2	Total health staff and reduced infant mortality rate
Health Model 3	CRS	3	Total health expenditure, total health staff and reduced infant mortality rate
Health Model 4	VRS	2	Total health expenditure and reduced infant mortality rate
Health Model 5	VRS	2	Total health staff and reduced infant mortality rate
Health Model 6	VRS	3	Total health expenditure, total health staff and reduced infant mortality rate

Source: Author's compilation. Notes: CRS = Constant Returns to Scale and VRS = Variable Returns to Scale.

Given the technical background, the study proceeds to analyse and present the technical and scale efficiency scores of the education and health sectors in Sections 5.2 and 5.3. However, prior to analysing the efficiency results, an important reminder from Chapter 3 is that, according to Fried et al. (2008), the efficiency results that are calculated through the VRS are always higher than the CRS results. This is because the VRS efficiency frontier is formed by the best convex efficient producer combinations and it envelops data tighter than the CRS. Put differently, the number of efficient firms on the VRS efficiency frontier are always higher than on the CRS frontier.

This increases the average efficiency scores of the studied DMUs. The opposite is the case in respect to the CRS efficiency frontier.

The other important concepts to be revisited are radial and slack movements that were defined in Chapter 3. Marschall and Flessa (2009) and Coelli et al. (2005) define slacks as input excesses and output shortfalls that are required above the original radial movements to steer DMUs to technical efficiency levels, post the radial shifts. Radial movements are initial input contractions or output expansions that are required for a firm to become efficient. Both slack and radial movements are only characterised with inefficient DMUs. Efficient DMUs with any slacks movements depict weak efficiency and require further radial movements. The next section discusses the efficiency results of the six education models that are summarised in Table 5.1.

5.2 EDUCATION SECTOR: DEA EFFICIENCY RESULTS

Table 5.2 contains provinces in column 1. The efficiency results of the six education models are presented in columns 2 to 7. The scale efficiencies are presented in the last column and the associated sub-columns.

Table 5.2: Provincial education technical and scale efficiency models

Province	Education Model 1	Education Model 2	Education Model 3	Education Model 4	Education Model 5	Education Model 6	Scale efficiency					
Eastern Cape	0,565	0,435	0,584	0,589	0,970	0,970	0,959	IRS	0,448	IRS	0,602	IRS
Free State	0,855	0,259	0,855	0,962	0,951	0,969	0,889	IRS	0,273	IRS	0,882	IRS
Gauteng	0,726	0,694	0,774	0,730	0,997	0,997	0,994	DRS	0,696	IRS	0,776	IRS
KwaZulu-Natal	0,923	1,000	1,000	1,000	1,000	1,000	0,923	DRS	1,000	-	1,000	-
Limpopo	1,000	0,634	1,000	1,000	0,933	1,000	1,000	-	0,680	IRS	1,000	-
Mpumalanga	0,834	0,370	0,834	0,888	0,963	0,963	0,939	IRS	0,384	IRS	0,866	IRS
Northern Cape	0,677	0,102	0,677	1,000	1,000	1,000	0,677	IRS	0,102	IRS	0,677	IRS
North West	0,865	0,293	0,865	0,948	0,925	0,949	0,912	IRS	0,317	IRS	0,911	IRS
Western Cape	0,736	0,343	0,736	0,791	0,960	0,960	0,930	IRS	0,358	IRS	0,766	IRS
Mean	0,798	0,459	0,814	0,879	0,967	0,979	0,914		0,473		0,831	

Source: Author's calculations derived from DEAP 2.1.

5.2.1 Education sector efficiency scores

Table 5.2 shows an average efficiency score of 79.8 per cent for the Education Model 1. Therefore, on average, there are eight inefficient provinces with room to minimise their TEE usage by 20.2 per cent; while maintaining the same output levels that are reflected in Table 4.7. The Limpopo Province is the only technically efficient DMU in 2017/18. This province spends R29 billion while maintaining 814 PSNSC with a pass rate ≥ 60 per cent. Limpopo's output is almost equal to Gauteng's output; however, Gauteng has TEE of R41.8 billion with 835 PSNSC with a pass rate ≥ 60 per cent, corresponding with its technical efficiency score of 72.6 per cent. Three provinces, Mpumalanga, Free State and the North West have technical efficiency scores of more than 80 per cent. They need to reduce their TEE by less than 20 per cent while respectively maintaining 445, 312 and 364 PSNSC with a pass rate ≥ 60 per cent. KwaZulu-Natal is very close to the efficiency frontier with an average score of 92.3 per cent with 1 243 PSNSC and a pass rate ≥ 60 per cent. The Eastern Cape is the least technically efficient province in this model. It has TEE of R33 billion with 523 PSNSC and a pass rate ≥ 60 per cent. The Northern Cape and the Western Cape have mean technical efficiency scores of 67.7 and 73.6 per cent respectively with 114 and 413 PSNSC and a pass rate ≥ 60 per cent. Figure 5.1 in Appendix 5 graphically represents the distribution of the technical efficiency scores for the Education Model 1.

Table 5.2 also indicates an average efficiency score of 45.9 per cent for the Education Model 2, meaning that eight inefficient provinces need to reduce the LER by 54.1 per cent while maintaining the same output levels. In this model, KwaZulu-Natal is the only technically efficient province with the LER of 31:1. Limpopo's technical inefficiency is 36.6 per cent. Its loss of prime position in this model is explained by a slightly higher LER of 32:1 which exceeds the average LER of 31:1 per school. Moreover, KwaZulu-Natal has 5 849 public schools, the most of any province in South Africa. The Northern Cape is the least efficient with the LER of 28:1 (89.8 per cent inefficiency rate) per school with only 545 schools. Four provinces, the Eastern Cape, Free State, Mpumalanga and the Western Cape have the LER of 30:1 and the North West of 31:1. Their technical efficiency scores are below 50 per cent; so, they need to improve their LER efficiency by more than 50 per cent. The Gauteng Province records a technical efficiency score of 69.4 per cent, needing to improve its LER inefficiency by 26 per cent. The Education Model 2 results are lower than the Education Model 1 by 33.9 per cent. Therefore, TEE is a good proxy of all the education inputs than the LER, as it includes all provincial expenditure items. The LER only considers the number of leaners and educators. Figure 5.2 in Appendix 5 depicts the configuration of the Education Model 2 efficiency frontier.

In terms of Education Model 3, where both TEE and the LER are simultaneously used as inputs, they complement each other and result in the improved technical efficiency scores for all the DMUs. The average efficiency score is 81.4 per cent, with inefficient DMUs having to reduce TEE and LER by 18.6 per cent. In this model, Limpopo and KwaZulu-Natal are on the efficiency frontier with the North West, Free State and Mpumalanga very close to the frontier; recording efficiency scores above 80 per cent. They have to improve their technical efficiency by less than 20 per cent. The Eastern Cape is the least efficient of all the DMUs with a technical inefficiency score of 41.6 per cent. Gauteng, Western Cape and the Northern Cape Provinces have technical efficiency scores of 77.4, 73.6 and 67.7 per cent, respectively indicating technical inefficiency levels of 22.6, 26.4 and 32.3 per cent. The shape of the technical efficiency frontier for the Education Model 3 is represented in Figure 5.3 in Appendix 5.

Table 5.2 reflects an improved TEE average efficiency score of 87.9 per cent for Education Model 4 under the VRS. Therefore, all the six inefficient provinces should reduce the average usage of TEE by 12.1 per cent. KwaZulu-Natal, Limpopo and the Northern Cape are on the pure technical efficiency frontier. So, KwaZulu-Natal and the Northern Cape were disadvantaged in the Education Model 1 when size was not considered. In this model they are efficient when compared to DMUs of similar size. The Northern Cape is the most affected by scale. The Eastern Cape is the furthest from the efficiency frontier, needing to reduce TEE by 41.1 per cent. The Western Cape and Gauteng are the seventh and eight most inefficient provinces in the Education Model 4 efficiency frontier, with the respective technical inefficiency scores of 27 and 20.9 per cent. Therefore, the Eastern Cape, Western Cape and Gauteng’s technical inefficiency levels are neither size nor scale related but are due to the poor usage of TEE. Figure 5.4 in Appendix 5 illustrates the distribution of efficiency scores of this frontier.

The pure technical efficiency results of the provinces in the Education Model 5 also are contained in Table 5.2. It shows that with the use of the LER as a single input, the pure technical efficiency scores of DMUs are largely affected by the effects of scale. The average technical efficiency score of all DMUs is 96.7 per cent under the VRS while it was 45.9 per cent under the CRS assumption. KwaZulu-Natal and the Northern Cape are the only provinces that are purely technically efficient in this model. Despite this, all DMUs are very close to the efficiency frontier, with the North West, the least efficient province having to improve its pure technical efficiency rate by 7.5 per cent. The pure technical efficiency frontier of the Education Model 5 is represented by Figure 5.5 in Appendix 5.

The mean pure technical efficiency score for the Education Model 6 where TEE and the LER are conjointly used as inputs under the VRS is 97.9 per cent. In this model, only three DMUs are purely technically efficient. These are KwaZulu-Natal, Limpopo and the Northern Cape. The six inefficient DMUs have to reduce the use of TEE and the LER by 2.1 per cent. This indicates that, despite only a third of the DMUs being on the efficiency frontier, the other six inefficient provinces are also nearly as efficient. All of them are negatively affected by the effects of scale in the Education Model 3. The North West Province is the least efficient DMU in this model with an inefficiency score of 5.1 per cent. Figure 5.6 in Appendix 5 graphically illustrates the efficiency frontier for the Education Model 6.

Table 5.2 also shows the scale efficiency scores for the studied DMUs. Scale efficiency is derived by dividing the observed CRS technical efficiency scores by the VRS scores. The first sub-column of column 8 shows the scale efficiency scores for the Education Model 1 divided by the Education Model 4 results. The next sub-column shows the type of scale efficiency associated with these models. Therefore, the average scale efficiency score of all DMUs when TEE is used as a single variable is 91.4 per cent. This shows very high levels of scale efficiency with all DMUs needing to improve scale efficiency by 8.6 per cent. As reported earlier, a few of them are largely affected by scale when TEE is the only input in use. Only Limpopo is CRS scale efficient, providing a benchmark for all the scale inefficient DMUs. The Northern Cape is the most affected by scale having to improve it by 32.3 per cent. The same is the case for the Free State - it should increase scale efficiency by 11.1 per cent. Six DMUs exhibit IRS and they have potential to increase their current operational capacity to become scale efficient. Gauteng and KwaZulu-Natal have DRS, needing to curtail their TEE usage to benchmark against the educational outcomes of Limpopo. Also, in Table 5.2, the third sub-column of column 8 indicates the average scale efficiency rate of 47.3 per cent when LER is used a single input. 88.9 per cent or 8 of the DMUs are scale inefficient. They are all on the IRS frontier with only KwaZulu-Natal being scale efficient. The last two sub-columns of column 8 show that the employment of TEE and the LER result in an average scale efficiency score of 83.1 per cent. Only KwaZulu-Natal and Limpopo are scale efficient in this scenario.

5.2.2 Education sector radial and slack movements

Table 5.3 reflects the radial and slack movements of all the education sector's CRS models. In the Education Model 1, the TEE expenditure that could be reduced by the eight inefficient provinces to become efficient while maintaining their prevailing output levels is 43.6 billion (equivalent to 20.2 per cent TEE inefficiency rate). The Limpopo province sets the TEE usage efficiency benchmark. It technically efficiently spends R29 billion (100 per cent efficiency rate) with 814 PSNSC and a pass rate ≥ 60 per cent. The Eastern Cape, the least efficient DMU in the sample should reduce TEE by R14.4 billion (43.5 per cent inefficiency score) to become efficient. That is, given the 523 PSNSC with a pass rate ≥ 60 per cent, the Eastern Cape spends R14.4 billion more than it should. Therefore, the Eastern Cape accounted for 33 per cent of the overall provincial TEE inefficiency in 2017/18.

Gauteng has TEE inefficiency of R11.3 billion (72.6 per cent efficiency score) which is 26 per cent of the overall provincial TEE inefficiency. The Western Cape's overall provincial TEE inefficiency is 12.2 per cent or R5.3 billion, in line with its technical efficiency score of 73.6 per cent. These two provinces have to respectively reduce these inefficiencies while simultaneously maintaining 835 and 413 PSNSC with a pass rate ≥ 60 per cent. Despite KwaZulu-Natal being located very close to the technical efficiency frontier, it needs to reduce its TEE inefficiency by 7.7 per cent or R3.7 billion to become technically efficient given its 1 243 PSNSC and a pass rate ≥ 60 per cent. This means that KwaZulu-Natal is responsible for 8.5 per cent of provincial TEE inefficiency. Mpumalanga accounts for 7.1 per cent of overall provincial TEE wastage, it has to decrease TEE by R3.1 billion (associated with its technical inefficiency score of 6.6 per cent) at the prevailing output of 445 PSNSC with a pass rate ≥ 60 per cent.

The remaining four provinces account for 13.3 per cent of the overall provincial TEE inefficiency. The North West is spending R2 billion (3.5 per cent inefficiency score) more than it should, given the output of 364 PSNSC and a pass rate ≥ 60 per cent. The Free State should reduce TEE by R1.9 billion (4.5 per cent inefficiency score) while maintaining the output measure at 312 PSNSC with a pass rate ≥ 60 per cent. The Northern Cape should minimise TEE by R1.9 billion (32.3 per cent inefficiency score) to produce 114 PSNSC with a pass rate ≥ 60 per cent.

The very low average technical efficiency score of 45.9 per cent of DMUs in the Education Model 2 is associated with the required significant reductions in the LER reflected in Table 5.3. The Northern Cape, the furthest province from the efficiency frontier has to reduce the LER from 28:1 to 2.8:1 (89.8 per cent inefficiency score) while keeping the same level of output. The Free State should reduce this ratio to 7.8:1 (74.1 per cent inefficiency score) to become efficient at its prevailing output levels. The North West should have the LER of 9.1:1 (70.7 per cent inefficiency rate) instead of the current 31:1 to reach technical efficiency. The Western Cape's required efficient LER is 10.3:1 (65.7 per cent inefficiency score). Mpumalanga, Eastern Cape, Limpopo and Gauteng have to respectively reduce their LERs to 11.1:1, 13:1, 20.3:1 and 20.8:1 (67, 56.5, 36.6 and 30.6 per cent inefficiency rates respectively). All these inefficient provinces have to match KwaZulu-Natal's technical efficiency rate of 100 per cent. The reduction in the LER is in line with the adopted input-minimisation orientation, however, given that the LER is calculated by dividing the number of learners by the number of teachers, a reduction in the LER signifies increasing the denominator (the number of teachers). As a result, Appendix 6 shows that the LER radial movements imply the appointment of additional 491 569 teachers by all the eight inefficient provinces.

In terms of the Education Model 3, Table 5.3 shows the overall provincial TEE inefficiency of R37.3 billion (18.6 per cent average technical inefficiency score). This implies that when the LER and TEE are used conjunctively in the education production process, the overall efficiency of the DMUs increases. In the Education Model 1, the overall provincial TEE inefficiency is R43.6 billion. A reduction of R6 billion is due to an increase in the technical efficiency of the Eastern Cape, Gauteng and KwaZulu-Natal. In this model, the Eastern Cape has TEE and the LER inefficiencies of R13.7 billion and 12.5:1 that are related to the inefficiency score of 41.6 per cent. Gauteng has R9.3 billion and a requirement to decrease the LER to 23.2:1 in line with its inefficiency rate of 22.6 per cent. The Free State, Mpumalanga. Northern Cape, North West and the Western Cape have TEE inefficiency of R1.9 billion, R3.1 billion, R1.9 billion, R2 billion and R5.3 billion respectively. These provinces have to also reduce their LERs to 12.3:1, 17.5:1, 4.5:1, 14.3:1 and 16.3:1 respectively. The LER radial movements for this model imply the appointment of an additional 263 331 teachers by these six inefficient provinces as reflected in Appendix 6. This is linked to their overall mean inefficiency rates of 14.5, 16.6, 32.2, 13.5 and 26.4 per cent respectively in the use of TEE and the LER. In this model, the Eastern Cape and Gauteng should draw lessons from Limpopo and KwaZulu-Natal while the other provinces should learn from Limpopo as their peer DMU.

