The Impact of Infrastructure Investment on Economic Growth in South Africa

By

Veron Vukeya

Student No. 20065619

A Dissertation Submitted to the Faculty of Commerce, Administration and Law in Fulfilment of the Requirement for the Master of Commerce (Economics) Degree.

University of Zululand
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DECLARATION

I, the undersigned, hereby declare that this dissertation, save for supervisory guidance received, is the product of my own work and effort. I have, to the best of my knowledge and belief, acknowledged all the resources of information in line with normal academic conventions. I further certify that the dissertation is original, and has not been submitted before at this or any other university for the award of any degree at any other university purpose of obtaining a degree.

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Veron Vukeya Date: 19 January 2015

ABSTRACT

The South African government has, in recent years, set up various economic and social infrastructure programmes in an attempt to curb the country's infrastructure deficit and hence accelerate economic growth and employment creation as prescribed by the national growth path (NGP), national development plan (NDP) and other authoritative documents. This research study uses single and multiple equation methodologies to provide an econometric assessment of the impact of government economic and social infrastructure investment on South African economic growth for the period 1983 – 2013. This study does so by ascertaining the relationship between these two forms of infrastructure investment and economic growth and analysing their impact on other macroeconomic variables such as private investment and employment. Overall findings reveal that in the long run, economic infrastructure investment is an important determinant of growth while social infrastructure investment crowds-out economic growth and private investment. The causality patterns found in this study suggest that growth tends to cause economic infrastructure investment. Conversely, no causal linkages were detected between growth and social infrastructure investment.

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LIST OF ACRONYMS

2SLS	-	Two Stage Least Squares
3SLS	-	Three Stage Least Squares
ADF	-	Augmented Dickey-Fuller
AEG	-	Augmented Engle -Granger
AIC	-	Akaike Information Criterion
AR	-	Autoregressive
ARDL	-	Autoregressive Distributed Lag
ASGISA	-	Accelerated and Shared Growth Initiative of South Africa
CCR	-	Canonical Cointegration Regression
CGE	-	Computable General Least Squares
CUSUM	-	Cumulative Sum of Squares
CUSUMQ	-	Cumulative Recursive Sum of Squares
DBSA	-	Development Bank of Southern Africa
DF	-	Dickey-Fuller

DOLS	-	Dynamic Ordinary Least Squares
ECM	-	Error Correction Model (Mechanism)
EG	-	Engle-Granger
EMP	-	Total Employment
FE	-	Fixed Effects
FFC	-	Financial and Fiscal Commission
FIFA	-	Fédération Internationale de Football Association (FIFA, English: International Federation of Association Football)
FMOLS	-	Fully Modified Ordinary Least Squares
FPE	-	Final Prediction Error
GDP	-	Gross Domestic Product
GEAR	-	Growth, Employment and Redistribution
GLS	-	Generalised Least Squares
GMM	-	Generalised Methods of Moments
GVA	-	Gross Value Added
HE	-	Expenditure on Health and Education
IMF	-	International Monetary Fund
INF	-	Economic Infrastructure Investment
IRF	-	Impulse Response (Reaction) Function
IV	-	Instrumental Variable
KPSS	-	Kwiatkowski-Phillips-Schmidt-Shin
LEMP	-	Log of Total Employment
LHE	-	Log of Expenditure on Health and Education
LINF	-	Log of Economic Infrastructure Investment
LPVT	-	Log of Private Capital Investment
LR	-	Long Run
NDP	-	National Development Plan
NGP	-	National Growth Path
NPC	-	National Planning Commission
OECD	-	Organisation for Economic Co-operation and Development
OLS	-	Ordinary Least Squares
PMG	-	Pooled Mean Group
PP	-	Phillips-Perron

PSS	-	Pesaran, Shin and Smith
PVT	-	Private Capital Investment
R&D	-	Research and Development
RDP	-	Reconstruction and Development Programme
RE	-	Random Effects
RSS_r	-	Restricted Residual Sum of Squares
RSS_{ur}	-	Unrestricted Residual Sum of Squares
SAM	-	Social Account Matrix
SARB	-	South African Reserve Bank
SBC	-	Schwarz Bayesian Criterion
SIC	-	Schwarz Information Criterion
SR	-	Short Run
STATS SA	-	Statistics South Africa
TE	-	Technical Efficiency
TFP	-	Total Factor Productivity
U.S.	-	United States
VAR	-	Vector Autoregressive
VECM	-	Vector Error Correction Model