Table 5.3: Total education expenditure and learner-to-educator radial and slack movements: CRS

Provinces	Eastern Cape	Free State	Gauteng	KwaZulu-Natal	Limpopo	Mpumalanga	Northern Cape	North West	Western Cape	Total
Model 1: CRS TEE only										
Original input	33 000 000	13 000 000	41 000 000	48 000 000	29 000 000	19 000 000	6 000 000	15 000 000	20 000 000	224 000 000
Input radial movement	(14 367 000)	(1 885 000)	(11 252 000)	(3 716 000)	-	(3 146 000)	(1 939 000)	(2 032 000)	(5 286 000)	(43 623 000)
Input slack movement	-	-	-	-	-	-	-	-	-	-
Input target	18 633 000	11 115 000	29 748 000	44 284 000	29 000 000	15 854 000	4 061 000	12 968 000	14 714 000	180 377 000
Original output	523	312	835	1 243	814	445	114	364	413	5 063
Output radial movement	-	-	-	-	-	-	-	-	-	-
Output target	523	312	835	1 243	814	445	114	364	413	5 063
DMU peers	5	5	5	5	5	5	5	5	5	
Model 2: CRS LER only										
Original input	30	30	30	31	32	30	28	31	30	272
Input radial movement	(17,0)	(22,2)	(9,2)	-	(11,7)	(18,9)	(25,2)	(21,9)	(19,7)	(145,8)
Input slack movement	-	-	-	-	-	-	-	-	-	-
Input target	13,0	7,8	20,8	31,0	20,3	11,1	2,8	9,1	10,3	126
Original output	523	312	835	1 243	814	445	114	364	413	5 063
Output radial movement	-	-	-	-	-	-	-	-	-	-
Output target	523	312	835	1 243	814	445	114	364	413	5 063
DMU peers	4	4	4	4	4	4	4	4	4	
Model 3: CRS TEE and LER										
TEE original input	33 000 000	13 000 000	41 000 000	48 000 000	29 000 000	19 000 000	6 000 000	15 000 000	20 000 000	224 000 000
TEE radial movement	(13 734 000)	(1 885 000)	(9 255 000)	-	-	(3 146 000)	(1 939 000)	(2 032 000)	(5 286 000)	(37 277 000)
TEE slack movement	-	-	-	-	-	-	-	-	-	-
TEE target	19 266 000	11 115 000	31 745 000	48 000 000	29 000 000	15 854 000	4 061 000	12 968 000	14 714 000	186 723 000
LER original input	30	30	30	31	32	30	28	31	30	272
LER radial movement	(12,5)	(4,3)	(6,8)	-	-	(5,0)	(9,0)	(4,2)	(7,9)	(49,7)
LER slack movement	-	(13,4)	-	-	-	(7,5)	(14,5)	(12,5)	(5,8)	(53,7)
LER target	17,5	12,3	23,2	31,0	32,0	17,5	4,5	14,3	16,3	169
Original output	523	312	835	1 243	814	445	114	364	413	5 063
Output radial movement	-	-	-	-	-	-	-	-	-	-
Output target	523	312	835	1 243	814	445	114	364	413	5 063
DMU peers	4;5	5	4;5	4	5	5	5	5	5	

Source: Author's table based on DEAP 2.1 efficiency results. Notes: DMU = Decision-making unit, TEE = Total education expenditure. LER = Learner-educator ratio, CRS = Constant returns to scale. TEE is in R'000.

In terms of the Education Model 4, Table 5.4 shows that only 66.7 per cent or 6 DMUs have radial movements of R32.2 billion (12.1 per cent inefficiency score) with respect to TEE. The Eastern Cape should reduce TEE by R13.6 billion (41.1 per cent inefficiency rate), Gauteng by R11.1 billion (27 per cent inefficiency score), the Western Cape by R4.2 billion (20.9 per cent inefficiency score), Mpumalanga by R2.1 billion (11.2 per cent inefficiency rate), North West by R786 million (5.2 per cent inefficiency score) and the Free State by R494 million (3.8 per cent inefficiency rate). The Eastern Cape, Free State, Mpumalanga, North West and the Western Cape have to benchmark their TEE usage and the PSNSC with a pass rate ≥ 60 per cent output levels with Limpopo and the Northern Cape. Gauteng should benchmark with Limpopo and KwaZulu-Natal who are its peers.

The Education Model 5 only has KwaZulu-Natal and the Northern Cape with pure technical efficiency scores of 100 per cent. The other 7 inefficient DMUs have very small radial movements since they are very close to optimality. As a result, there are small changes in the LER radial movements in this model. This implies that the inefficient provinces should slightly improve their prevailing LERs. The LER results under the VRS model are significantly varied as opposed to the CRS. In line with literature tenets, it is prudent to adopt the VRS results. The slight LER changes imply the appointment of 14 729 teachers by these seven provinces as reflected in Appendix 6. These provinces should appoint additional teachers as follows: Limpopo: 3 866 (LER target of 29.9:1), the North West: 2 462 (LER target of 28.7:1). the Western Cape:1 962 (LER target of 28.8:1), Mpumalanga:1 826 (LER target of 28.9:1), the Eastern Cape: 1 693 (desired LER of 29.1:1), the Free State:1 535 (LER of 28.5) and Gauteng:1 385 (LER target of 29.9:1). They must do so while maintaining the same levels of PSNSC with a pass rate ≥ 60 per cent. In this model, all the inefficient DMUs should consult the Northern Cape and KwaZulu-Natal for lessons.

The Education Model 6 is the last of the education models. Table 5.4 illustrates that when TEE and the LER are used together under the VRS, the six inefficient provinces have collective slack and radial movements of R24.7 billion. They also need to appoint 9 684 additional teachers in line with the inefficiency score of 2.1 per cent. Eastern Cape has a TEE radial movement of R1 billion and a slack movement of R10.8 billion and the LER target of 29.1:1 (1 693 additional teachers). These efficiency improvement requirements are linked to the Eastern Cape's inefficiency rate of 3 per cent in the use of both inputs. Gauteng has a TEE radial shift of R115 million, a slack movement of R8.1 billion and the LER input target of 29.9:1 (1 036 more teachers). The Western Cape has a TEE radial movement of R804 million, a slack movement R2.1 billion and the LER target of 28.8:1 (1 962 more teachers). The inefficiencies in these two provinces are associated with their inefficiency rates of 0.3 and 4 per cent respectively in the application of TEE and the LER.

The North West (inefficiency of score of 5.1 per cent), Mpumalanga (3.3 per cent inefficiency rate) and Free State (3.1 per cent inefficiency weight) have radial requirements of R676 million, R702 million and R404 million respectively. They respectively have the LER input targets of 29.4:1 (1 782 more teachers), 28.9:1 (1 826 extra teachers) and 29.1:1 (1 385 more teachers). Therefore, in terms of the LER, the overall radial reductions for the inefficient provinces are minimal but imply the appointment of additional 9 684 teachers as reflected in Table 5.11 in Appendix 6. In this model, the Eastern Cape, Gauteng and the Western Cape have the Northern Cape and KwaZulu-Natal as their peers while the Free State, Mpumalanga and the North West peers are Northern Cape, KwaZulu-Natal and Limpopo Provinces.

Table 5.4: Total education expenditure and learner-to-educator radial and slack movements: VRS

Provinces	Eastern Cape	Free State	Gauteng	KwaZulu-Natal	Limpopo	Mpumalanga	Northern Cape	North West	Western Cape	Total
Model 4: VRS TEE only										
Original input	33 000 000	13 000 000	41 000 000	48 000 000	29 000 000	19 000 000	6 000 000	15 000 000	20 000 000	224 000 000
Input radial movement	(13 561 000)	(494 000)	(11 070 000)	-	-	(2 124 000)	-	(786 000)	(4 176 000)	(32 211 000)
Input slack movement	-	-	-	-	-	-	-	-	-	-
Input target	19 439 000	12 506 000	29 930 000	48 000 000	29 000 000	16 876 000	6 000 000	14 214 000	15 824 000	191 789 000
Original output	523	312	835	1 243	814	445	114	364	413	5 063
Output radial movement	-	-	-	-	-	-	-	-	-	-
Output target	523	312	835	1 243	814	445	114	364	413	5 063
DMU peers	5;7	5;7	4;5	4	5	5;7	7	5;7	5;7	
Model 5: VRS LER only										
Original input	30	30	30	31	32	30	28	31	30	272
Input radial movement	(0,9)	(1,5)	(0,1)	-	(2,1)	(1,1)	-	(2,3)	(1,2)	(9,2)
Input slack movement	-	-	-	-	-	-	-	-	-	-
Input target	29,1	28,5	29,9	31,0	29,9	28,9	28,0	28,7	28,8	263
Original output	523	312	835	1 243	814	445	114	364	413	5 063
Output radial movement	-	-	-	-	-	-	-	-	-	-
Output target	523	312	835	1 243	814	445	114	364	413	5 063
DMU peers	4;7	4;7	4;7	4	4;7	4;7	7	4;7	4;7	
Model 6: VRS TEE and LER										
TEE original input	33 000 000	13 000 000	41 000 000	48 000 000	29 000 000	19 000 000	6 000 000	15 000 000	20 000 000	224 000 000
TEE radial movement	(1 005 000)	(404 000)	(115 000)	-	-	(702 000)	-	(767 000)	(804 000)	(3 797 000)
TEE slack movement	(10 780 000)	-	(8 063 000)	-	-	-	-	-	(2 073 000)	(20 916 000)
TEE target	21 215 000	12 596 000	32 822 000	48 000 000	29 000 000	18 298 000	6 000 000	14 233 000	17 123 000	199 287 000
LER original input	30	30	30	31	32	30	28	31	30	272
LER radial movement	(0,9)	(0,9)	(0,1)	-	-	(1,1)	-	(1,6)	(1,2)	(5,8)
LER slack movement	-	-	-	-	-	-	-	-	-	-
LER target	29,1	29,1	29,9	31,0	32,0	28,9	28,0	29,4	28,8	266
Original output	523	312	835	1 243	814	445	114	364	413	5 063
Output radial movement	-	-	-	-	-	-	-	-	-	-
Output target	523	312	835	1 243	814	445	114	364	413	5 063
DMU peers	4;7	4;5;7	4;7	4	5	4;5;7	7	4;5;7	4;7	

Source: Author's table based on DEAP 2.1 efficiency results. Notes: DMU = Decision-making unit, TEE = Total education expenditure. LER = Learner-educator ratio, VRS = Variable returns to scale. TEE is in R'000.

5.3 HEALTH SECTOR EFFICIENCY

Table 5.5 lists provinces in column 1. Column 2 contains pure technical efficiency scores for the Health Model 1 CRS scenario; where THE is used as a single input. Column 3 presents the pure technical efficiency scores for nine DMUs from a CRS perspective, using THS as the only input (Model 2). Column 4 shows the pure technical efficiency rates of the Health Model 3 based on the CRS with THE and THS as inputs. Columns 5, 6 and 7 contain the pure technical efficiency results for the Health Models 4, 5 and 6 which are VRS models. They follow the same notion outlines above for the CRS models. Column 8 and its sub-columns represent scale efficiency scores and the type of scale characterising the extent of production of each DMU.

5.3.1 Health sector efficiency scores

In terms of the technical efficiency results of the Health Model 1, Table 5.5 shows a very low average health efficiency score of 35.7 per cent. This implies that all the eight inefficient provinces should reduce their THE usage by 64.3 per cent while maintaining the same levels of the RIMR reflected in Table 4.7. The North West Province is very close to the health efficiency frontier with an efficiency score of 80 per cent while maintaining the RIMR of 8.1 per cent. Gauteng is the only technically efficient province. Seven or 77.8 per cent of DMUs have technical efficiency scores ranging between 6.4 and 30 per cent, needing to reduce THE by 70 to 93.6 per cent. The Eastern Cape is the least technically efficient province with an efficiency score of 6.4 per cent. This is despite the province having the third largest THE of R22.8 billion and highest RIMR of 14 per cent. In terms of the low technical efficiency rates, the Eastern Cape is followed by Mpumalanga with 12.9 per cent, the Free State with 13.7 per cent, the Northern Cape with 18.3 per cent, KwaZulu-Natal, Limpopo and the Western Cape with technical efficiency scores of 30 per cent each. Figure 5.7 in Appendix 7 shows the efficiency frontier for the Health Model 1.

As it relates to the Health Model 2, the mean efficiency score is 35.4 per cent, implying the requirement for eight inefficient DMUs to reduce THS by 64.6 per cent. The technical efficiency scores for all the DMUs, except for the Eastern Cape are similar to the Health Model 1 scores. The Eastern Cape is still the worst performing DMU with a technical efficiency score of 3.5 per cent. It has THS of 40 424, the third largest in the sample with the highest RIMR of 14 per cent. Gauteng is still the most technically efficient DMU in this model. The distribution of the technical efficiency scores are depicted in Figure 5.8 in Appendix 7.

Table 5.5: Provincial health sector technical and scale efficiency results

Province	Health Model 1	Health Model 2	Health Model 3	Health Model 4	Health Model 5	Health Model 6	scale efficiency					
Eastern Cape	0,064	0,035	0,063	1,000	1,000	1,000	0,064	DRS	0,035	DRS	0,063	DRS
Free State	0,137	0,137	0,607	0,313	0,313	0,670	0,440	DRS	0,440	DRS	0,906	DRS
Gauteng	1,000	1,000	1,000	1,000	1,000	1,000	1,000	-	1,000	-	1,000	-
KwaZulu-Natal	0,300	0,300	0,375	1,000	1,000	1,000	0,300	DRS	0,300	DRS	0,375	DRS
Limpopo	0,300	0,300	0,648	1,000	1,000	1,000	0,300	DRS	0,300	DRS	0,648	DRS
Mpumalanga	0,129	0,129	0,504	0,143	0,143	0,542	0,900	IRS	0,900	IRS	0,930	IRS
Northern Cape	0,183	0,183	1,000	0,417	0,417	1,000	0,440	DRS	0,440	DRS	1,000	-
North West	0,800	0,800	1,000	1,000	1,000	1,000	0,800	IRS	0,800	IRS	1,000	-
Western Cape	0,300	0,300	0,552	0,333	0,333	0,635	0,900	IRS	0,900	IRS	0,635	DRS
Mean	0,357	0,354	0,639	0,690	0,690	0,872	0,572		0,568		0,729	

Source: Author's calculations derived from DEAP 2.1. Note: The total education expenditure is in R'000.

As it pertains to the Health Model 3, Table 5.5 indicates an average technical efficiency score of 63.9 per cent, at prevailing RIMR reflected in Table 4.7 when THE and THS are used together as inputs of the health production frontier. Therefore, these variables complement each other, as the use of one without the other decreases the technical efficiency scores. In this model, Gauteng, Northern Cape and the North West Provinces are technically efficient. The Free State, Limpopo, Mpumalanga and the Western Cape's technical efficiency scores surpasses the 50 per cent efficiency mark. KwaZulu-Natal and the Eastern Cape's technical efficiency scores are below 50 per cent, with the latter as an extreme inefficient outlier. The Health Model 3 efficiency frontier is reflected in Figure 5.9 in Appendix 7.

The pure technical efficiency results for Health Model 4 are also reflected in Table 5.5. When only THE is used as an input under the VRS, the average efficiency score is 69 per cent. This is 33.3 per cent higher than THE technical efficiency results obtained in the Health Model 1. This implies that the size of provinces matters in determining their technical efficiency as it relates to THE usage. Figure 5.10 in Appendix 7 shows that five provinces, the Eastern Cape, Gauteng, KwaZulu-Natal, Limpopo and the North West Provinces are purely technically efficient. This implies that four provinces have to reduce their THE by 31 per cent. This model also shows that the Eastern Cape, KwaZulu-Natal, North West and Limpopo are largely disadvantaged when scale is disregarded. They are efficient under the VRS while they were not under the CRS. The Mpumalanga Province is the least purely technical efficient DMU in this scenario with inefficiency rate of 85.7 per cent. It is followed by the Free State, the Western Cape and the Northern Cape Provinces with the inefficiency rates of 68.7, 66.7 and 58.3 per cent.