CHAPTER ONE

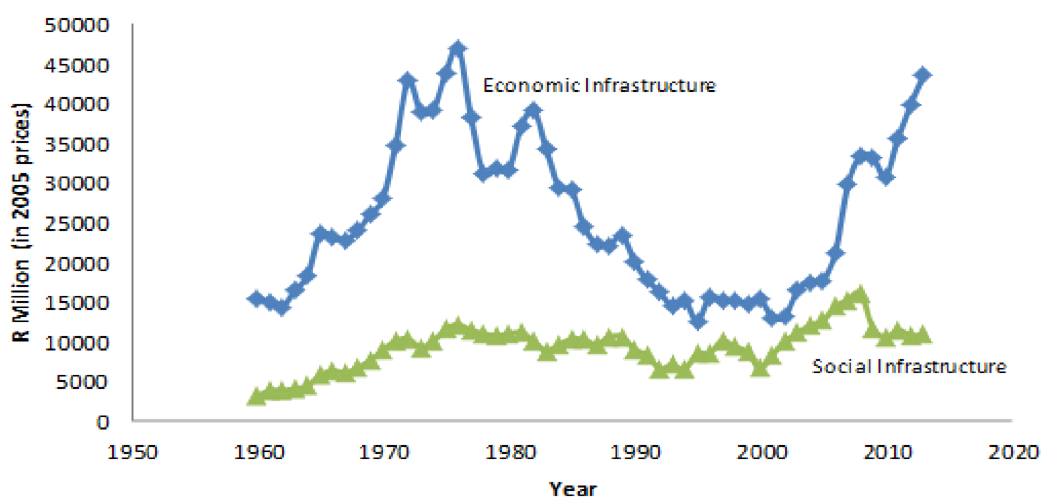
OVERVIEW OF THE STUDY

1.0 Introduction

The South African economy is riddled with poverty, inequality as well as high rates of unemployment (Kumo, 2012; Financial and Fiscal Commission (FFC), 2012; Organisation for Economic Co-operation and Development (OECD), 2013; Presidency, 2014; World Bank, 2014b). Unfortunately, the country is also in a declining economic growth rate trend spell, thus making it virtually impossible to address these harsh economic and social challenges (OECD, 2013; National Treasury, 2014; World Bank, 2014b). South African government policy reports, white papers and documents such as the Accelerated and Shared Growth Initiative of South Africa (ASGISA) of 2006, the New Growth Path (NGP) of 2011 and the National Development Plan (NDP) of 2012 remain central in identifying and harnessing the factors, processes and actions that are necessary in order to firmly place the South African economy on the path of sustained economic development. Moreover, this body of policy documents and initiatives has identified infrastructure investment as an area of critical significance in firmly placing South Africa on a high growth trajectory (Mbanda and Chitiga, 2013; Perkins, Fedderke and Luiz, 2005).

As debates regarding the role of infrastructure – often defined as large-scale public systems, services and facilities essential for economic activity including energy, transportation, telecommunication, water, health and educational facilities – on the growth process persist, a plethora of existing empirical works on the subject show that investment in infrastructure is associated with a positive contribution to economic growth (Baldwin and Dixon, 2008; Chetty, 2007; Gjini and Kukeli, 2012; Prud'homme, 2004; World Bank, 1994). According to Heymans and Thome-Erasmus (1998), infrastructure contributes to growth by lowering the cost of production, consumption, and transactions, thus improving service provision and development outcomes. According to Kumo (2012), South Africa has better developed infrastructure such as roads, educational institutions and health facilities by developing country standards, however, it is poorly located and there is still a large infrastructure deficit (Presidency, 2014). According to the National Planning Commission (NPC) (2014) and the National Treasury (2012), infrastructure investment equivalent to 25 per cent of GDP (gross domestic product) is required in emerging economies for a significant rise in growth, but South Africa's infrastructure investment to GDP ratio is still well below the prescribed level. In 2013 the infrastructure investment to GDP ratio was recorded at 19.3 per cent, which is a significant increase compared to the ratio of 14.9 in the year 2000 as per the South African Reserve Bank (SARB) online statistics. The South African critical infrastructure needs are partly attributed to discriminatory practices of the apartheid government (Perkins, 2011; Presidency, 2014) and partially as a result of underinvestment during the 1980s and 1990s (National Treasury, 2012), as depicted by Figure 1.1. Merrifield (2000) notes that infrastructure investment may also have fallen due to overcapacity in certain areas.

Figure 1.1: Government Infrastructure Investment



Source: Generated by the researcher, SARB data.

In response to the insufficiency of infrastructure, the government has, in recent years, set up various economic and social infrastructure programmes. Figure 1.1, which shows the net government infrastructure investment from 1960 to 2013, depicts that economic and social infrastructure investment regained momentum from the early 2000s. In the present day, there have been large financial resources directed towards infrastructure investment by the government and over the next three years, public infrastructure and maintenance spending is projected to exceed R844 billion (National Treasury, 2014).

Given that the relationship between growth and infrastructure is an important subject, this research attempts to quantify the impact of infrastructure investment on economic growth in South Africa. While a number of recent South African studies have dealt with this issue, their findings are mixed and, most of them, for example Abedian and Van Seventer (1995), Cheteni (2013), Development Bank of Southern Africa (DBSA) (1998), Fedderke, Perkins and Luiz (2006), Perkins *et al*., (2005), Kumo (2012), Mabugu, Chitiga and Rakabe (2009)and Mbanda and Chitiga (2013), have neglected to distinguish between economic and social infrastructure. In light of this, this research looks at infrastructure from both the economic and social perspectives and examines their individual contribution to growth. Additionally, this study examines the crowding-in and out effects of both economic and social infrastructure on private investment, which existing literature has also failed to model. The rest of this chapter is structured as follows: section 1.1 clearly defines the nature of the research in the problem statement; section 1.2 outlines the purpose of the study; respective hypotheses are presented in section 1.3; section 1.4 motivates the significance of the study; and in section 1.5 the organisation of the rest of the research is explained.

1.1 Problem Statement

The South African government has dedicated vast financial resources in the past couple of years towards infrastructure development with the intention to stimulate economic activity. The National Treasury (2012; 2013; 2014) has also indicated its plan to continue to prioritise the development of infrastructure. Based on estimation by the National Treasury (2014), gross fixed capital growth is predicted to increase from 3.2 per cent in 2013 to 6 per cent in 2016. While theoretical literature (see for example, Barro (1990), Keynes (1936), Smith (1776), Solow (1956) and Romer (1986; 1990)) backs this growth strategy, a large number of empirical studies conducted, both locally and internationally, also find strong evidence in support of a favourable impact of infrastructure investment on economic growth, for example, Aschauer (1989), Canning and Pedroni (1999), Cheteni (2013), DBSA (1998), Dash and Sahoo (2010), Kamps (2006), Munnell (1990a), Nketiah-Amponsah (2009) and Perkins *et al*., (2005). In light of these findings, one would expect the South African economic growth rate to be much higher than it currently is, however, the South African growth rate has not shown any improvement even with such an investment. Instead, the economic growth rate trend has been gradually declining overtime (National Treasury, 2014). This is, however, not particularly surprising since empirical evidence on the subject matter is not as clear cut, as some studies find a negative correlation, while others find no association between infrastructure and growth; see for example, Ghali (1998), Pritchett (1996), Gadinabokao and Daw (2013), Gutierrez (2005) and, Kustepeli, Gulcan and Akgungor (2012). In this regard, it is imperative to evaluate the short and long run infrastructure investment impact on economic growth in South Africa and determine whether the continued increase in infrastructure investment is justified, especially since it will come at great expense to government and hence the tax payers over the foreseeable future. Moreover, credit rating agencies question the South African government's credibility in maintaining the fiscal balance and hence the recent downgrades. Thus the scope of this research study is to estimate the coefficients that approximate the impact of the various forms of infrastructure investment on economic growth as well as the link between government infrastructure investment spending and private investment and employment.