The frontier for THS in the Health Model 5 is exactly similar to the one for the Health Model 4, meaning that the pure technical efficiency scores for the DMUs are similar when individually assessing THS and THE. This implies that either one of these variables suffices to assess the pure technical efficiency of the health sector under the VRS. Therefore, similar conclusions are applicable in both models. The results of the Health Model 6 are also reflected in Table 5.5. They show that when both THE and THS are considered under the VRS, the average pure technical efficiency of the DMUs increases by 23.3 per cent compared to the Health Model 3 results. The Health Model 6 mean pure technical efficiency score is 87.2 per cent, meaning that three inefficient DMUs should reduce the usage of THE and THS by 12.8 per cent. Figure 5.11 in Appendix 7 depicts six pure technically efficient DMUs in the Health Model 6. These are the Eastern Cape, Gauteng, KwaZulu-Natal, Limpopo, Northern Cape and the North-West. The pure technical inefficient DMUs are the Free State (33 per cent inefficiency score), Mpumalanga (45.8 per cent inefficiency score) and the Western Cape (36.5 per cent inefficiency rate).

Table 5.5 also shows scale efficiency scores for the DMUs under consideration. The first sub-column of column 8 shows scale efficiency for the Health Model 1 divided by the Health Model 4 results. The next sub-column shows the type of scale efficiency. Therefore, average scale efficiency score of all the DMUs when THE is used as a single variable is 57.2 per cent, depicting some high levels of scale inefficiency. The scale inefficient DMUs need to improve scale efficiency by 42.8 per cent. Only Gauteng is CRS scale efficient, providing a benchmark for all scale inefficient DMUs. The Western Cape, Mpumalanga and the North West Provinces are very close to scale efficiency. They are the only DMUs on the IRS frontier while the other five scale inefficient DMUs are on a DRS.

The third sub-column of column 8 in Table 5.5 indicates the average scale efficiency rate of 56.8 per cent when THS is used as a single input. Eight DMUs are scale inefficient. The Western Cape, Mpumalanga and the North West Provinces are very close to scale efficiency. They are the only DMUs on IRS frontier while the other five scale inefficient DMUs are on a DRS. The last two sub-columns of column 8 show that when both inputs are employed, the average scale efficiency is 61.7 per cent. Gauteng, Northern Cape and the North West are scale efficient, Mpumalanga is the only DMU on the IRS while the other scale inefficient provinces are on a DRS.

5.3.2 Health sector radial and slack movements

Table 5.6 shows the radial and slack movements for all the health DEA models. In the Health Model 1, the overall THE that could be reduced by the eight inefficient provinces to become efficient while maintaining their prevailing output levels is R46.4 billion (technical inefficiency score of 64.3 per cent). The Gauteng Province defines THE usage efficiency frontier. It is technically efficient while maintaining the RIMR of 10 per cent. To be at the ideal efficiency point, the Eastern Cape, the least efficient DMU in the sample should reduce THE by R20.6 billion in line with its inefficiency score of 93.6 per cent. That is, given its RIMR of 14 per cent, the Eastern Cape is overspending by R20.6 billion. This implies that the Eastern Cape accounts for 44.4 per cent of the overall provincial THE inefficiency in 2017/18. The Free State's and Mpumalanga's respective THE inefficiency of R6.9 billion (86.3 per cent inefficiency score) and R6.1 billion (87.1 per cent rate of inefficiency) are 14.9 and 13.1 per cent of overall provincial THE inefficiency, given the current levels of RIMR of 11 and 9 per cent. The Northern Cape has a THE radial movement of R4.9 billion (81.7 per cent inefficiency score), accounting for 10.6 per cent of provincial THE inefficiency with an RIMR of 11 per cent. KwaZulu-Natal, Limpopo, Western Cape and the North West Province collectively account for 17 per cent or R7.9 billion (associated with their respective 70, 70, 70 and 80 per cent inefficiency rates) of the overall THE inefficiency at the prevailing RIMR of 12.4, 12.4, 9.3 and 8.1 per cent respectively.

Table 5.6: Health expenditure and health staff radial and slack movements: CRS

Provinces	Eastern Cape	Free State	Gauteng	KwaZulu-Natal	Limpopo	Mpumalanga	Northern Cape	North West	Western Cape	Total
Model 1: CRS THE only										
Original input	22 000 000	8 000 000	1 000 000	4 000 000	4 000 000	7 000 000	6 000 000	1 000 000	3 000 000	56 000 000
Input radial movement	(20 600 000)	(6 900 000)	-	(2 800 000)	(2 800 000)	(6 100 000)	(4 900 000)	(200 000)	(2 100 000)	(46 400 000)
Input slack movement	-	-	-	-	-	-	-	-	-	-
Input target	1 400 000	1 100 000	1 000 000	1 200 000	1 200 000	900 000	1 100 000	800 000	900 000	9 600 000
Original output	14	11	10	12	12	9	11	8	9	96
Output radial movement	-	-	-	-	-	-	-	-	-	-
Output target	14	11	10	12	12	9	11	8	9	96
DMU peers	3	3	3	3	3	3	3	3	3	
Model 2: CRS THS only										
Original input	40 000	8 000	1 000	4 000	4 000	7 000	6 000	1 000	3 000	74 000
Input radial movement	(38 600)	(6 900)	-	(2 800)	(2 800)	(6 100)	(4 900)	(200)	(2 100)	(64 400)
Input slack movement	-	-	-	-	-	-	-	-	-	-
Input target	1 400	1 100	1 000	1 200	1 200	900	1 100	800	900	9 600
Original output	14	11	10	12	12	9	11	8	9	96
Output radial movement	-	-	-	-	-	-	-	-	-	-
Output target	14	11	10	12	12	9	11	8	9	96
DMU peers	3	3	3	3	3	3	3	3	3	
Model 3: CRS THS and THE										
THS original input	40 000	8 000	1 000	4 000	4 000	7 000	6 000	1 000	3 000	74 000
THS radial movement	(37 470)	(3 148)	-	(2 500)	(1 407)	(3 469)	-	-	(1 343) -	49 337
THS slack movement	-	-	-	-	-	-	-	-	-	-
THS target	2 530	4 852	1 000	1 500	2 593	3 531	6 000	1 000	1 657	24 663
THE original input	424 000	17 000	66 000	68 000	33 000	20 000	6 000	17 000	31 000	682 000
THE radial movement	(397 181)	(6 689)	-	(42 500)	(11 607)	(9 912)	-	-	(13 875) -	481 764
THE slack movement	-	-	-	-	-	-	-	-	-	-
THE target	26 819	10 311	66 000	25 500	21 393	10 088	6 000	17 000	17 125	200 236
Original output	14	11	10	12	12	9	11	8	9	96
Output radial movement	-	-	-	-	-	-	-	-	-	-
Output target	14	11	10	12	12	9	11	8	9	96
DMU peers	7;8	7;8	3	8	7;8	7;8	7	8	7;8	

Source: Author’s table based on DEAP 2.1 efficiency results. Notes: DMU = Decision-making unit, THE = Total health expenditure. THS = Total health staff, CRS = Constant return to scale. THE is in R’000.

Table 5.6 also indicates the actual THS reductions related to the Health Model 2. In this model all the provinces have a mean health staff inefficiency score of 64.6 per cent, equivalent to 64 400 health personnel than required. The Eastern Cape is the furthest from the efficiency frontier and has to reduce THS by 38 600 (96.5 inefficiency weight) while still maintaining the RIMR at 14 per cent. The Eastern Cape's overstaffing is 59.9 per cent of total provincial overstaffing. The Free State has 6 900 (86.3 per cent inefficiency weight) more personnel than it should, Mpumalanga 6 100 (87.1 per cent inefficiency score) and the Northern Cape 4 900 (81.7 per cent inefficiency score) at the prevailing RIMRs. KwaZulu-Natal and Limpopo are each supposed to reduce their total health workers by 2 800 (30 per cent efficiency rate) and the Western Cape by 2 100 (30 per cent efficiency score). The North West is closest to the efficiency frontier defined by Gauteng, it only has 200 (20 per cent inefficiency rate) more health personnel than required.

In terms of Health Model 3, when THE and THS are simultaneously applied as inputs, the overall THE inefficiency is R481.8 million in line with improvement in efficiency scores from 35 to 63.9 per cent. The Eastern Cape is attributed to 82.4 per cent or R397.2 million of the overall THE inefficiency. KwaZulu-Natal is required to curtail THE by 8.9 per cent 42.5 million to become efficient. The remaining four inefficient provinces account for 8.7 per cent of overall THE inefficiency in this model. All the inefficient provinces have to reduce THS by 49 337. The Eastern Cape has a daunting task of reducing 37 470 (93.7 per cent inefficiency rate) health sector employees with the other five inefficient DMUs having to collectively reduce THS by 11 867 in line with their efficiency scores that are reflected in Table 5.5 while maintaining prevailing RIMRs. The peers for the Eastern Cape, Free State, Limpopo, Mpumalanga and the Western Cape are the North West and the Northern Cape and for KwaZulu-Natal is Gauteng.

In terms of Health Model 4, only five DMUs are purely technically inefficient with an overall inefficiency score of 31 per cent, translating into total health spending inefficiency of R17 billion. Mpumalanga accounts for R6 billion (85.7 per cent inefficiency score) of this amount, the Free State for R5.5 billion (68.7 per cent inefficiency weight), Northern Cape for R3.5 billion (58.3 per cent inefficiency score) and the Western Cape for R2 billion (66.7 per cent inefficiency score). This overspending could be curtailed while maintaining the same RIMRs. The Free State and the Northern Cape should draw lessons from Gauteng and KwaZulu-Natal while Mpumalanga, North West and the Western Cape should learn from Gauteng. The model shows the output slacks of 1, 2 and 1 per cent for Mpumalanga, North West and the Western Cape respectively. Given the nature of the IMR, it is not ideal to increase this measure.

The same five provinces are inefficient in Health Model 5. Their mean inefficiency score of 31 per cent is equivalent to 17 000 health workers more than required. The Free State accounts for 32.4 per cent or 5 500 of this amount (68.7 per cent inefficiency score), Mpumalanga 35.3 per cent or 6 000 (85.7 per cent inefficiency score), Northern Cape 20.6 per cent or 3 500 (58.3 per cent) and the Western Cape for 11.8 per cent or 2 000 (66.7 per cent inefficiency score) excess health staff. The model shows output slacks of 1, 2 and 1 per cent for Mpumalanga, North West and the Western Cape respectively. The Free State's peers are Gauteng and KwaZulu-Natal and the rest of the DMUs could draw lessons from Gauteng.

In terms of the Health Model 6, only three provinces have a mean inefficiency score of 12.8 per cent, equivalent to inefficient total health spending radials of R26.1 million and 6 940 excess health staff. KwaZulu-Natal shows "weak efficiency" with a slack of R35 million. The Northern Cape has reached the efficiency point. The Free State has excess staff and health expenditure of 2 644 and R5.6 million (33 per cent inefficiency rate) respective, Mpumalanga 3 202 and R9.2 million (45.8 per cent inefficiency score) and the Western Cape of 1 094 and R11.3 million (36.5 per cent inefficiency weight). The model shows an output slack of 0.7 per cent for Mpumalanga. The Free State and the Western Cape can improve their performance by benchmarking with Limpopo, Northern Cape and North West while Mpumalanga's peers are the Northern Cape and the North West.

Table 5.7: Health expenditure and health staff radial and slack movements: VRS

Provinces	Eastern Cape	Free State	Gauteng	KwaZulu-Natal	Limpopo	Mpumalanga	Northern Cape	North West	Western Cape	Total
Model 4: VRS THE only										
Original input	22 000 000	8 000 000	1 000 000	4 000 000	4 000 000	7 000 000	6 000 000	1 000 000	3 000 000	56 000 000
Input radial movement	-	(5 500 000)	-	-	-	(6 000 000)	(3 500 000)	-	(2 000 000)	(17 000 000)
Input slack movement	-	-	-	-	-	-	-	-	-	-
Input target	22 000 000	2 500 000	1 000 000	4 000 000	4 000 000	1 000 000	2 500 000	1 000 000	1 000 000	39 000 000
Original output	14	11	10	12	12	9	11	8	9	96
Output radial movement	-	-	-	-	-	-	-	-	-	-
Output slack movement	-	-	-	-	-	1	-	2	1	4
Output target	14	11	10	12	12	10	11	10	10	
DMU peers	1	4;3	3	4	5	3	4;3	3	3	
Model 5: VRS THS only										-
Original input	40 000	8 000	1 000	4 000	4 000	7 000	6 000	1 000	3 000	74 000
Input radial movement	-	(5 500)	-	-	-	(6 000)	(3 500)	-	(2 000)	(17 000)
Input slack movement	-	-	-	-	-	-	-	-	-	-
Input target	40 000	2 500	1 000	4 000	4 000	1 000	2 500	1 000	1 000	57 000
Original output	14	11	10	12	12	9	11	8	9	96
Output radial movement	-	-	-	-	-	-	-	-	-	-
Output slack movement	-	-	-	-	-	1	-	2	1	4
Output target	14	11	10	12	12	10	11	10	10	100
DMU peers	1	3;4	3	4	4	3	3	3	3	
Model 6: VRS THS and THE										
THS original input	40 000	8 000	1 000	4 000	4 000	7 000	6 000	1 000	3 000	74 000
THS radial movement	-	(2 644)	-	-	-	(3 202)	-	-	(1 094)	(6 940)
THS slack movement	-	-	-	-	-	-	-	-	-	-
THS target	40 000	5 356	1 000	4 000	4 000	3 798	6 000	1 000	1 906	67 060
THE original input	424 000	17 000	66 000	68 000	33 000	20 000	6 000	17 000	31 000	682 000
THE radial movement	-	(5 618)	-	-	-	(9 153)	-	-	(11 305)	(26 076)
THE slack movement	-	-	-	(35 000)	-	-	-	-	-	(35 000)
THE target	424 000	11 382	66 000	33 000	33 000	10 847	6 000	17 000	19 695	620 924
Original output	14	11	10	12	12	9	11	8	9	96
Output radial movement	-	-	-	-	-	-	-	-	-	-
Output slack movement	-	-	-	-	-	0,678	-	-	-	0,678
Output target	14	11	10	12	12	9,7	11	8	9	97
DMU peers	1	5;8;7	3	5	5	7;8	7	8	7;5; 8	

Source: Author's table based on DEAP 2.1 efficiency results. Notes: DMU = Decision-making unit, THE = Total health expenditure. THS = Total health staff, VRS = variable return to scale. THE is in R'000.

5.4 CONCLUSION

In this chapter, the results of all the six education and six health models were presented. The results of the education and health models vary significantly between the CRS and the VRS perspectives. The average efficiency results of the education sector ranged from 45.9 to 97.9 per cent with the VRS results being the highest. The CRS average technical efficiency scores of the education sector were 79.8, 45.9 and 81.4 per cent (Education Models 1,2 and 3) while the VRS results were 87.9, 96.7 and 97.9 per cent (Education Models 4,5 and 6) respectively. The average efficiency scores for the health sector were between 35.4 and 87.2 per cent. The CRS average technical efficiency scores for the health sector are 35.7, 35.4 and 63.9 per cent (Health Models 1, 2 and 3) and 69, 69 and 87.2 per cent (Health Models 4,5 and 6). The technical efficiency literature prescribes that if there is great variability between the CRS and the VRS, then the VRS results can be adopted as valid. Moreover, the VRS models compare "like for like" as they consider the varying size of provinces while they tightly enclose the production technology to yield the best technical efficiency scores. Therefore, from this point onwards, only the VRS models are used to discuss the findings of this study.