1.2 Objective of Study

Given the emphasised importance of infrastructure investment for sustainable economic growth, the main objective of this research is to provide a comprehensive assessment of the impact that government economic and social infrastructure investment has had on South African economic growth from 1983 to 2013. The research seeks to do so by ascertaining the relationship between infrastructure investment and economic growth, examining the magnitude or elasticity at which economic and social infrastructure investment independently influence economic growth in both the short and long run, and analysing the impact of infrastructure investment on other macroeconomic variables such as private investment and employment. This analysis also enables the researcher to ascertain the main economic growth determinants in South Africa, through the investigation of the relationship between economic growth, employment, private and public investment and infrastructure investment.

1.3 Hypotheses

To achieve the objective of this research, the following four hypotheses are tested:

Hypothesis 1: There is a significant and positive relationship between economic infrastructure and economic growth in the South African economy.

Hypothesis 2: There is a significant and positive relationship between social infrastructure and economic growth in the South African economy.

Hypothesis 3: Infrastructure investment promotes private investment, thus crowding-in private investment in South Africa.

Hypothesis 4: There are bidirectional causal linkages between all variables in the system: infrastructure investment, economic growth, employment and private investment.

1.4 Intended Contribution to Knowledge

There is limited empirical work on the role played by government infrastructure investment on the South African economy and this study wishes to extend the analysis of the subject matter in three respects. Firstly, following a Chinese study by Sahoo *et al*., (2012), this research considers the impact of both economic and social infrastructure on economic growth, employment and private investment. The bulk of existing South African literature, such as studies by Fedderke and Garlick, (2008); Fedderke *et al*., (2006), Perkins *et al*., (2005), Kumo (2012) Mbanda and Chitiga (2013), does not incorporate social infrastructure into the respective econometric models. The analysis of both forms of infrastructure is of high significance in the context of their implications for economic policy and hence this research adds to the body of knowledge by considering both economic and social infrastructure. Secondly, this study gives an updated account of the interactions between the above-mentioned macroeconomic indicators. It should be noted that although Kularatne (2006) does take both types of infrastructure into consideration, his study, however, does not analyse these infrastructure effects beyond 2004. Lastly, this dissertation employs econometric methods not utilised before (to the best of the researcher's knowledge) in a single infrastructure-growth interaction analysis. Specifically, the study estimates: the impulse reaction function (IRF), and the variance decomposition and Granger causality tests within the vector autoregressive (VAR) framework; the Johansen (1991) vector error correction model (VECM); single equation techniques including the fully modified ordinary least squares (FMOLS), canonical cointegrating regressions (CCR), dynamic ordinary least squares (DOLS), and autoregressive distributed lag (ARDL) models in order to address the earlier-stated objective and hypotheses. Although VAR and VECM estimation techniques are common in infrastructure related studies in South Africa, single equation methods such as the FMOLS, CCR and DOLS have not been employed before for this type of analysis. The use of various estimation modelling techniques allows the researcher to compare the different findings and hence to derive a more conclusive answer to what the impact of infrastructure investment on economic growth in South Africa is. Most importantly, findings from this study will be valuable to government, policy makers and researchers.

1.5 Organisation of the Study

The dissertation consists of six chapters. This chapter gives an overview of the entire research study. Chapter two presents relevant theories dedicated to exploring determinants of economic growth and the role played by infrastructure investment. In order to locate this study within its appropriate theoretical context, the theory also serves to identify the pertinent variables used in the empirical literature and this study. Additionally, the chapter gives an account of the conceptual literature behind infrastructural links to growth and a historic overview of infrastructure investment and development in South Africa.

Chapter three covers empirical considerations on the impact of infrastructure on economic growth. All pertinent existing empirical studies in South Africa and a selection of international studies are reviewed in an attempt to identify general findings on the subject matter and gaps that this study may address. Additionally, the empirical review is used to identify appropriate variables and models to estimate in order to quantify the relationship between infrastructure and growth in a South African context.

Chapter four discusses relevant statistical estimation concepts, techniques and the econometric specification of the models to be estimated in chapter five. The chapter is divided into two sections that cover time series statistical estimation methodology and model specification. Under the first section, the concepts of stationarity, cointegration and their designated tests are presented, followed by VAR, VECM and ARDL modelling frameworks and functionalities. The second section covers the theoretical model to be estimated and a description of the chosen variables that pertain to the study's econometric model.

Chapter five covers the empirical analysis, gives detailed explanations of the various stages of the estimation procedure and discusses the results of this study. The analysis begins with preliminary examinations to determine the basic properties of the data used for econometric analysis and to guide the researcher in the selection of appropriate estimation techniques to employ. The short and long run interactions of the study's growth model are examined through the use of the VAR and VECM frameworks. Single equation estimation methods, which include the FMOLS, DOLS and ARDL techniques, are used for confirmatory purposes.

Chapter six concludes the study by succinctly summarising the empirical findings and outlining their relevance to macroeconomic policy prescriptions. Accordingly, policy recommendations and strengths and weaknesses of the study are provided.

CHAPTER TWO

THEORETICAL LITERATURE REVIEW

2.0 Introduction

This chapter reviews relevant theoretical and conceptual literature dedicated to exploring determinants of economic growth in order to locate this study within its appropriate theoretical context. For the purpose of demonstrating growth's role in the process of infrastructure investment, the chapter is divided into three sections. The first section explores relevant growth theories, the second section gives an insightful overview of conceptual literature on infrastructure investment and the last section reviews infrastructure investment in South Africa.

2.1 Theories of Economic Growth

Theoretical developments on factors driving economic growth date back to Adam Smith's *Wealth of Nations,* which is considered to be the founding work of modern economics. Soon after Smith's (1776) work, numerous growth theories erupted, including the work of Ricardo (1817), Schumpeter (1934), and Keynes (1936). Between the 1950s and 1970s, the most widespread model of economic growth was the Harrod-Domar model which attempted to put together key features of Keynes' (1936) general theory in a long run economic growth model (Mallick, 2002; Sala-i-Martin, 1990a). According to King and Levine (1994), the Harrod-Domar model formed the original theoretical basis for capital fundamentalism, which regards capital accumulation as a fundamental instrument to increasing the rate of economic growth.