In respect of the education sector, the study observed that the average pure technical efficiency of the Education Model 4 is 87.9 per cent, implying TEE inefficiency of 12.1 per cent or R32.2 billion by all the six inefficient provinces (Eastern Cape: R13.6 billion, Gauteng: R11.1 billion, the Western Cape: R4.2 billion, Mpumalanga: R2.1 billion, the North West: R786 million and the Free State R494 million). Therefore, KwaZulu-Natal, Limpopo and the Northern Cape are the most purely technical efficient provinces in the use of TEE in 2017/18. In the Education Model 5, the average pure technical efficiency score is 96.7 per cent, meaning that seven inefficient provinces could improve their LER usage by 3.3 per cent or by appointing 14 729 additional teachers (Limpopo: 3 866, North West: 2 462, Western Cape: 1 962, Mpumalanga: 1 826, Eastern Cape: 1 693, Free State: 1 535 and Gauteng 1 385). The pure technical efficiency results for Education Model 6 using TEE and LER is 97.9 per cent, requiring on aggregate that six inefficient provinces should reduce TEE and the LER inefficiencies by 2.1 per cent (or TEE of R24.7 billion) and 5.8 per cent (or by appointing 9 684 teachers) respectively. These translate to the Eastern Cape having to reduce TEE by R11.8 billion and teachers by 1 693, Gauteng by R8.2 billion and 1 385 teachers, Western Cape by R2.9 billion and 1 962 teachers, North West by R767 million and 1 782 educators, Mpumalanga by R702 million and 1 826 teachers and the Free State by R404 million and 1 036 teachers.

As it pertains to the health sector, the study observed a pure technical efficiency score of 69 per cent from Health Model 4, implying the need to reduce THE by 31 per cent or R17 billion by the four inefficient provinces (Mpumalanga: R6 billion, Free State: R5.5 billion, Northern Cape: R3.5 billion and the Western Cape by R2 billion). For Health Model 5, the same four provinces need to reduce THS by 31 per cent or 17 000 (Mpumalanga: 6 000, Free State: 5 500, Northern Cape: 3 500 and the Western Cape: 2 000) workers. In terms of Health Model 6, three provinces have an average inefficiency rate of 12.8 or THE wastage of R61.1 million (KwaZulu-Natal: R35 million, Western Cape: R11.3 million, Mpumalanga: R9.2 million and the Free State: R5.6 million). The same provinces with the exception of KwaZulu-Natal have the same inefficiency rate with respect to the use of THS. They need to reduce THS as follows, Mpumalanga: 3 202, Free State: 2 644 and the Western Cape: 1 094. This chapter also determined scale efficiencies. In the education sector, the scale efficiency rate for TEE is 92.4 per cent, for the LER is 47.3 per cent and for both inputs is 83.1 per cent. Scale efficiencies for health models are 57.2, 56.8 and 72.9 per cent respectively.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

The different technical efficiency analytical instruments were discussed in the preceding chapters. The most relevant method, DEA was selected to analyse the technical efficiency of the provincial education and health sectors in South Africa. Despite some of its shortcomings, DEA emerged as the most appropriate technique to achieve this objective. Over and above the untested narratives of the existence of provincial technical inefficiency in these sectors, the current study provides tangible solutions by measuring the prevailing technical efficiency and inefficiency levels. The comprehensive technical efficiency results were presented in Chapter 5. This chapter summarises the research findings in Section 6.2. Section 6.3 presents the policy recommendations, Section 6.4 outlines the contributions of the current study to DEA literature and the public sector technical efficiency discourse in South Africa, particularly in the areas of education and health. Study limitations are discussed in Section 6.5, Section 6.6 provides some suggestions for future research; and Section 6.7 concludes the study.

6.2 SUMMARY

The research uses the education and health sectors' data collected for 2017/18 for the nine provinces to provide timely results. The periodic publications of the National Treasury, the Department of Basic Education and provincial audited annual reports provided data for financial and non-financial variables. As explained earlier, the scientific analytical method used to measure technical efficiency of provinces in this study is DEA. The study used the CCR and the BCC DEA methodologies to compute the technical, pure technical and scale efficiency measures in both sectors. It assessed three variables in each sector for technical efficiency analysis. For the education sector, the two input variables that were adopted are TEE and the LER. A single output measure, the PSNCS with a pass rate ≥ 60 per cent was used. As it relates to the health sector, THE and THS were used as inputs while the RIMR within all provincial hospitals was selected as an output variable. All actual values of these variables were obtained and used in the technical efficiency analysis. That is, there was no missing data. As reflected in Chapter 5, data was inputted into six CRS and six VRS models. For both sectors and both models, the study first assessed the technical and pure technical efficiency using only the financial variables, followed by the single use of the non-financial variables and by the conjunctive use of all variables. This resulted in six education and six health models. The average technical efficiency scores of these models are summarised in Figure 6.1 in Appendix 9. As reported in Chapter 5, the study only uses the six VRS models to summarise the results and to formulate policy proposals and recommendations.

6.2.1 Education sector

As discussed in Chapter 5, the technical efficiency levels of the provincial education sector are generally higher than those of the health sector. As it pertains to the education sector, Table 6.1 reflects that the average pure technical efficiency score of 87.9 per cent in model 4 translates into TEE inefficiency of R32.2 billion with six provinces being inefficient. The technical efficiency score of 96.7 per cent in Model 5 is attributed to the LER inefficiency of 9.2 per cent by seven provinces, translating into additional teacher requirements of 14 729. The more parsimonious Model 6 yielded the mean technical efficiency score of 97.7 per cent, implying TEE inefficiency of R24.7 billion and LER reductions of 5.8 per cent (9 684 additional teachers). The average technical efficiency of provinces increases when there is less wastage of TEE and improvements in the LER. KwaZulu-Natal, is the most efficient province, followed by the Northern Cape and Limpopo Provinces.

Table 6.1: Education VRS scores, radial and slack movements

Province	Education Model 4: TEE		Education Model 5: LER			Education Model 6: TEE and LER			
	Score	TEE Inefficiency	Score	LER Inefficiency	Teachers	Score	TEE Inefficiency	LER inefficiency	Teachers
Eastern Cape	0,589	(13 561 000)	0,970	(0,9)	1 693	0,970	(11 785 000)	(0,9)	1 693
Free State	0,962	(494 000)	0,951	(1,5)	1 535	0,969	(404 000)	(0,9)	1 036
Gauteng	0,730	(11 070 000)	0,997	(0,1)	1 385	0,997	(8 178 000)	(0,1)	1 385
KwaZulu-Natal	1,000	-	1,000	-	-	1,000	-	-	-
Limpopo	1,000	-	0,933	(2,1)	3 866	1,000	-	-	-
Mpumalanga	0,888	(2 124 000)	0,963	(1,1)	1 826	0,963	(702 000)	(1,1)	1 826
Northern Cape	1,000	-	1,000	-	-	1,000	-	-	-
North West	0,948	(786 000)	0,925	(2,3)	2 462	0,949	(767 000)	(1,6)	1 782
Western Cape	0,791	(4 176 000)	0,960	(1,2)	1 962	0,960	(2 877 000)	(1,2)	1 962
Mean/sum	0,879	(32 211 000)	0,967	(9,2)	14 729	0,979	(24 713 000)	(5,8)	9 684

Source: Author’s calculations based on DEAP 2.1 efficiency results. Notes: Mean refers to scores. Sum applies to the other variables. THE is in R’000.

6.2.2 Health sector

In respect of the health sector, Table 6.2 shows that the technical efficiency score of 69 per cent for the Health Model 4 is equivalent to THE inefficiency of R17 billion. This is related to four inefficient provinces. The same four provinces have THS inefficiency of 17 000 in Health Model 5 linked to 31 per cent inefficiency rate. The radial and slack movements are reduced significantly in Health Model 6 with four inefficient provinces having THE inefficiency of R61.1 million and three provinces having THS inefficiency of 6 940 associated with mean pure technical efficiency score of 87.2 per cent.

Table 6.2: Health VRS scores, radial and slack movements

Province	Health Model 4: THE		Health Model 5: THS		Health Model 6: THE and THS		
	Score	THE Inefficiency	Score	THS Inefficiency	Score	THE Inefficiency	THS Inefficiency
Eastern Cape	1,000	-	1,000	-	1,000	-	-
Free State	0,313	(5 500 000)	0,313	(5 500)	0,670	(5 618)	(2 644)
Gauteng	1,000	-	1,000	-	1,000	-	-
KwaZulu-Natal	1,000	-	1,000	-	1,000	(35 000)	-
Limpopo	1,000	-	1,000	-	1,000	-	-
Mpumalanga	0,143	(6 000 000)	0,143	(6 000)	0,542	(9 153)	(3 202)
Northern Cape	0,417	(3 500 000)	0,417	(3 500)	1,000	-	-
North West	1,000	-	1,000	-	1,000	-	-
Western Cape	0,333	(2 000 000)	0,333	(2 000)	0,635	(11 305)	(1 094)
Mean/sum	0,690	17 000 000	0,690	(17 000)	0,872	61 076	(6 940)

Source: Author's calculations based on DEAP 2.1 efficiency results. Note: Mean refers to scores. Sum applies to the other variables. THE is in R'000.

6.3 POLICY OPTIONS AND RECOMMENDATIONS

Some recommendations that have a bearing on policy development and reforms in the education and health sectors can be obtained from the empirical analysis, its observations and findings. The recommendations can be employed to improve the technical efficiency of the education and health sectors in South Africa. The main issue that was derived from the empirical results is that the inefficiency of the education and health sectors is due to the overuse of education and health expenditure, total health staff and slightly higher than required LER. For some provinces, this is due to scale inefficiency. Provinces and, more specifically, policy makers in provincial education and health sectors should take advantage of this study to assess various ways to achieve the optimal use of these inputs. The results of this study also provided information on the technical efficiency of peer DMUs, presenting an opportunity for efficiency benchmarking amongst the efficient and inefficient and for adoption of best practices. The study allows inefficient provinces to learn from the efficient ones in terms of improving their operational efficiency.

6.3.1 Education sector policy options and recommendations

For the education sector, the study presents three policy options stemming from the pure technical efficiency results of the three VRS models. To improve the overall technical efficiency of provinces, the following specific recommendations are proposed

- Policy option 1: Target reducing total education expenditure inefficiencies by R32.2 billion in six inefficient provinces. Education expenditure should be reduce as follows, Eastern Cape: R13.6 billion, the Free State: R494 million Gauteng: R11.1 billion, Mpumalanga by R2.1 billion, North West by R786 million and the Western Cape by 4.2 billion. KwaZulu-Natal and Limpopo provinces should be considered as the efficient benchmark in this regard.
- Policy option 2: Target reducing the LER inefficiency in seven inefficient provinces by 9.2 per cent, thereby appointing 14 729 teachers in the seven provinces with inefficient LERs. The teacher appointments to reduce the LERs should be as follows, Limpopo: 3 866 teachers, the North West: 2 462 teachers, the Western Cape: 1 962, Mpumalanga: 1 826 teachers, the Eastern Cape: 1 693 teachers, Free State: 1 535 and Gauteng: 1 385 teachers.

- Policy option 3: If policy makers have the objective of simultaneously addressing TEE and the LER inefficiencies, they should focus on assisting the same six provinces alluded to under policy option 1. In terms of expenditure, these provinces have a total TEE inefficiency of R24.7 billion. The Eastern Cape should be helped to reduce TEE by R11.8 billion. Gauteng should also be prioritised to curtail R8.2 billion. The Western Cape should be assisted to find measures to reduce TEE by R2.9 billion. North West, Mpumalanga and Free State by R676 million, R702 million and R404 million respectively while maintaining the same outputs levels. In terms of the LER, the overall reduction by the inefficient provinces is 5.8 per cent or a teacher requirement of 9 684. The North West should appoint 1 782 teachers, the Western Cape and Mpumalanga should appoint additional 1 962 and 1 826 teachers respectively. The Free State and Gauteng need 1 036 and 1 385 teachers respectively. This should happen while maintaining the same levels of PSNSC with a pass rate ≥ 60 per cent.

The study makes the following recommendations in respect of the education sector:

- Given that TEE efficiency and the appointment of additional teachers by reducing the LER are linked, it is recommended that policy option 3 (Education Model 6) be adopted by policy makers to simultaneously reduce TEE and the LER. This will improve the overall pure technical efficiency of the education sector. Given that provinces needing to appoint additional teachers are the same provinces with total education expenditure inefficiency of R32.2 billion and R24.7 billion in Models 4 and 6. Therefore, these six provinces do not need additional budget allocations to deal with teacher shortages. They have room to redirect existing excess expenditure to employ additional teachers to elevate service delivery levels in the education sector. Only Limpopo needs additional budget allocations to employ more teachers as it is efficient in using its current education allocations.
- It is recommended that inefficient provinces should benchmark practices to address TEE and the LER inefficiencies as follows: The Eastern Cape, Gauteng and the Western Cape should consult with the Northern Cape and KwaZulu-

Natal. The Free State, Mpumalanga and the North West with the Northern Cape, KwaZulu-Natal and Limpopo Provinces.

- Overall, given the shortage of teachers in core areas, government should focus on reducing expenditure on non-teaching posts across the inefficient provinces. The inefficient provinces could collectively use the savings from implementing the efficiency measures to adequately appoint and train the required 9 684 teachers. It is recommended that they appoint competent teachers who can provide quality teaching for all school subjects and phases, given deficiencies in specialised areas such as mathematics and science. The appointment of additional teachers in public schools relative to the existing number of learners is essentially a recommendation for the public sector to operate a system with small class sizes.
- The savings can be reinvested to enhance teacher training, acquire more learning resources, educational facilities and allow teachers to offer paid extra lessons to improve the education results. Insofar as policy recommendations are concerned, this study suggests that efficiency measures and benchmarks be developed for all provinces and continually monitored by the National Department of Education. This could promote efficient and evidence-based budgeting.

6.3.2 Health sector policy options and recommendations

- Policy option 1 (Health Model 4): Target minimising total health expenditure in four inefficient provinces: The Free State, Mpumalanga, Northern Cape and the Western Cape. Their collective THE inefficiencies amount to R17 billion. The Free State should curtail overspending by R5.5 billion and the Northern Cape by R3.5 billion. They could draw lessons from Gauteng and KwaZulu-Natal. Mpumalanga is spending R6 billion more on healthcare than it should while the Western Cape should reduce THE inefficiency by R2 billion. All the interventions to realise efficient spending should be implemented while maintaining the prevailing levels of RIMRs. These two provinces can benchmark their health operations with Gauteng for technical efficiency improvements.

- Policy option 2 (Health Model 5): Target reducing the over usage of health staff in the four inefficient provinces. In terms of minimising total health staff, there is overstaffing in the Free State, Mpumalanga, Northern Cape and the Western Cape. Their consolidated THS inefficiency is 17 000 people. The Free State should reduce THS by 5 500 benchmarking with Gauteng and KwaZulu-Natal, Mpumalanga by 7 000, Northern Cape by 6 000 and the Western Cape by 2 000 with all of them benchmarking with Gauteng while maintaining the same levels of RIMR.
- Policy option 3 (Health Model 6): In cases where the interest of policy makers is to improve THS and THE at the same time, the Free State, Mpumalanga and the Western Cape should respectively reduce THS by 2 644, 3 202 and 1 094 while maintaining the same levels of RIMR. The same provinces should be assisted to cut their spending inefficiencies by R61 million. The Free State by R5.6 million, Mpumalanga by R9.2 million and the Western Cape by R11.3 million while KwaZulu-Natal should curtail THE by R35 million. The Free State and the Western Cape should learn from Limpopo, the Northern Cape and the North West to improve their efficiency while Mpumalanga should benchmark with the last two provinces.

The following recommendations are proposed to improve the overall provincial health technical efficiency:

- The study recommends the adoption of policy option 3 (Health Model 6) to conjunctively reduce THE and THS resulting in high overall technical efficiency results.
- It is also recommended that any potential savings in terms of health spending should be directed build more hospitals and refurbish the existing ones to cater for large population numbers that are reliant on the public health system. This investment could also reduce the high per capita numbers and overcrowding in public hospitals to improve operational performance and health outcomes.
- Moreover, overcrowded hospitals amid low professional health workers place pressure on the few appointed core health staff complement. This warrants for the use of potential savings to appoint more personnel, especially medical practitioners, specialists and researchers while reducing personnel expenditure

in non-core areas, as there is a general shortage of healthcare practitioners in South Africa. This implies the improvement of the ratio of practitioners to nursing assistants and attended patients. Moreover, it is essential to retrain health professionals using the realised efficiency gains in order to reduce the alarming numbers of medical legal claims. This could also free up additional resources to enhance service delivery.