Solow (1956), who is regarded as the pioneer for almost all analysis of growth in the exogenous neoclassical framework, extended the Harrod-Domar model (King and Levine, 1994; Knight, Loayza and Villanueva, 1993; Mallick, 2002). A key feature of these neoclassical models is the decreasing returns to capital accumulation (Mankiw, Romer and Weil, 1992). It is this feature of the neoclassical growth models that lead to the conclusion that capital accumulation is not the main factor in long run growth. Instead, these models emphasise that it is technology that raises living standards and growth. Technology is however assumed to happen by chance.

In the late 1980s and early 1990s, these neoclassical growth models were extended to develop the endogenous growth models, also referred to as new growth models (Diebolt and Monteils, 2000; Lucas, 1988; Mallick, 2002; Rebelo, 1991; Romer 1986). Key to endogenous growth models is the non-existence of diminishing returns in the process of accumulating factors of production (Chandra and Sandilands, 2005; Rossi, 2011; Sala-i-Martin, 1990b). These models highlight the existence of constant or increasing returns, and contrary to neoclassical theory, growth is an endogenous process with capital accumulation, research and innovation - embedding technological progress (Rossi, 2011). Endogenous growth theory broadens the concept of capital from physical goods to include human capital in the form of education, experience, and health (Barro, 1996). The role of human capital as a significant determinant of technological progress, and economic growth has emerged as a key factor in these models (Fedderke, 2002; Mallick, 2002).

This section reviews relevant theoretical literature dedicated to exploring determinants of economic growth. In subsections 2.1.1, 2.1.2 and 2.1.3, growth theories by Smith (1776), Ricardo (1817) and the Cobb Douglas production function are briefly explained. In subsection 2.1.4, an account of Schumpeter's (1934) theory of economic development is discussed. The general theory of employment, interest and money is explored in subsection 2.1.5. Subsections 2.1.6, 2.1.7 and 2.1.8 briefly explore the Harrod-Domar, Nurkse (1953) and Kaldor (1957) growth theories, respectively. Subsection 2.1.9 gives a detailed insight into the Solow (1956) growth model which suggests that exogenous technological progress is a key determinant of long run growth through its expansionary effect on a society's production capabilities. Rostow's (1959) stages of economic growth are discussed in subsection 2.1.10. Romer (1990), in subsection 2.1.11, expands Solow's (1956) model by modelling the determinants of technological progress and concludes that economic growth is a function of human capital stock. Finally, subsection 2.1.12 explores Barro's (1990) model of growth.

2.1.1 Smith's Growth Theory

Smith's (1776) work is considered to be the founding work of modern economics. Considerable portions of his work are spent refuting the policies of mercantilism, which is an economic theory practice that dominated European thought between the 16th and 18th centuries with the purpose of building a wealthy and powerful state through the accumulation of bullion and trade protectionism. The goal of these policies was to achieve a favourable balance of trade that would ensure increased accumulation of gold and silver, maximum utilisation of resources for manufacturing and also to maintain domestic employment. Mercantilists emphasise the importance of developing the country by means of restricting imports through tariffs, quotas and other protectionist measures, and encouraging exports through the promotion of domestic merchants and producers by means of subsidies and industry and market related research. This economic theory also regards a large population as a form of wealth which made possible the development of bigger markets and greater security against foreign invasion. Mercantilism was the driving force behind colonisation, and according to this theory, colonies existed for the sole purpose of providing the mother country with raw materials and markets for domestic goods, among other things.

Contrary to the mercantilism policies, Smith (1776) argues that economic growth is strongly attributed to capital accumulation by capitalists. He further identifies the rise in the labour force and the improvement in efficiency through the use of capital by workers in the production process as other sources of growth. While capital accumulation increases productivity and growth in output by increasing capital per worker, labour division and specialisation increases output by increasing the productivity of labour due to a rise in efficiency and innovation or improvement in production techniques.

According to Smith (1776), the growth process is triggered by investment in capital, which leads to a rise in productivity, output, wages and a larger market. Consequently, there is more specialisation of labour and therefore an increase in productivity and output. Although there are increasing returns from labour specialisation, growth reaches a stationary state due to the effects of increasing the employment of labour with every rise in capital, which causes a decline in profits and therefore investment. Although Smith (1776) argues against government intervention, he finds it imperative for government to protect the nation through military expenditure, law and order and to provide and maintain public institutions and public works that benefit society.

2.1.2 David Ricardo's Growth Theory

Following Smith (1776), Ricardo (1817) also argues that investment in capital accumulation by capitalists is the source of economic growth. As the economy grows, there is a rise in demand, labour input and land use. According to Ricardo (1817), this increases rents and wages, however, due to the cultivation of inferior land and over cultivation of existing land to meet the increased demand, with every increased portion of capital employed on the land there will be a decreased rate of production. These diminishing returns on land and decreased rate of production lead to a decline in profits, thus reducing capital accumulation and economic growth, leading to a stationary state. No room was created for government intervention.

2.1.3 Cobb Douglas Production Function Theory

Since 1928, the Cobb-Douglas functional form incorporating labour, capital, and physical output, has been employed to study the relationship between the level of output and the quantities of inputs used. Although this model provides a simplified view of the economy especially since many other factors and inputs affect economic performance, it has proved to be accurate nonetheless. The model assumes a multiplicative form of the economy:

$$Y = AK^{\beta_1}L^{\beta_2}$$

(2.1)

where Y represents output, and K and L denote capital and labour, respectively. A scalar measures the real output per unit of input and it is at times referred to as the level of technology, reflecting the rate at which unit inputs are converted into output. Therefore, total factor productivity is measured by:

$$A = \frac{Y}{K^{\beta_1}L^{\beta_2}}$$

(2.2)

The exponents β_1 and β_2 measure capital and labour shares of output, respectively. If the sum of these coefficients is unity, the property of constant returns to scale is indicated, and if this sum is greater than or less than unity, then increasing or decreasing returns to scale is indicated, respectively.

2.1.4 Schumpeter's Theory of Economic Development

According to Schumpeter (1934), economic development is the result of discontinuous technical changes through entrepreneurial innovations. The process of economic development can be initiated by the introduction of new production processes, new products, the discovery of new markets, discovery of some new source of supply, and change in the structure and organisation of industries in the economy created by entrepreneurs. The entrepreneurs who partake in these innovative activities are rewarded through monopoly rents in cases where their innovations are successfully implemented. However, these monopoly rents eventually diminish as more innovations by other entrepreneurs are introduced and take over the market. Schumpeter (1934) argues that competition among market participants leads to a desire to seek out new ways to improve technology, new ways to do business and other types of advantages that would increase profit margins and directly impact the entrepreneur's standard of living. In this theory, governments play a role in increasing economic growth through fostering a business climate and focusing on deregulating trade.

2.1.5 The General Theory of Employment, Interest and Money

This theory by Keynes (1936) stems chiefly from his study aimed at identifying driving forces behind the changes in the scale of aggregate output and employment. He argues that output and employment depend on decisions made in the present day to produce, which depend in turn on the current decision to invest and on expectations of current and potential consumption. Most notably, he emphasises the importance of investment and active government intervention in the short run for the expansion of aggregate income, output and employment. This theory, which centres on recurrent shocks that abruptly decrease aggregate demand alludes to the notion that increasing government spending stimulates overall demand in the economy, economic activity and therefore, economic growth and employment (Keynes, 1936; Snowdon and Vane, 2005). The principle of aggregate demand postulates that in a closed economy, the level of output is determined by aggregate expenditure by households, firms and government.

According to Keynes (1936), consumption expenditure is endogenous and depends on aggregate income, which in turn is determined by the volume of employment. He further elaborates on the positive association between employment and output, arguing that labour demand is influenced by expected income from the output those employed are anticipated to produce. The volume of labour which firms employ is dependent on households' expected consumption spending and expected investment by firms. Since the volume of output that firms sell depends on spending by consumers, it is consumer spending that controls employment. Consequently, low levels of spending will result in low demand for labour and a decline in income due to a fall in the level of employment, which could lead to deficits for households, firms and government. In such a case, government may be compelled to provide unemployment relief, otherwise income and employment rates will decline, possibly continuing to extreme lengths.

New investment, from the perspective of this theory, depends on its expected returns, which themselves are influenced by the rate of interest. The association between investment and output is also a positive one. Low interest rates, which are affected by changes in monetary policy, induce an increase in investment. Thus, an increase in investment spending will result in an increase in employment in firms which produce capital goods. Newly employed workers in capital-goods industries will spend some of their income on consumption goods and save the rest. The rise in demand for consumer goods will in turn lead to increased employment in consumer-goods industries and results in further cycles of expenditure. As a consequence, an initial rise in autonomous investment produces a more than proportionate rise in income. The same multiplier process will apply to consumer expenditure (Snowdon and Vane, 2005). In support of Smith's (1776) notion of the role of government in public capital provision, Keynes (1936) further expresses that:

"I expect to see the State, which is in a position to calculate the marginal efficiency of capital goods on long views and on the basis of the general social advantage, taking an ever greater responsibility for directly organising investment" (Keynes, 1936: 164).

Instead of using monetary policy to induce private sector investment, Keynes (1936) suggests that the government can also directly participate in capital investment to do away with market failures and instability of economies. He believes that economies are unstable by nature and that full efficiency is only possible with a boost from government policy and public investment (Black, Calitz, Steenekamp, 2008; Fortin, 2003). Keynes' (1936) theory creates a basis for the research in this dissertation by recognising government investment as an important factor to foster economic growth.

2.1.6 The Harrod-Domar Growth Model

The Harrod-Domar growth model (Harrod, 1939; Domar, 1946) also emphasises the role played by saving and investment in determining growth. The model states that given a constant capital-output ratio, the rate of growth becomes dependent on the rate of saving. Thus, the rate of economic growth is jointly determined by the level of saving and the capital output ratio, which is the productivity of investment. The model's main argument is that an economy that has high levels of saving is able to channel them into investments, raising capital stock and generating economic growth through the increase in production of goods and services. The implications of the model suggest that for a country to realise economic growth, it is essential for the government to encourage saving and support technological advancement.

2.1.7 Nurkse's Balanced Growth Theory

This theory stipulates that economic growth in underdeveloped countries is stimulated by large simultaneous investments in numerous industries. Nurkse (1953) acknowledges that the expansion and inter-sectoral balance between agriculture and manufacturing is necessary so that each of these sectors provides a market for the products of the other and in turn, supplies the necessary raw materials for the development and growth of the other. The whole growth process is triggered by these coinciding large scale investments in sectors by government through the mobilisation of domestic saving and borrowing from international organisations, resulting in the expansion in the size of the market and productivity. Consequently, due to the increase in the size of the market, the private sector is given an incentive to invest, leading to the growth and development of the economy. However, the unbalanced growth theory (see Hirschman (1958), for example) argues that growth need not take place in a balanced manner. Instead, uneven investments can correct or complement existing imbalances within industries in an economy and still ensure growth.

2.1.8 The Solow Growth Model

Solow's (1956) growth model is an exogenous growth model that falls within the neoclassical economic growth framework. He attempts to explain the determinants of long run economic growth and show how capital accumulation, effective labour and population growth play a role in economic growth determination. He concludes that technological progress affects the level of an economy's output and its growth in the long run. The model predicts that in steady-state (long run equilibrium of the economy), the level of income per capita will be determined by rates of saving, population growth and technical progress, which are assumed to be exogenous (Mallick, 2002; Mankiw, 2010; Mankiw, Romer and Weil, 1992). The model focuses on output, which Solow (1956: 66) alternatively terms "the community's real income", capital, labour and knowledge/effectiveness of labour. According to the production function of the model, the last three factors are combined at any time in the economy to produce output. This can be shown by equation (2.3).

$$Y(t) = F(K(t), A(t)L(t)) \qquad (2.3)$$

Assuming a Cobb-Douglas production function, equation (2.3) may be written as:

$$Y(t) = K(t)^{\alpha}(A(t)L(t))^{1-\alpha}, \qquad 0 < \alpha < 1 \qquad (2.4)$$