- The study also cautions that given healthcare personnel and infrastructure challenges, South Africa is not ready to implement the NHI scheme. The scheme will require additional financial and human resources amidst the existing inefficiencies. Instead of taking on the NHI at this juncture, which would be very costly, South Africa can make huge improvements in public healthcare provision by improving efficiency and re-allocating those resources 'saved' through efficiency measures, to improving the quality of healthcare and extending healthcare to more recipients. Implementing the NHI without implementing the efficiency measures will setup the health sector for certain failure. In general, provinces should also review the high spending levels on goods and services to ensure value-for-money.

6.3.3 General observation and recommendations

- The study provides scientific evidence that prevailing expenditure in education and health sectors can be reduced without negatively affecting the education and health outcomes.
- In general, the National Treasury should request inefficient provinces to increase monitoring and oversight of their technical efficiency performance on the use of THE, THS, TEE and the LER in relation to the provision education and healthcare.
- For transparency and to encourage efficiency, the provincial education and health technical efficiency rankings should be determined and published annually by government for public scrutiny.
- The national and provincial treasuries should consider the outcomes of this study to make informed budget allocation decisions. The technical efficiency rankings could also be used to support complex fiscal decisions. Therefore, the

policy makers can use the results of this study to conduct evidence-based budgeting.

- Individual provinces should consider asking individual public schools and hospitals to conduct further technical efficiency analysis for improved management and performance. This will, however, require provinces to monitor the accuracy of the data of these units to ensure that their technical efficiency studies are credible and allow for accurate efficiency measurement and decision making.
- As reflected in Chapter 2, provincial education and health budgets accounted for R414.5 billion or 73 per cent of total provincial budgets in 2017/18. The efficiency results of this study show that allocating substantial funds for these functions does not necessarily translate into their efficient use. Therefore, when provinces spend efficiently, the resultant savings could be used to extend services in other areas of service delivery. This is important given the prevailing fiscal pressures in South Africa. That is, improving the technical efficiency of provinces can help to alleviate the prevailing fiscal deficit and stimulate economic growth.

6.4 CONTRIBUTIONS OF THE STUDY

Aristovnik (2011) states that, the world over, tight budgets and increasingly demanding citizens put governments under persistent pressure to realise efficiency. Therefore, providing information about the efficiency of the public sector is a useful tool for informed decision making. It also strengthens public knowledge and enables citizens to scrutinise fiscal decisions and sectors performance. A thorough survey of the efficiency literature presented in Chapter 3 indicates that there is limited research on provincial education and health technical efficiency related to South Africa, despite these sectors comprising 73 per cent of the overall provincial budgets. As a result, this study directly bridged the existing research gap by assessing the efficiency of these important sectors and proposed timely and relevant reforms. It further provided information regarding the exact levels of existing technical inefficiencies to inform fiscal decisions. Therefore, by presenting this information, the study provided policy makers and budget analysts with specific information for technical efficiency improvements.

Of the 34 studies in Appendices 2 and 3, only six include South Africa as a DMU and most are cross-country comparative technical efficiency studies rather than studies on provincial benchmarking. These studies do not focus on the intricate and individual technical efficiency details of provincial education and health sectors. The current study focuses on relative efficiency between the internal or South African provinces and presents solutions that are implementable domestically; including opportunities for benchmarking amongst the efficient and inefficient provinces. The current study appears be the maiden study to present the exact levels of provincial technical efficiencies and inefficiencies in the fields of primary and secondary education in South Africa.

The aforementioned six studies vaguely discuss education and health expenditure at a macro level, presenting minimum scope for lessons and reforms. In terms of the aforementioned six studies in Appendices 2 and 3, only one is in the education sector and five are in the health sector. The education sector study by Prasetyo and Zuhdi (2013) analysed South Africa as one of the 81 DMUs. The study adopted an output-maximisation orientation based on the VRS DEA to evaluate the efficiency of education systems of these DMUs from 2006 to 2010 to maximise the Human Development Index (HDI). To the contrary, the current study minimises TEE and LER using both the CRS and the VRS models and it also considers scale efficiency. Moreover, above the assessed TEE variable, none of the education studies discussed the LER to an extent of determining the number of teachers that are needed by specific provinces to improve the education system. Therefore, given the importance of the LER and TEE, the study provides essential information aiming to resolve a major challenge in the education sector. Therefore, it carries a significant weight in terms of practical contribution.

In terms of the health sector, the five health studies were conducted by Kim and Kang (2014) Prasetyo and Zuhdi (2013), Benneyan et al. (2007), Kirigia et al. (2001) and Kirigia et al. (2000). These studies are contained in Appendix 3. The first three studies are not clear in terms of the level of government being considered in the health sector efficiency analysis.This makes it very difficult to implement reforms for efficiency improvement. Moreover, the three studies lack in-depth detail on South Africa (especially on provinces) as the current study does. They are also cross-country comparative efficiency studies, except for the last two studies that were conducted in

South Africa, which analysed the technical efficiency of public clinics and hospitals in KwaZulu-Natal. Despite these studies applying both the CRS and the VRS with an input-minimisation perspective as the current study does, neither of them used expenditure as an input in the production process. They all used non-financial variables. Despite the current study not discussing individual schools and hospitals, the provincial technical efficiency results are good pointers in terms of where most of the efficient or inefficient schools and hospitals might be located. The current study is province-specific and focuses on DMUs that are directly responsible for the provision of healthcare services. The current study also uncovered the weakness of country-comparative studies of assuming that in general, education or health provision in South Africa is inefficient. The current study proves that some individual provinces are quite efficient in the provision of education and healthcare.

Appendix 4 contains 18 additional South African efficiency analytical studies that have used different technical efficiency determination methods, including DEA. Most of these studies are beyond the scope of the current study; they either focused on other sectors not related to the education and health sectors or, where they do, they used other analytical methods, such as the SFA, FDH, the Technique for Order Preference by Similarity to The Ideal Solution (TOPSIS) and the Ingredients Approach. 12 of the 18 studies were in the public sector but not necessarily in the education and health sectors. Of the public sector studies, only four were in the education and health sectors, others were in local government, energy, agriculture and water and sanitation sectors. Of these studies, 5 were in the private sector: banking and insurance industries. In terms of the four studies that are relevant to this study, the one by Taylor and Harris (2004) focused on the technical efficiency of the South African Universities. The study by Lawanson and Novignon (2016) used the SFA to determine the relative efficiency of Sub-Saharan African countries, including South Africa. This study is also country-comparative in nature and applies a different methodology from the present study. The study by Olukoga (2007) used the Ingredients Approach to determine the unit costs of district hospitals in South Africa. The study by Rahmayanti and Horn (2011) used DEA stage 1 to sample 63 developing countries for a period from 1990 to 2003. The study was interested in the relationship between efficiency and size of government expenditure and growth. Therefore, it presents a different focus to the current study.

In summary, the current study contributed methodologically by producing research that uses both the CRS and the VRS DEA models to add to the limited existing literature as it pertains to South Africa. Given the review of international DEA literature, it appears that the current study is the first DEA study to comprehensively measure and evaluate the relative technical efficiency of provincial education and healthcare provision in South Africa. The study also generated new knowledge by providing the exact levels of provincial education and health technical efficiencies and inefficiencies. Therefore, this study could assist policy makers in terms of what provinces could focus on in terms of the education and health provision efficiency improvements.

6.5 STUDY LIMITATIONS

The boundary of the current study was the determination and analysis of the technical efficiency of provincial education and health sectors in South Africa. However, as reflected in Chapter 2, municipalities are also said to have significant inefficiencies and the national government is also not immune to this problem. Most importantly, it is quite evident from Sections 6.2 and 6.3 that, despite the study presenting information on technical efficiency and inefficiency levels of TEE, THE, THS and the LER, it does not explain the factors causing the inefficiencies or efficiencies. As a result, it is difficult to understand why such inefficiencies or efficiencies exist. After efficiency measurement, it would be ideal to identify the sources of inefficiency and to propose commensurate remedial actions. However, given that the current study is based on DEA, all the drawbacks of this methodology as presented in Chapter 4 apply to it. The main drawback is failure to incorporate other external environmental factors that might have a bearing on the computed technical efficiency scores which could assist to explain the variations in technical efficiency.

This study also suffers from a small sample size problem. This is in the context of having just considered nine provinces who are at a general level of administering the education and health sectors. However, this limitation is structural given that South Africa only has nine provinces. Moreover, provinces are not necessarily the actual hospitals and schools that are expected to realise technical efficiency. So, the current study presents a generalised provincial technical efficiency picture. As with the international literature that generalised the technical efficiency results, this study is a culprit in this regard and is devoid of information on the technical efficiency of the individual hospitals and schools. Moreover, the current study only considers the input-minimisation while education and health sectors are also about output-maximisation. The current study also assesses the technical efficiency using a single financial year. Therefore, the study could be deficient of information that is related to the prevailing sectoral technical efficiency trends in specific provinces which could allow for more targeted intervention and improvement efforts.

6.6 SUGGESTIONS FOR FUTURE RESEARCH

This study is based on general provinces data. Therefore its findings are also generalised. Therefore, a possible area of future research is to extend the DEA model to specific hospitals and schools to determine their technical efficiency. This would ensure that different units are not painted with the same brush. Moreover, future research could assess the technical efficiency of schools and hospitals from an output-orientated measure since their objective is not only to contain costs. Future studies could also analyse the efficiency of provinces or of individual hospitals and schools over a longer period to analyse efficiency trends to determine improvements or regression. The current study serves as a baseline study for future studies for determining allocative and cost efficiency. In future, other studies could also determine the technical efficiency of municipalities and the national government in South Africa. Lastly, regression models could also be used to analyse the other external environmental factors that could be linked to the technical efficiency that was computed in this study.

6.7 CONCLUDING REMARKS

The research provided valuable information about technical efficiency of all nine South African provinces. It is a reference point for fiscal policy reforms as they relate to the efficiency of provincial education and health sectors. It also provides a platform for provinces to engage one another with a view of deriving best practices in the education and health sectors. The scientific evidence provided by this research can be adopted by individual hospitals and schools to assess their technical efficiency. It could also be adopted by the public sector in general to address general fiscal pressures. Therefore, the research adds value to the fiscal policy discourse in South Africa. The research achieved its intended objectives of determining the technical efficiency of provincial education and healthcare in South Africa.

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APPENDIX 1: THE FRAMEWORK FOR EXPENDITURE ASSIGNMENT IN SOUTH AFRICA

Schedule 4, Part A: Functional areas of concurrent national and provincial legislative competence	Schedule 4, Part B: Local government matters	Schedule 5, Part A: Functional areas of exclusive provincial legislative competence	Schedule 5, Part B: Local government matters	Proposed additions: Functional areas of exclusive national legislative competence
Administration of indigenous forests	Air pollution	Abattoirs	Beaches and amusement facilities	Higher education
Agriculture	Building regulations	Ambulance services	Billboards and display of advertisement in public places	Defence
Airports other than international and national airports	Child care services	Archives other than national archives	Cemeteries, funeral parlours and crematoria	National parks, botanical and zoological gardens
Animal control and diseases	Electricity and gas reticulation	Libraries other than national libraries	Cleansing	National policing
Casinos, racing, gambling and wagering, excluding lotteries and sports pools	Fire-fighting services	Liquor licences	Control of public nuisances	Marine resources
Consumer protection	Local tourism	Museums other than national museums	Control of undertakings to sell liquor and food to the public	National transportation
Cultural matters	Municipal airports	Provincial planning	Facilities for accommodation, care and burial of animals	National public works
Disaster management	Municipal planning	Provincial cultural matters	Fencing and fences	National roads
Education at all levels, excluding tertiary education	Municipal health services	Provincial recreation and amenities	Dog licencing	Foreign and home affairs
Environment	Municipal public transport	Provincial sport	Local amenities	National libraries

Health services	Municipal public works	Provincial roads and traffic	Local sport facilities	National museums
Housing	Storm water management systems	Veterinary services, excluding regulation of the profession	Markets	National archiving systems
Indigenous law and customary law	Trading regulations		Municipal abattoirs	National lotteries and sport pools
Industrial promotion	Water and sanitation services limited to potable water system and domestic waste water and sewage disposal systems		Municipal parks and recreation	National and international airports
Language policy and regulation of official languages			municipal roads	Regulation of veterinary services
Media services			Noise pollution	National policy formulation for all sectors
Nature conservation, excluding national parks, botanical gardens and marine resources			Public places	Water resources management and bulk distribution
Police, except national and municipal police			Refuse removal, refuse dumps and solid waste disposal	Energy resources management, generation and transmission
Pollution control			Street trading	
Population development			Street lighting	
Property transfer fees			Traffic and parking	

Provincial public enterprises in respect of functional areas in Schedule 4 Part A and Schedule 5 Part A				
Public transport, except municipal transport				
National and provincial public works				
Regional planning and development				
Road traffic regulation				
Tourism, except local tourism				
Trade, except local trade				
Traditional leadership				
Urban and rural development				
Vehicle licensing				
Welfare services				

Source: Author’s table based on Constitution of the Republic of South Africa (1996)

APPENDIX 2: SUMMARY OF SELECTED PRIMARY AND SECONDARY EDUCATION DEA EFFICIENCY STUDIES

Author (s)	Factors of production	Outputs	Data range	DMUs	Stage 1 DEA	Stage 2 DEA	Input, output to DMU ratio	DEA model and orientation
1. Arias Ciro and Torres García (2018)	3 inputs (financial and non-financial) Teacher-to-pupil ratio Government expenditure per secondary student % of GDP Private expenditure per secondary student % of GDP	2 outputs Enrolment rates PISA reading, Maths and science literacy scores	4 years: 2012-2015	37 developing and developed countries	X	X	5.3	VRS, output maximisation
2. Halkiotis et al. (2018)	3 inputs (financial and non-financial) Teacher-to- student ratio Students: average number of students per class Expenditure: average annual expenditure per pupil	4 outputs Percentage of students admitted to university Percentage of students admitted to higher education technological institutes Percentage of students with excellent performance to university entrance between 18 and 20 Percentage of students with excellent performance to university entrance between 18 and 20	1 year: 2015	23 high schools: Greece	X		3.3	CRS and VRS, input minimisation, scale efficiency
3. Gavurova et al. (2017)	1 input (financial) Government expenditure on secondary education % of GDP	3 outputs PISA maths score PISA reading score PISA science score	1 year: 2015	31 European countries	X		7.8	VRS, output maximisation

4. Lauro, et al. (2016)	4 inputs (non-financial) Personnel: number of teachers employed Personnel: number of school staff Capital: number of computers Capital: number of classrooms	3 outputs Number of students served by the school Average pass rate from grade 1 to 5 Average grade 5 standardised Prova Brasil score	1 year: 2011	465 elementary schools: City of Rio de Janeiro	X	X	66.4	VRS, output maximisation
5. Yuan and Shan (2016)	3 inputs (financial and non-financial) Expenditure: total budget per capita Expenditure: equipment budget per capita Teacher-to-pupil ratio	3 outputs Quota per class Quota per school Student density per Km2	5 years: 2008 - 2012	17 Shanghai districts	X		2.8	CRS and VRS, output maximisation and input-minimisation, scale efficiency
6. Huguenin (2015)	3 inputs (financial and non-financial) Personnel: number of full-time equivalent teaching staff Personnel: number of full-time equivalent administrative and technical staff Expenditure: school budget	3 outputs Grade 2 results in French and mathematics Grade 4 results in French, German and mathematics Grade 6 results in French, German and mathematics	2 years: 2010 - 2011	90 primary schools: Switzerland	X	X	15	VRS, input minimisation
7. Hussain et al. (2015)	3 inputs (non-financial) Personnel: number of teachers employed Capital: number of institutes Capital: infrastructure	2 outputs Enrolment rate Student-teacher ratio	20 years: 1993 - 2012	6 rural and 6 urban areas: Pakistan	X		2.4	VRS and CRS, output maximisation

8. Lavado and Domingo (2015)	1 input (financial) Education expenditure per capita	2 outputs Percentage of pupils completed primary education Percentage of pupils completed secondary education	7 years: 2006 - 2012	38 Asian countries	X		12.7	VRS and CRS, output maximisation and input minimisation
9. Baciu and Bolezat (2014)	1 input (financial) Actual education expenditure	2 outputs Secondary school enrolment Quality of education results: mathematics and science	10 years: 2000 - 2009	27 countries: EU member states.	X		9	VRS and CRS, input minimisation
10. Salazar Cuéllar (2014)	2 inputs (financial and non-financial) Expenditure: public education expenditure per student Percentage of teachers per student	3 outputs Youth literacy rate Net enrolment rate Completion rate	10 years: 2000 - 2009	15 countries: Latin America	X		3	VRS, input minimisation and output maximisation
11. Yawe (2014)	5 inputs (non-financial) Personnel: total number of teachers in a given primary school Students: total number of pupils in a primary school Capital: total number of classrooms in a primary school Capital: total number of toilets in a primary school Capital: average class size	4 outputs Pass rates: number of pupils who passed examinations with 4–12 aggregates Pass rates: number of pupils who passed examinations with 13–23 aggregates Pass rates: number of pupils who passed examinations with 24–29 aggregates Pass rates: number of pupils who passed examinations with 30 –34 aggregates	11 years: 1995 - 2005	500 primary schools: Uganda	X		55.6	VRS and CRS output maximisation, scale efficiency

12. Prasetyo and Zuhdi (2013)	3 inputs (financial) Government expenditure per capita Education subsidies Other educational transfers	2 outputs HDI: years of schooling of adults aged 25 years HDI: years of schooling of children of school entering age	5 years: 2006 - 2010	81 countries (including South Africa)	X		20.3	VRS, output maximisation
13. Aristovnik (2011)	1 input (financial) % GDP per capita secondary school expenditure per student	3 outputs Primary school enrolment Primary school teacher-pupil ratio Primary school completion rate	9 years: 1999 - 2007	37 EU countries	X		9.3	VRS, input minimisation and output maximisation

Sources: The Authors.