From equation (2.3) and (2.4), $Y(t)$ captures output, $K(t)$ is capital stock, $A(t)$ denotes the level of technology and $L(t)$ represents labour, while the collective term $A(t)L(t)$ represents technological progress/effective labour. According to the model, the amount of output obtained from units of capital and labour increases over time as these factors of production change, however, there is technological progress only when the amount of knowledge $A(t)$ increases (Romer, 2006). Key assumptions about the production function of the model are that capital and labour exhibit constant returns to scale in output, but with decreasing marginal returns to capital. The former indicates that real output will grow at the same relative rate and output per labour will be constant. The latter implies that as the volume of capital increases, holding labour constant, the production function becomes flatter (Romer, 2006; Sala-i-Martin, 1990a). Mathematically, marginal product of capital and labour are respectively expressed as:

$$\frac{\partial Y(t)}{\partial K(t)} = \alpha K(t)^{\alpha-1}(A(t))^{1-\alpha} = \alpha\left(\frac{Y(t)}{K(t)}\right) \tag{2.5}$$

$$\frac{\partial Y(t)}{\partial L(t)} = (1-\alpha)K(t)^{\alpha}A(t)^{1-\alpha} = (1-\alpha)\left(\frac{Y(t)}{L(t)}\right) \tag{2.6}$$

Decreasing returns in capital and labour may be given as:

$$\frac{\partial MPK(t)}{\partial K(t)} = -\alpha\,(1-\alpha)\frac{Y(t)}{K(t)^2} \quad < 0 \tag{2.7}$$

$$\frac{\partial MPK(t)}{\partial K(t)} = -\alpha\,(1-\alpha)\frac{Y(t)}{L(t)^2} \quad < 0 \tag{2.8}$$

Solow (1956) clarifies how investment (through saving), labour and depreciation are the forces that influence the accumulation of capital stock. An increase in saving means a higher level of investment for capital, thus the greater the volume of output. Conversely, depreciation and population growth rate affect capital accumulation negatively, as depreciation wears out capital and population spreads capital stock more thinly among the large population of workers present in the economy (Mankiw, 2010). Regardless of the starting level of capital of the economy, the economy ends up in a steady state level of capital. This is an indication that higher saving leads to faster growth, but this effect is only temporary because depreciation and population offset its positive impact. Solow (1956) further maintains that capital accumulation by itself cannot explain sustained growth since in a case where investment exceeds depreciation and the labour force, capital stock will rise, and it therefore will decrease in an instance where depreciation and the labour force exceed investment. These adjustments in capital occur up to a point where a steady state level is reached.

To explain sustained growth of the economy, Solow (1956) introduces technological progress, where its increase makes the labour force more effective by providing them with knowledge about production methods (Mankiw, 2010). Since technological progress enables labour to be more productive, the production of more output is evident, ensuring persistent economic growth. Solow (1956) concludes that sustained growth in income per worker is an outcome of technological progress. Although this model gives an account of a long run growth to technological progress, it fails to model the origins and factors influencing it. The exogenously-determined technological progress-led growth assumption, the inability of physical capital accumulation to explain long run growth and its failure to distinguish between the different types of capital make this model too simplistic for the analysis of this research. To remedy these shortcomings, Romer (1986; 1990) - to be discussed later in the section - introduces endogenous technological change and considers the role played by human capital in determining economic growth.

2.1.9 Kaldor's Model of Growth

Kaldor (1957) follows Harrod's and the Keynesian approach to formulate a model of economic growth that attempts to provide an endogenous explanation for technological progress. Kaldor (1957) argues that economic growth is a function of technological progress, which itself depends on capital accumulation through domestic savings. According to the model, in order to foster high rates of accumulation, a country must generate the necessary resources through high rates of domestic saving. The ability to absorb technical change and willingness to invest in capital business ventures are crucial drivers to economic growth. Kaldor (1961) proposes six stylised facts of economic growth in capitalist countries:

- Output per worker/labour productivity grows overtime
- Capital per worker grows overtime
- The rate of return on capital is constant

- Labour and capital receive constant shares of total income
- The rate of growth varies across countries.

2.1.10 Rostow's Stages of Economic Growth

This theory sees development as a linear process in which economies develop in a set of identical and universal stages over time and eventually reach a level of sufficient and sustainable growth. Rostow (1959) argues that within a society, sequential economic phases of modernisation can be achieved through five stages:

1. The Traditional Society Stage

This stage involves society whose structure is developed within limited production function, thus limited to subsistence output. The economic system is dominated by agriculture and traditional cultivation methods. Limitations to productivity are due to the lack of modern science and technology. Although there is a ceiling to productivity, the traditional society is not stationary, there are fluctuations in the volume and pattern of trade, level of income and output and population rates, but only to a certain point.

2. Preconditions for take-off

This is a transitional stage where trading becomes a central economic activity due to technological advancement in economic sectors complemented by industrial revolution, increased investment in infrastructure and raw materials in which other societies may have an economic interest. This stage was arguably historically heightened by invasions of advanced societies into traditional societies.

3. Take-off

This stage is characterised by a rapid growth stage as a result of in growth in sectors where modern industrial techniques are applied. During this stage societies experience a rise in urbanisation and industrialisation, while the rise in technological innovation shifts the economy progressively towards the manufacturing sector.

4. Drive to Maturity

This is a stage where a society has effectively extended modern technology to the bulk of its resources. There is diversification and expansion of industries. Growth becomes self-sustaining, enabling further investment in value adding industries and development. There is rapid development of both economic and social infrastructure.

5. High Mass Consumption

The final stage of growth exhibits high levels of output, employment in the service sector and higher consumption of durable goods, with the dominating role of the secondary sector. Societies in this stage move away from extending modern technology and allocate increased resources to social welfare and security.

2.1.11 Endogenous Technological Change Models

Romer's (1990) model is essentially a neoclassical model with technological progress augmented to give an endogenous explanation of the determinants of technological change which are not explained by neoclassical growth models. This model is an extension of his 1986 *Increasing Returns and Long run Growth* model where he presents knowledge as a basic capital input in production that has an increasing marginal productivity.