APPENDIX 3: SUMMARY OF HEALTH SECTOR DEA EFFICIENCY STUDIES

Author(s)	Factors of production	Outputs	Data range	DMUs	Stage 1 DEA	Stage 2 DEA	Input, output to DMU ratio	DEA model and orientation
1. Campanella et al. (2017)	3 inputs (non-financial) Capital: number of beds per patients admitted Personnel: number of medical doctors per patient admitted Personnel: number of nurses per patient admitted	3 outputs 30-day risk-adjusted mortality for acute myocardial infarction 30-day risk-adjusted mortality for congestive heart failure 30-day risk-adjusted mortality for pneumonia.	Not provided	50 Italian hospitals	X	X	8.3	CRS, input minimisation
2. Lo Storto and Goncharuk (2017)	3 inputs (non-financial) Personnel: number of practicing medical doctors Personnel: number of practicing midwives, nurses and healthcare assistants	4 outputs Ratio of infant mortality (less than 1 year) to total population Number of healthy life years at birth Average life expectancy Population	4 years: 2011 - 2014	32 European countries	X		5.3	CRS, input-minimisation and output-maximisation

3. Alhassan et al. (2015)	5 inputs (non-financial) Personnel: number of clinical staff Personnel: number of support staff Capital: number of observation beds Capital: number of detention wards Capital: number of consulting rooms	4 outputs Number of baby deliveries Daily visits: number of out-patient visits Daily visits: number of antenatal and postnatal visits Number of family planning, reproduction and child health visits	Not provided	64 health facilities: Ghana	X	X	7.1	CRS and VRS, input minimisation
4. Jarjue et al. (2015)	2 inputs (non-financial) Personnel: average number of full time staff of each health centre at year end Capital: average number of beds in each health centre at the end of the year	2 outputs Admissions: total number of inpatients admitted Dismissals: total number of outpatients treated and discharged	2 years: 2011-2012	41 secondary health care centres: Gambia	X		10.3	VRS, output maximisation

5. Asandului et al. (2014)	3 inputs (financial and non-financial) Personnel: number of doctors Capital: number of hospital beds Expenditure: public health expenditure % of GDP	3 outputs Life expectancy at birth Health adjusted life expectancy Infant mortality rate	1 year: 2010	30 EU countries	X		5	CRS and VRS, input minimisation
6. Asandului, and Fătulescu (2014)	2 inputs (financial and non-financial) Public health expenditure Non immunised rate	2 outputs Disease prevalence: incidence of Tuberculosis Health indicator: adult survival rate	1 year: 2008	27 EU states	X		6.8	CRS, input minimisation
7. Baciu and Bolezat (2014)	1 input (financial) Actual health expenditure	2 outputs Life expectancy Infant survival rate	10 years: 2000 - 2009	27 countries: EU member states	X		9	VRS, input minimisation
8. Kim and Kang (2014)	2 inputs (financial and non-financial) Actual health expenditure Schooling	2 outputs Life expectancy Mortality rate	1 year: 2007	170 countries: High, middle and low income countries (South Africa included)	X		42.5	CRS, input minimisation

9. Anton (2013)	3 inputs (financial and non-financial) Capital: number of hospital beds per 100 000 inhabitants Personnel: number of physicians per 100 000 inhabitants Expenditure: total health expenditure per capita	2 outputs Infants deaths per 1 000 live births Life expectancy at birth in years	2009	20 Health Systems: Central and Eastern Europe	X		4	VRS, output maximisation
10. Prasetyo and Zuhdi (2013)	3 indicators (financial) Government expenditure per capita Health subsidies Other health transfers	1 indicator Human Development Index: Life expectancy at birth	5 years: 2006 - 2010	81 countries (including South Africa).	X		20.3	VRS, input minimisation

11. Varabyova and Schreyögg (2013)	4 inputs (non-financial) Capital: number of hospital beds Personnel: hospital staff Personnel: number of physicians Personnel: number of employed nurses	2 outputs Number of discharges Mortality rate	10 years: 2000 - 2009	31 OECD countries	X	X	5.2	CRS, input minimisation and output maximisation
12. Chowdhury et al. (2010)	6 inputs (financial and non-financial) Time: number of staff working hours Time: number of nursing working hours Capital: number of beds Expenditure: medical cost for surgical supplies Expenditure: non-medical cost for surgical supplies Expenditure: total equipment cost	2 outputs Daily visits: total number of outpatient visits Admissions: total number of inpatient days	4 years: 2003 - 2006	113 acute care Ontario hospitals: Canada	X		16.6	VRS, orientation not clear

13. Marschall and Flessa (2009).	4 inputs (financial and non-financial) Expenditure: health personnel costs Expenditure: annual depreciation costs of equipment Expenditure: costs of vaccinations Capital: building area of the district health centres	4 outputs General consultations and nursing care Baby deliveries at maternity wards Immunisation and special services Family planning, pre-natal and post-natal consultations	1 year: 2004	20 health care centres: Burkina Faso	X	X	2.5	CRS and VRS, output maximisation
14. Akazili et al. (2008)	4 inputs (financial and non-financial) Personnel: number of non-clinical staff Personnel: number of clinical staff Personnel: number of beds and cots Expenditure: drugs and supplies	5 outputs Daily visits: general outpatient visits Daily visits: number of antenatal care visits Number of child deliveries Number of immunised children Number of family planning visits	1 year: 2004	89 health care centres: Ghana	X		9.9	CRS and VRS, input minimisation. Scale efficiency

15. Benneyan et al. (2007)	5 inputs (financial and non-financial) Capital: number of hospital beds Personnel: number of trained medical people Expenditure: total health expenditure per capita Immunisation rate Median age	6 outputs Healthy life expectancy at birth Adult mortality rate Infant mortality rate TB prevalence Adverse event rate Equity	Not provided	180 countries (including South Africa).	X		16.4	CRS and VRS, input minimisation and output maximisation
16. Masiye (2007)	4 inputs (financial and non-financial) Expenditure: non-labour costs Personnel: number of medical doctors Personnel: number of administrative and other staff Personnel: number of nurses, Lab techs and Pharmacists	4 outputs Procedures: number of operations performed Admissions: number of inpatient beds occupied Number of baby deliveries Number of ambulatory visits	1 year: 2003	30 hospitals: Zambia	X		3.8	VRS, output maximisation

17. Afonso and St Aubyn (2006)	4 inputs (non-financial) Personnel: number of practicing physicians Personnel: number of practicing nurses Capital: acute care beds per 1 000 habitants Capital: high tech diagnostic medical equipment	3 outputs Life expectancy at birth Infant survival rate Potential years of lives not lost	4 years: 2000 - 2003	30 OECD countries	X	X	4.3	VRS, output maximisation
18. Zere et al. (2006)	3 inputs (financial and non-financial) Expenditure: total recurrent health expenditure Capital: number of beds Personnel: number of nursing staff	2 outputs Daily visits: number of outpatient visits Admissions: number of inpatient days	5 years: 1997 - 2001	30 District hospitals in Namibia	X		6	CRS and VRS, input minimisation

19. Gannon (2005)	2 inputs (non-financial) Capital: average number of beds per year Personnel: average number of people employed per year	2 outputs Dismissals: number of inpatient discharges per year Daily visits: number of outpatient consultations per year	6 years: 1995-2000	60 hospitals: Ireland	X		15	CRS, input minimisation
20. Kirigia et al. (2001)	2 inputs (non-financial) Number of employed nurses Number of general staff	8 outputs Antenatal care visits Number of baby deliveries Number of child health care visits Number of dental care visits Number of family planning visits Number of psychiatry visits Number of STI related care visits Number of TB related visits	1 year: 1996	155 public clinics: KZN	X		15.5	CRS and VRS, input minimisation and output maximisation. Scale efficiency.

21. Kirigia et al. (2000)	9 inputs (non-financial) Number of doctors, Number of admin staff Number of nurses Number of general staff Number of provisioning staff Number of paramedics Number of beds Number of technicians, Number of other staff	4 outputs Inpatient days Outpatient department visits Surgical operations Life births	2 years: 1995 to 1996	55 provincial hospitals: KZN	X		4.2	CRS and VRS, input minimisation. Scale efficiency.

APPENDIX 4: OTHER EFFICIENCY MEASUREMENT STUDIES IN SOUTH AFRICA

Author (s)	Sector	Factors of production	Outputs	Data range	DMUs	Methodology
1. Erasmus and Makina (2014)	Banking	6 inputs Deposits Other liabilities Shareholders' equity Staff costs Non-interest expense Fixed assets	2 outputs Loans and Overdrafts Non-interest income	7 years: 2006 - 2012	5 SA major Banks	DEA: Stage 1
2. Alhassan and Biekpe (2015)	Finance	3 inputs Management expenses Total equity Total liabilities	3 outputs Net premium earned Claim incurred Investment income	6 years: 2007 - 2012	76 insurers	DEA: Stages 1 and 2
3. Theunissen and Oberholzer (2013)	Finance	4 inputs Salary Total allowances (medical, retirement, travel, motor) Total bonuses Gains on shares	2 outputs Company performance Company size	1 year: 2010	221 JSE listed companies	DEA: Stage 1

4. Maredza and Ikhide (2013)	Banking	3 inputs Number of full-time employees of the bank Fixed assets of the bank Client deposits and current accounts	1 output Advances and loans to customers	11 years: 2000 - 2010	4 big SA banks	Hicks-Moorsteen (TFP) indices: Stages 1 and 2
5. Ncube (2009)	Banking	3 inputs Number of bank employees Capital Funds	1 output Advances and deposits	6 years: 2000 - 2005	8 SA banks	SFA: Stages 1 and 2
6. Lawanson and Novignon (2016)	Health	5 inputs Public health expenditure % of total spending Public health expenditure expressed in purchasing power parity Real GDP per capita HIV prevalence rate Education	1 output Infant mortality rate versus infant survival rate	7 years: 2005 - 2011	45 African countries (SA included)	SFA: Stages 1 and 2

7. Olukoga (2007)	Health	4 inputs Unit costs per inpatient day in district hospitals Unit costs of paediatric inpatient days in district hospitals Unit costs of medical inpatient days in district hospitals Unit costs of surgical inpatient days in district hospitals	3 outputs Number of inpatient days Admissions Average hospital length of stay	1 year: 2002	5 District hospitals in South Africa	The ingredients approach
8. Mbuvi, et. al (2012)	Water and sanitation	2 inputs Total number of employees The length of water distribution mains	2 outputs Water supply service coverage Volumetric water sold	Unclear	51 African water utilities (including SA)	DEA: Stages 1 and 2
9. Speelman et al. (2007)	Water and sanitation	5 inputs Land Labour Water Expenditure on pesticides Expenditure on fertilizers	1 output Rand value of production of small-scale irrigation schemes	1 year: 2005	60 farms: North-West	DEA: Stages 1 and 2

10. Brettenny and Sharp. (2016)	Water and sanitation	1 input Operating costs	3 outputs System input volume The number of households served The number of units receiving free basic water and/or sanitation services	1 year: 2010	88 Water services authorities	DEA: Stage 1
11. Taylor and Harris (2004)	Education	2 inputs Total expenditure Capital employed	2 outputs Academic qualifications completed research output	4 years: 1994 - 1997	10 universities	DEA: Stages 1 and 2
12. Dollery and Van der Westhuizen (2009)	Local government	2 inputs Operating income Staff costs	5 outputs Number of households RDP water RDP sanitation RDP refuse RDP electricity	1 year: 2007	231 municipalities , 46 district municipalities	DEA: Stage 1
13. Mahabir (2014)	Local government	1 input Municipal expenditure per capita	3 outputs Access to piped water Grid electricity connections A ventilated pit latrine and a flushable toilet Removal of solid waste at least one a week	5 years: 2005 to 2009	129 municipalities	FDH: Stages 1 and 2

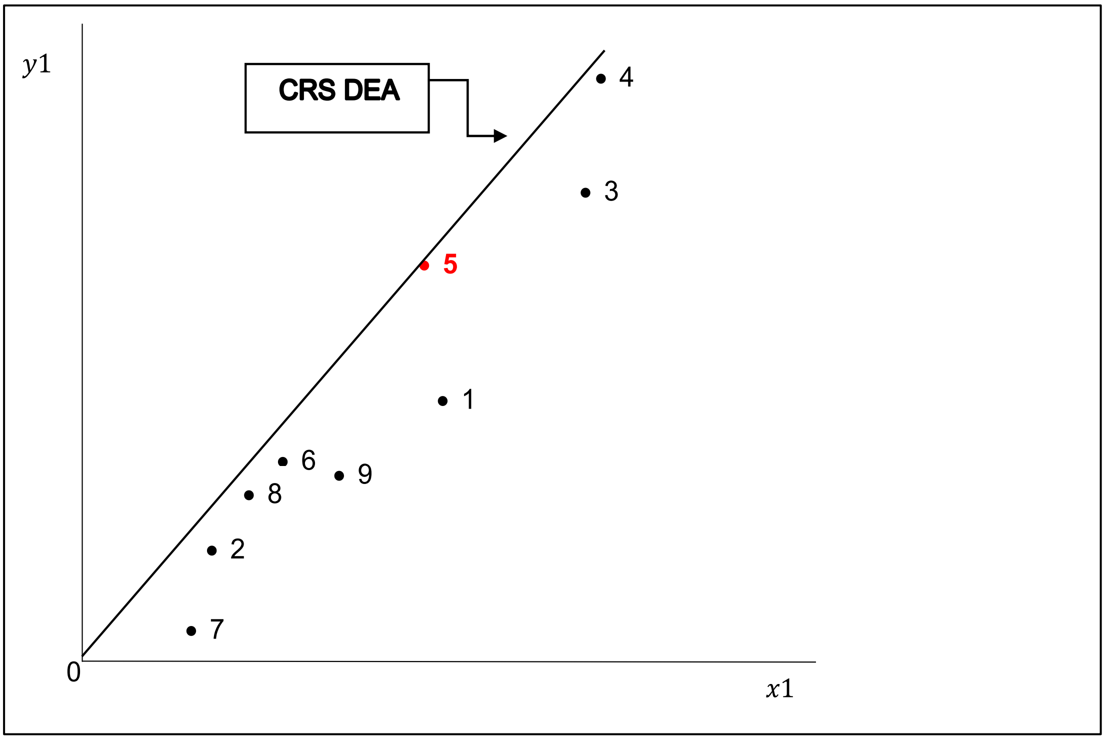
14. Monkam (2014)	Local government	1 input Municipal operating expenditure	5 outputs The number of consumer units receiving water The number of consumer units receiving sewerage and sanitation. The number of consumer units receiving solid waste management The number of consumer units receiving electricity The total population per municipality	6 years: 2007 - 2012	231 local municipalities	DEA: Stages 1 and 2 and SFA
15. Rahmayanti and Horn (2011)	Public sector: cross-cutting sectors (including health and education)	3 inputs Share of final consumption of government to GDP Labour force Capital share relative to GDP, trade openness and FDI.	3 outputs Literacy rate for education Life expectancy for health Electricity usage for infrastructure	14 years: 1990 - 2003	63 developing countries (including SA)	DEA: Stage 1
16. Cai (2011)	Innovation	2 inputs General expenditures on R&D Total R&D personnel	3 outputs WIPO patents granted Scientific and technical journal articles High-technology and ICT services exports	9 years: 2000 - 2008	22 countries (including SA)	DEA: Stage 1 and 2

17. Aye, et. al (2018a)	Agriculture	4 inputs Land Fertilizer Labour Capital	2 outputs Production CO_2	44 years: 1979 - 2014	1 country (South Africa)	Fuzzy Technique for Order Preference by Similarity to The Ideal Solution (TOPSIS).
18. Aye, et. al (2018b)	Energy	4 outputs Labour force Capital stock CO_2 emissions Energy consumption	1 output Gross Domestic Product	49 years: 1965 - 2014	1 country (South Africa)	Technique for Order Preference by Similarity to The Ideal Solution (TOPSIS).