2.1.11.1 Knowledge Spill-Over Effects, or Learning by Doing

Romer (1986) argues that technological progress is a result of a learning-by-doing (spill-over) effect due to physical capital investment, thus, investing creates knowledge (through experience) which has the positive effect of raising labour efficiency and productivity (Fedderke, 2002; Romer, 1986; Sala-i-Martin, 1990b). He assumes that knowledge is a non-rival and non-excludable public good. These assumptions imply that firms undertaking an investment cannot internalise the knowledge it creates, consequently, becoming available to all firms in the economy (Fedderke, 2002). As a result of the inability of investing firms to appropriate all the benefits from their investments, the private sector may in general under-invest. Therefore, according to this model, the economy has a suboptimal equilibrium in the absence of any government intervention as the social marginal product of knowledge is greater than the private marginal product in the competitive equilibrium.

To ensure that the equilibrium in the model is Pareto-optimal while encouraging investment and keeping the economy productive, Romer (1986) suggests that government should create incentives for investment through subsidies in capital goods purchases and production. Shortcomings of this model are: firstly, it creates a possibility of underinvestment by the private sector; secondly, intentional devotion of resources to the process of accumulating knowledge cannot be accounted for due to the nature of knowledge as a public good (Fedderke, 2002). One can also argue that the model does not consider direct knowledge attainment (human capital aspect) by economic agents as an important input in the production process. Knowledge accumulation in this model is unintentional – it is merely an externality that arises from private sector physical capital investment. For a more explicit human capital role in long run growth and intentional development of new technology, Romer (1990) presents a monopolistic equilibrium model of technological change.

2.1.11.2 The Intentional Creation of New Knowledge through Research and Development

In Romer (1990), long run economic growth in the model is driven mainly by technological change through the increase in the stock of human capital devoted to research and development (Arnold, 2000; Fedderke, 2002; Mallick, 2002). According to this model, technological progress arises from intentional decisions by forward-looking, profit-maximising private agents in an economy. Technology is treated as a mixed good with non-rival and partially excludability characteristics. He separates the rival and excludable component of knowledge, which is human capital, from the non-rival and yet excludable technological component. According to this model, human capital and existing knowledge are crucial in the production of new knowledge and its output (Rivera and Romer, 1990). Research outputs in the form of new knowledge or design are considered to be production inputs in the capital-goods production sector that can be used to produce output in the consumer-goods production sector (Diebolt and Monteils, 2000; Fedderke, 2002; Romer, 1990). Interaction within these sectors involves the research sector supplying a design to the sector responsible for capital-goods production which therefore gains monopoly power, (by obtaining patent rights for the innovation), over that particular production design and utilise it to produce capital goods. These goods are then rented to the consumer-goods production sector (Diebolt and Monteils, 2000).

The analysis presented in the model is based on three important properties. Firstly, technological change provides the incentive for continued aggregate capital accumulation as it enhances productivity and therefore growth. Secondly, since technological progress arises from intentional decisions by economic agents, agents willing to participate in research may be strongly encouraged to do so by incentives that exist in the market for such initiatives such as research subsidies. Policies that induce investment in research and therefore human capital promote long-term economic growth (Mallick, 2002). Lastly, technology induces fixed costs only, once research costs are incurred, the knowledge or production design gained can be used continuously will no additional cost (Fedderke, 2002), making technology a non-rival input and creating a platform for positive knowledge spillovers (McCallum, 1996).

With these three properties, the nature of equilibrium is monopolistic and exhibits increasing returns to scale. These increasing returns are purely the source of human capital devoted in research as not only do they increase the production of knowledge, they also expand the range of physical capital available to producers in the consumer-goods production sector (Fedderke, 2002), enabling long run sustained growth (Diebolt and Monteils, 2000; Mallick, 2002). According to Romer (1990), human capital can be devoted to either the research or the final output sector. This model assumes fixed levels of labour supply and population. The total stock of human capital in the population and the fraction supplied to the market is fixed. Given these assumptions, the Cobb-Douglas consumer-goods production function in the economy can be written as:

$$Y(H_Y, L, x) = H_Y^{\alpha} L^{\beta} \sum_{k=0}^{n} x_i^{1-\alpha-\beta} \tag{2.9}$$

In equation (2.9), aggregate final output Y is expressed as a function of human capital devoted to output H_Y, labour L and physical capital x. Returns to scale in the equation are constant. Aggregate production of knowledge is taken to be a deterministic function of the research inputs of human capital and the existing total stock of knowledge. Specifically, the production of knowledge can be expressed as:

$$\dot{A} = \delta H_{\mathrm{A}} A \tag{2.10}$$

where $\dot{A}$ is the change in the aggregate stock of knowledge, δ is the productivity parameter, H_{A} represents the quantity of labour devoted to research and the total stock of knowledge is given by A. Equation (2.10) implies that the production of research output uses human capital and the accumulated stock of human knowledge, the sum of all previous designs in existence (Fedderke, 2002). Knowledge accumulation increases as A and H_{A} increase. Growth in A increases the productivity of human capital, δH_{A}. The production function is linear in A and H_{A} respectively when the other factor is fixed (Diebolt and Monteils, 2000), supporting an assumption by Romer (1986) where knowledge grows continuously without bounds (McCallum, 1996; Romer, 1990).

Important conclusions drawn from this model are that allocating more human capital to research leads to higher rates of production of new designs and the larger the total stock of capital goods designed and knowledge gained, the higher the productivity of the researcher, thus stronger economic growth than otherwise would have been achieved should human capital be devoted elsewhere (Diebolt and Monteils, 2000). Another noteworthy implication of the model is that economies with larger total stock of human capital will experience stronger growth compared to economies with lower total stock of human capital (Diebolt and Monteils, 2000; Fedderke, 2002; Romer, 1990). In essence, the total quantity of human capital and its average level per individual determine the rate of growth in an economy through its direct and positive impact on the productivity of labour (Diebolt and Monteils, 2000; Mallick, 2002). Fedderke (2002) argues that due to the non-rival and excludability characteristics of technological progress, market failures may arise due to factors such as: the private sector systematically under-investing in knowledge assumption; business-stealing effects and monopoly pricing by firms with patent rights to the technological design. In such a case, subsidies on the accumulation of knowledge may be given to the private sector as incentives (Arnold, 2000).