Sources: The Authors.

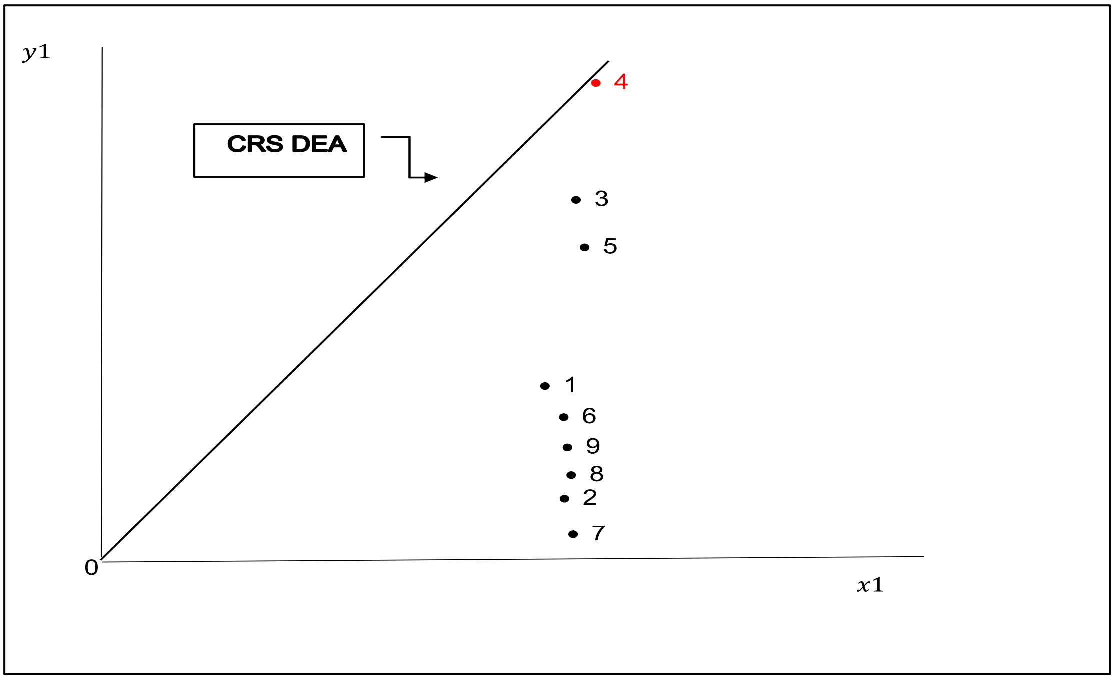
APPENDIX 5: EDUCATION EFFICIENCY FRONTIERS

Figure 5.1: Education Model 1 DEA efficiency frontier



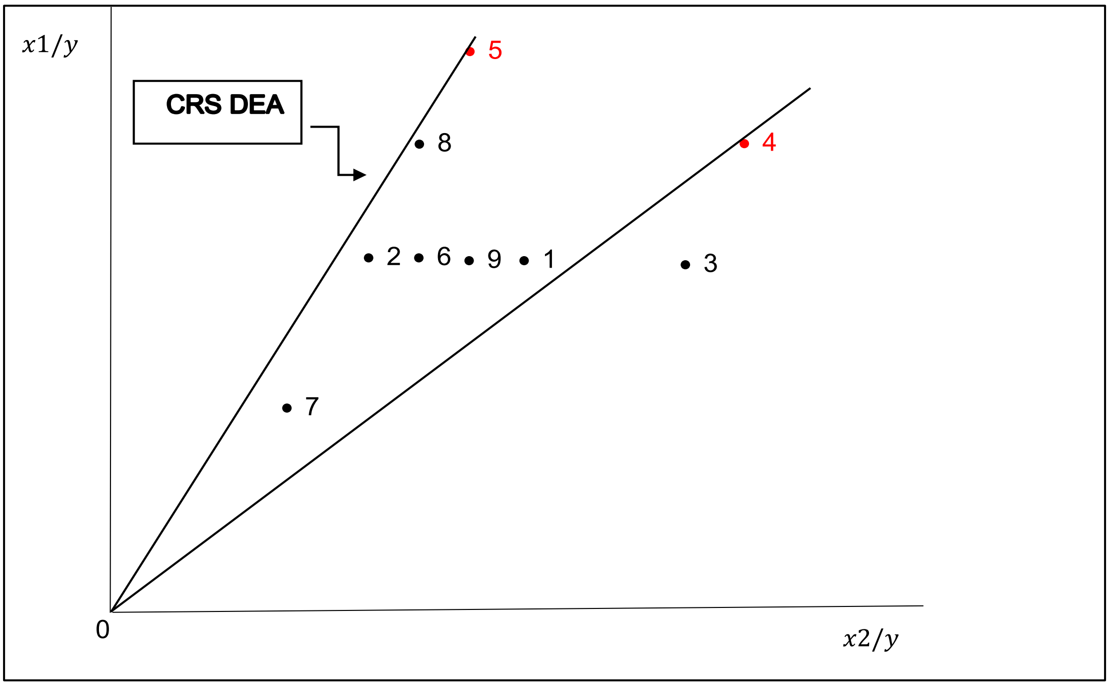
Source: Author's graph based DEAP Version 2.1 efficiency results.

Figure 5.2: Education Model 2 DEA efficiency frontier



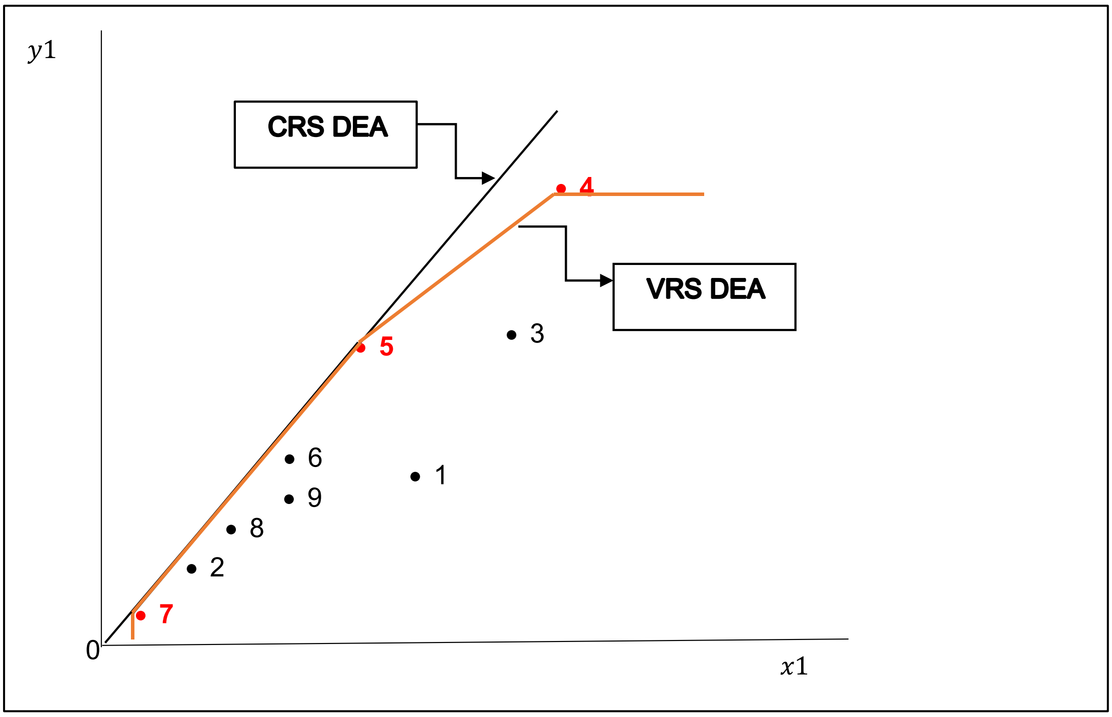
Source: Author's graph based DEAP Version 2.1 efficiency results.

Figure 5.3: Education Model 3 DEA efficiency frontier



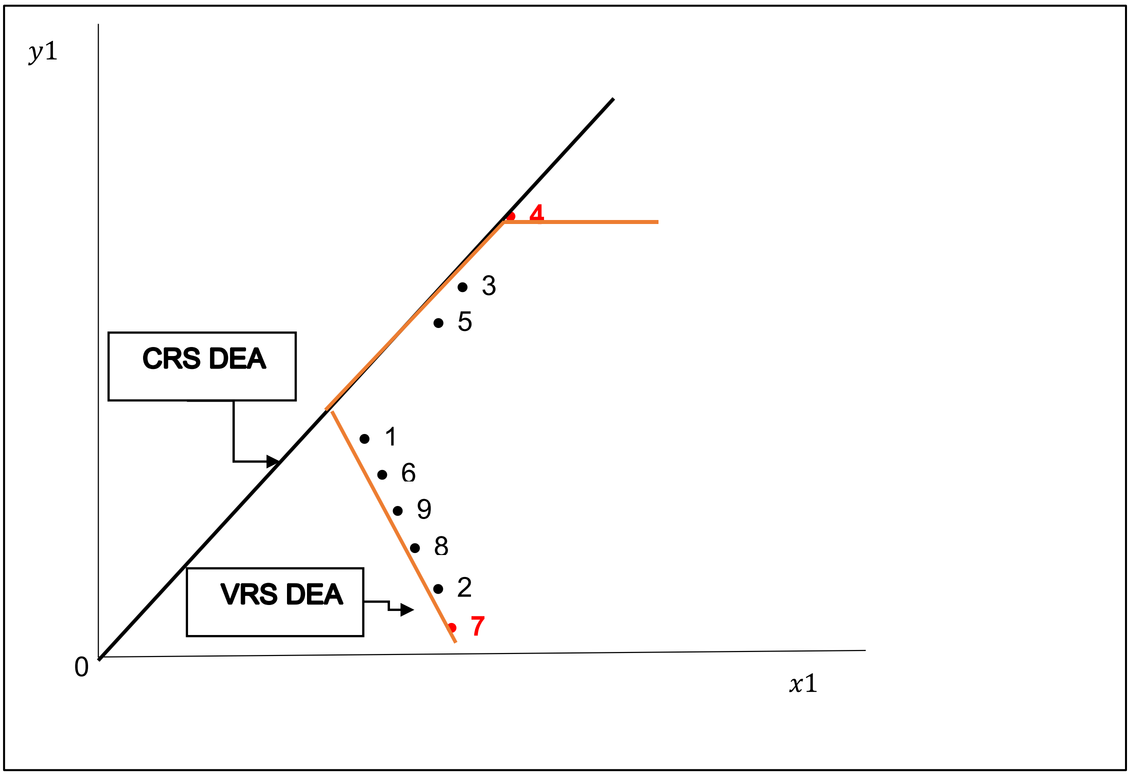
Source: Author's graph based DEAP Version 2.1 efficiency results.

Figure 5.4: Education Model 4 DEA efficiency frontier



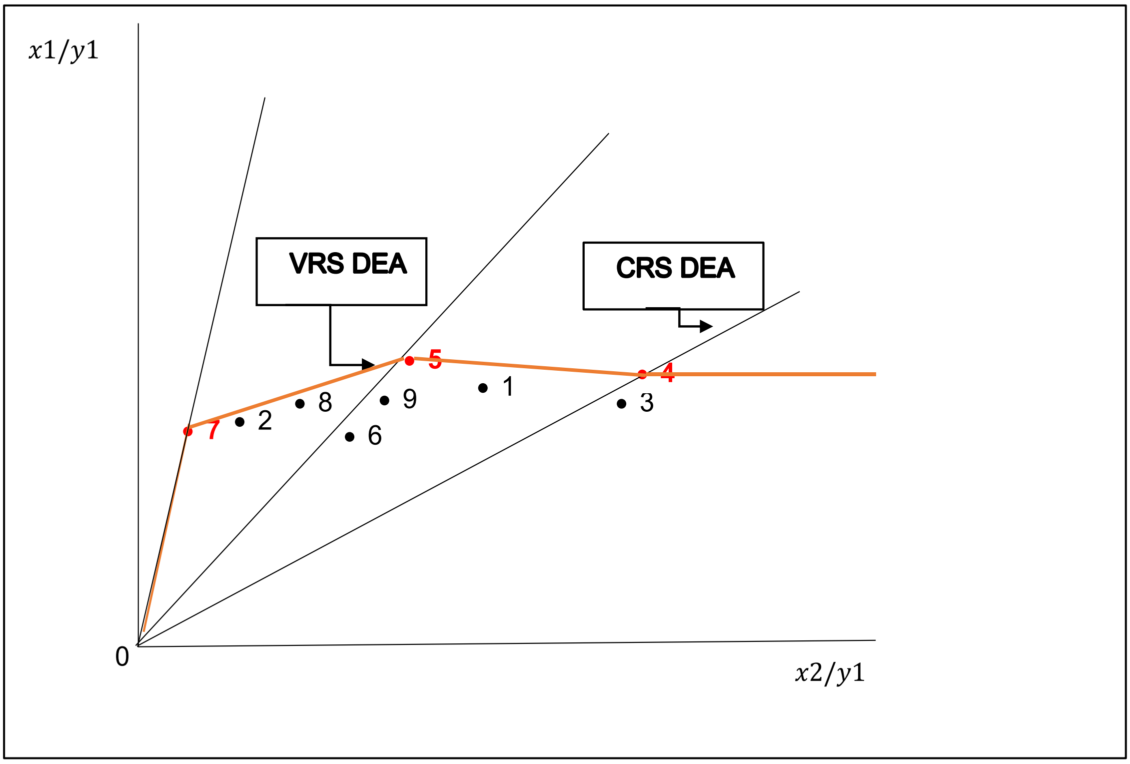
Source: Author's graph based DEAP Version 2.1 efficiency results.

Figure 5.5: Education Model 5 DEA efficiency frontier



Source: Author's graph based DEAP Version 2.1 efficiency results.

Figure 5.6: Education Model 6 DEA efficiency frontier



Source: Author's graph based DEAP Version 2.1 efficiency results.

APPENDIX 6: TEACHER REQUIREMENTS

Education Model 2 LER radial movements: CRS

Province	Learners	LER	Educators	Educator requirements
Eastern Cape	1 775 602	13,0	136 585	77 261
Free State	688 976	7,8	88 330	65 690
Gauteng	2 109 890	20,8	101 437	32 257
KwaZulu-Natal	2 773 823	30,7	90 288	-
Limpopo	1 659 635	20,3	81 755	30 115
Mpumalanga	1 026 151	11,1	92 446	58 765
Northern Cape	291 461	2,8	104 093	93 866
North West	820 545	9,1	90 170	64 042
Western Cape	1 084 111	10,3	105 253	69 572
Total	12 230 194	13,7	890 358	491 569

Source: Author's calculations based on DEAP 2.1 and the Department of Basic Education (2018b).

Education Model 3 LER radial movements: CRS

Province	Learners	LER	Educators	Educators requirement
Eastern Cape	1 775 602	17,5	101 463	42 139
Free State	688 976	22,2	31 035	8 395
Gauteng	2 109 890	9,2	229 336	160 156
KwaZulu-Natal	2 773 823	30,7	90 288	-
Limpopo	1 659 635	32,1	51 640	-
Mpumalanga	1 026 151	18,9	54 294	20 613
Northern Cape	291 461	25,2	11 566	1 339
North West	820 545	21,9	37 468	11 340
Western Cape	1 084 111	19,7	55 031	19 350
Total	12 230 194	16,3	662 120	263 331

Source: Author's calculations based on DEAP 2.1 and the Department of Basic Education (2018b).

Education Model 5 LER radial movements: VRS

Province	Learners	LER	Educators	Educator requirements
Eastern Cape	1 775 602	29,1	61 017	1 693
Free State	688 976	28,5	24 175	1 535
Gauteng	2 109 890	29,9	70 565	1 385
Natal	2 773 823	30,7	90 353	-
Limpopo	1 659 635	29,9	55 506	3 866
Mpumalanga	1 026 151	28,9	35 507	1 826
Cape	291 461	28,5	10 227	-
North West	820 545	28,7	28 590	2 462
Cape	1 084 111	28,8	37 643	1 962
Total	12 230 194	29,6	413 583	14 729

Source: Author's calculations based on DEAP 2.1 and the Department of Basic Education (2018b).

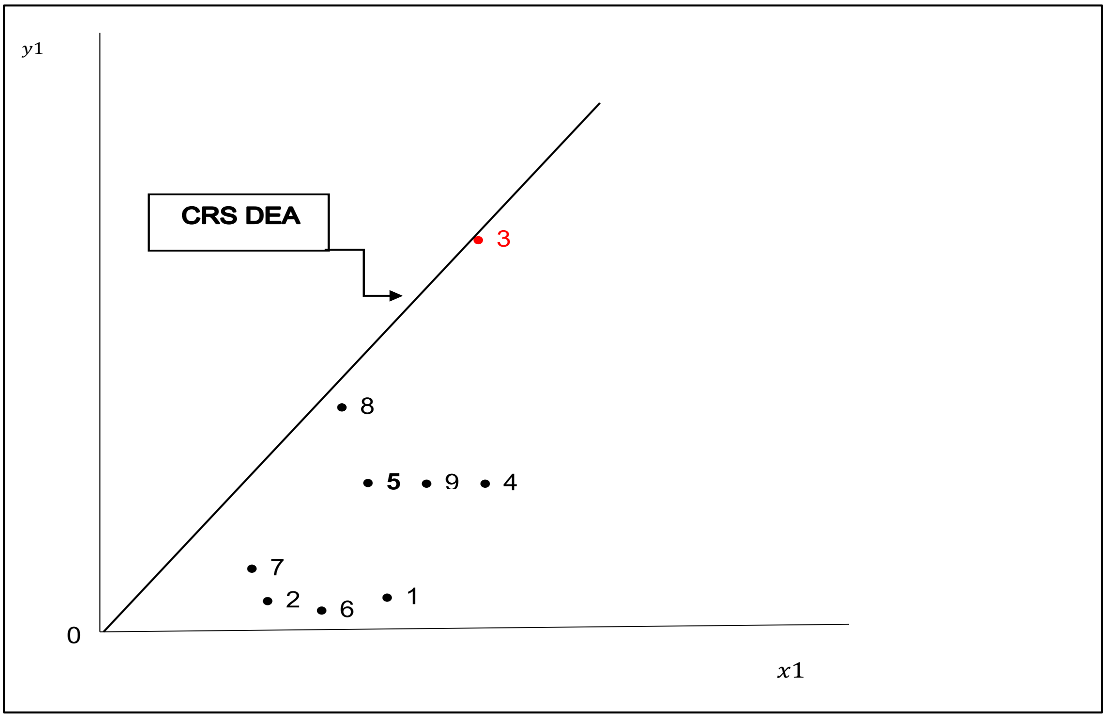
Education Model 6 LER radial movements: VRS

Province	Learners	LER	Educators	Educator requirements
Eastern Cape	1 775 602	29,1	61 017	1 693
Free State	688 976	29,1	23 676	1 036
Gauteng	2 109 890	29,9	70 565	1 385
Natal	2 773 823	30,7	90 353	-
Limpopo	1 659 635	32,1	51 640	-
Mpumalanga	1 026 151	28,9	35 507	1 826
Cape	291 461	28,5	10 227	-
North West	820 545	29,4	27 910	1 782
Cape	1 084 111	28,8	37 643	1 962
Total	12 230 194	29,9	408 537	9 684

Source: Author's calculations based on DEAP 2.1 and the Department of Basic Education (2018b).

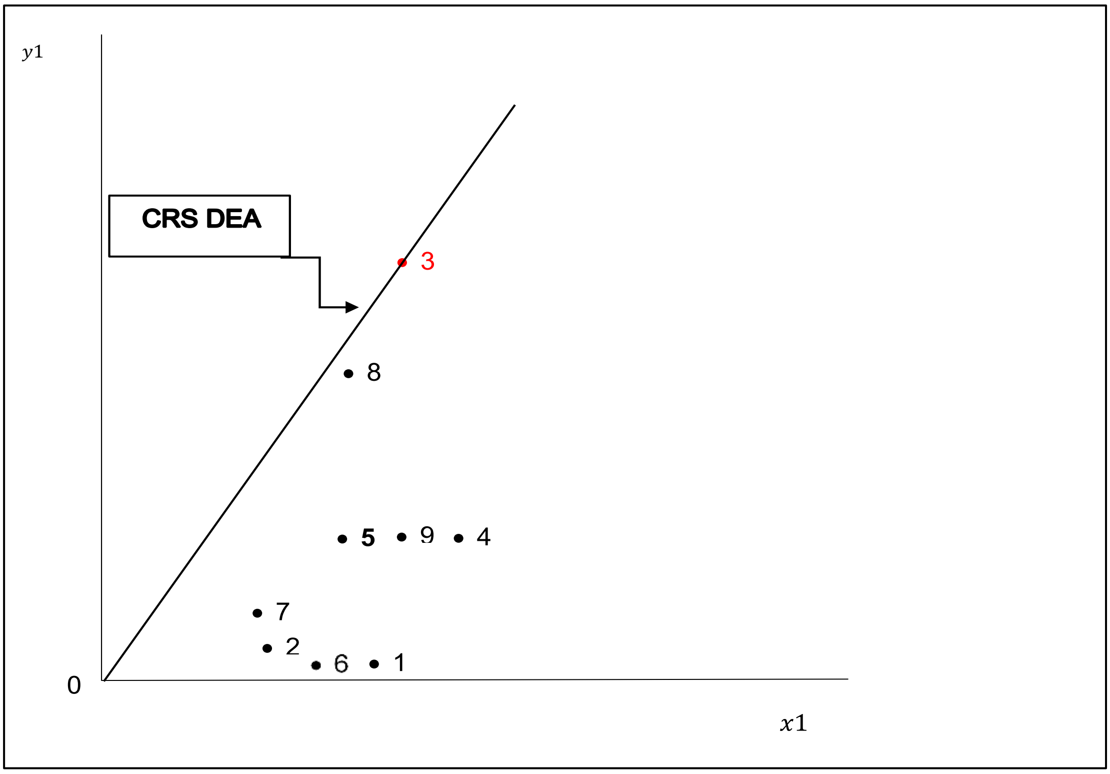
APPENDIX 7: HEALTH EFFICIENCY FRONTIERS

Figure 5.7: Health Model 1 DEA efficiency frontier



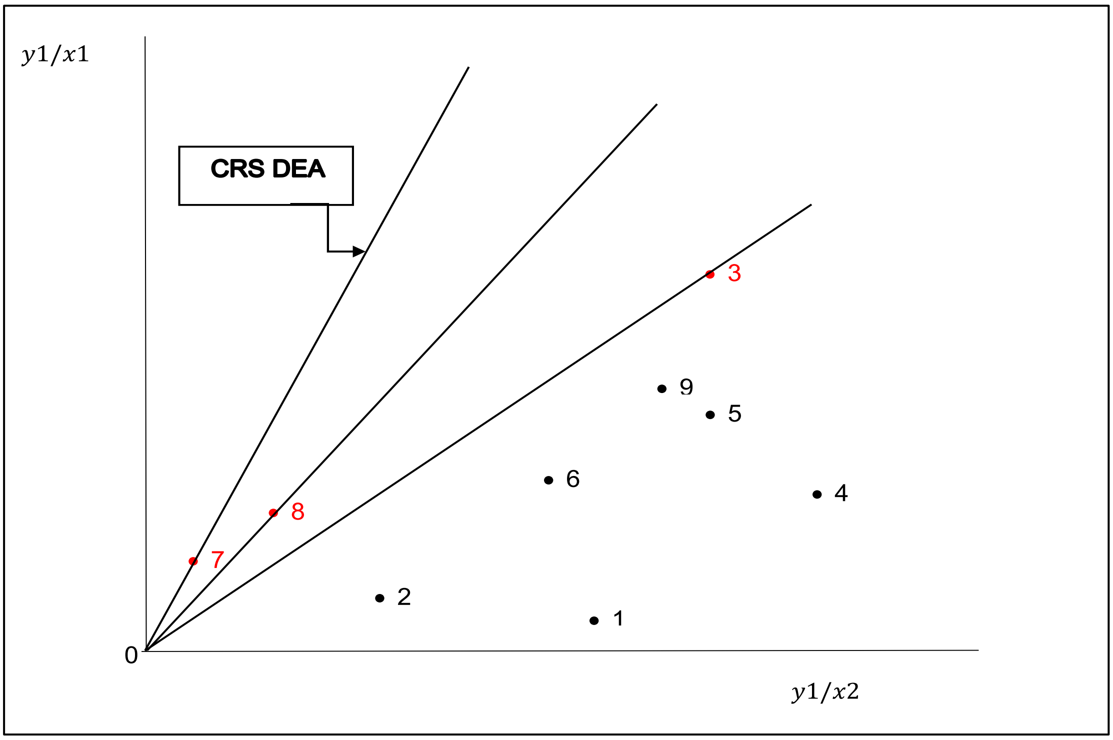
Source: Author's graph based DEAP Version 2.1 efficiency results.

Figure 5.8: Health Model 2 DEA efficiency frontier



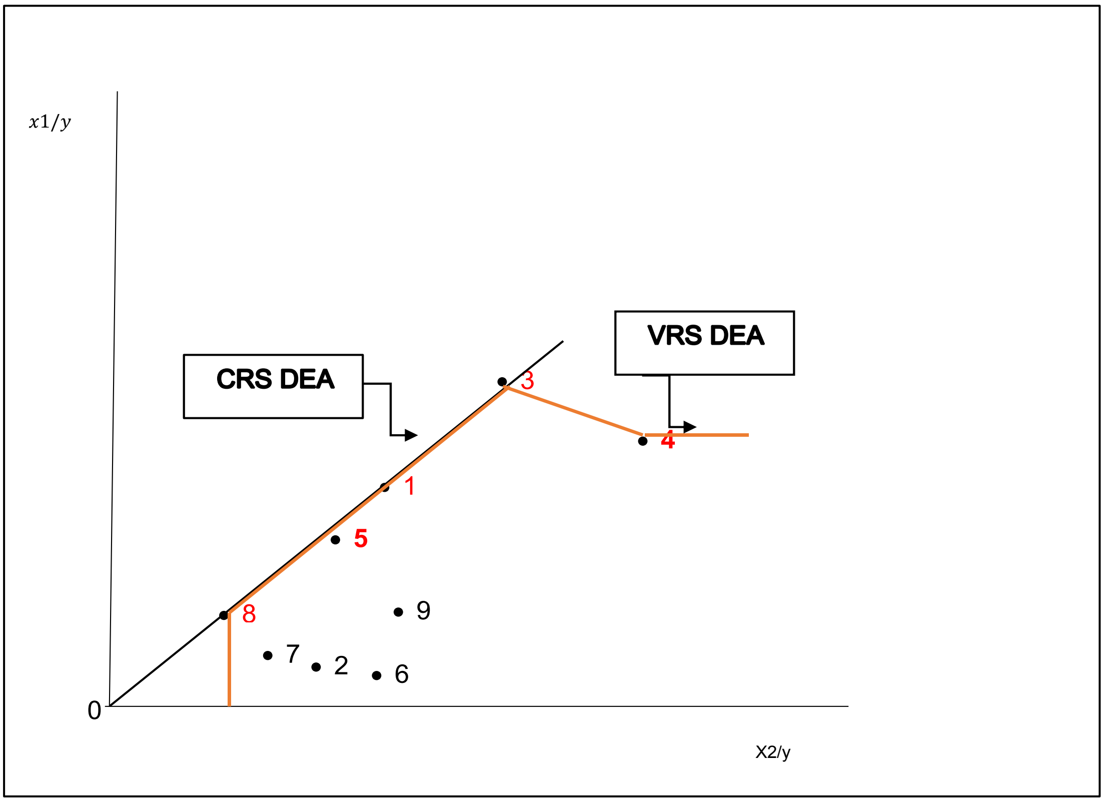
Source: Author's graph based DEAP Version 2.1 efficiency results.

Figure 5.9: Health Model 3 DEA efficiency frontier



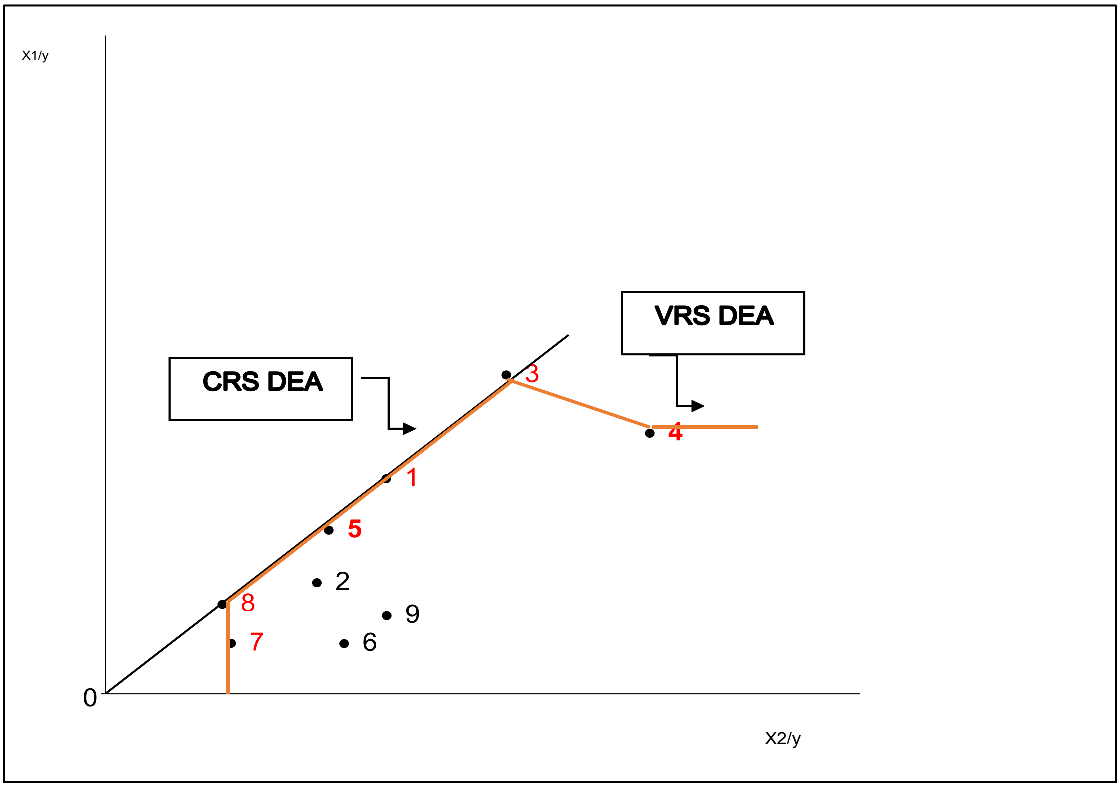
Source: Author's graph based DEAP Version 2.1 efficiency results.

Figure 5.10: Health Model 4 DEA efficiency frontier



Source: Author's graph based DEAP Version 2.1 efficiency results.

Figure 5.11: Health Model 6 DEA efficiency frontier



Source: Author's graph based DEAP Version 2.1 efficiency results.