2.1.12 The Simple Model of Endogenous Growth

Barro's (1990) model incorporates government spending in a simple, constant returns model of economic growth to show the impact of productive public investment financed through a flat-rate income tax on the growth rate. The notion behind endogenous growth models is that capital accumulation embeds technological improvements (Rossi, 2011). This model specifically extends on two strands of endogenous growth literature, one where returns on private and public investment diverge, so that benevolent government policy leads to suboptimal rates of saving and economic growth, and another line of research that involves models without externalities.

To construct his model, Barro (1990) considers a broad concept of capital, encompassing both human and non-human capital. Human investment in the model includes "…education and training, as well as expenses for having and raising children" (Barro, 1990: 105). Non-human investments can be considered in this case to be physical/economic infrastructure investments such as highways and electricity. An assumption of the model is that constant returns to scale in the factors can be roughly accumulated and growth can be raised if both human and physical capital are considered together. These two factors are possible complements in the production process and production may indicate diminishing returns for both types of capital should they be used separately. Importantly, Barro (1990) assumes that the economy is always in a steady state, where all variables grow at the same rate.

Given the constant returns to scale in the broad concept of capital, he introduces government spending into the model. He assumes a closed economy where the government does not own any capital nor produce any goods or services; the government merely buys a flow of output from the private sector. These productive services that the government provides correspond with inputs the private sector needs. The role of public services is a direct input into private production. This production role creates opportunities for positive linkages between government investment and growth, implying that government investment plays a contributory role in the productivity of private investment (Rossi, 2011). The Cobb-Douglas production function can be written as:

$$y = Ak^{1-\alpha}g^{\alpha}, \qquad 0 < \alpha < 1 \tag{2.11}$$

Where y denotes output per worker, A measures the level of technology, k represents the representative producer's quantity of capital and g is productive government expenditure per worker. These services are assumed to be non-rival and non-excludable, to support these assumptions. Barro (1990) dismisses the assumption of existence of externalities that arise from use of public services. From the model, output is determined by parallel combinations of k and g in the production process of the economy. Production exhibits constant returns to scale in k and g together, however, it exhibits diminishing returns in k and g separately. Diminishing returns are a consequence of not increasing government inputs by an equivalent ratio as private inputs. The marginal products of k and g are shown respectively by equations (2.12) and (2.13).

$$\frac{\partial y}{\partial k} = A(1-\alpha)\left(\frac{g}{k}\right)^{\alpha} \quad > 0$$

(2.12)

$$\frac{\partial y}{\partial g} = A\alpha\left(\frac{k}{g}\right)^{1-\alpha} \qquad > 0$$

(2.13)

When government expenditure is financed by a flat-rate income tax, Barro (1990) argues that government runs a balanced budget since quantity of public services provided to each household-producer equates revenue from tax and aggregate expenditure, $\tau = g/y$. He asserts that the "economy has no transitional dynamics and is always in a position of steady state growth", where all quantities grow at an identical constant rate (Barro, 1990: 108). Assuming that a representative, infinitely – lived household seeks to maximise overall utility:

$$U = \int_0^{\infty} u(c)e^{-\rho t}dt$$

(2.14)

where c is consumption per worker and ρ > is the constant rate of time preference. Population, which corresponds to the number of workers and consumers is constant, Barro (1990) uses the utility function:

$$u(c) = \frac{(c^{1-\sigma}-1)}{(1-\sigma)}$$

(2.15)

From equation (2.15), σ > 0, so that marginal utility has the constant utility – σ. Since the balanced budget constraint imposes a tax rate ($\tau = g/y$), the steady state growth rate (γ) is given as:

$$\gamma = \frac{c}{c} = \frac{y}{y} = \frac{g}{g} = \frac{1}{\sigma} \cdot \left[\left(1-\frac{g}{y}\right) \cdot A \cdot \left(\frac{g}{k}\right)^{\alpha} \cdot (1-\alpha) - \rho\right]$$

(2.16)

Barro (1990) argues that different values of productive government expenditure relative to output and the tax rate have two effects on the growth rate. An increase in the tax rate reduces the growth rate, whereas, expanding productive government expenditures relative to output raises the growth rate by raising the marginal product of capital. He adds that the size of government is crucial for such an analysis and that the first condition dominates when the size of the government spending is large and the latter does so when the government expenditure is small. In conclusion, in a case where public services are provided freely and complementary to the private sector production, the rate of output growth can be positively related to the share of government purchases.

According to Fedderke *et al*., (2006), the theoretical link between k and g in Barro's (1990) model is that infrastructure investment g can prevent diminishing returns to scale in private sector capital k, raise the marginal product of private sector capital $\partial y/\partial k$ and raise the growth rate of output. Barro (1990) indicates that the optimum provision of public investment implies that output will increase by the same proportional increase in government spending and once the marginal product of g falls below unity, further increases in g/y are harmful to the economy due to tax effects (Fedderke *et al*., 2006).

Barro's (1990) model is later extended, for example, by Barro and Sala-i-Martin (1992, 1995), to incorporate labour into the production function along with infrastructure investment and private capital. Barro's (1990) model represents the core theoretical background for this dissertation and from it appropriate variables required for analysis are chosen, including the labour element in Barro and Sala-i-Martin (1992, 1995). The variables include: public sector infrastructure investment, total employment rates, private sector investment, human capital and the level of output.

2.2 Conceptual Literature on Infrastructure Investment

This section gives a conceptual account of literature on infrastructure investment. Subsection 2.2.1 explores definitions of infrastructure. The two different categories of infrastructure are presented in subsection 2.2.2 and the impacts and determinants of infrastructure investment are presented in subsections 2.2.3 and 2.2.4 respectively.

2.2.1 Definitions of Infrastructure

The term 'infrastructure' originated during World War II as a military term that referred to underlying structures (Srinivasu and Srinivasa-Rao, 2013). Since then, the term has been widely used by economists, yet with no precise definition. Gramlich (1994) suggests that a definition that makes most sense is one where infrastructure is defined as large capital intensive monopolies such as transportation facilities, communication systems, water and sewer lines. He adds that the broad version of the definition includes human capital as well.

Fourie (2006b) maintains that there are two ways in which infrastructure can be defined, firstly by describing it in terms of its characteristics and secondly, through the compilation of a list of all possible infrastructure goods that provide services and outputs including transport, communications, education, energy and water supply. On the former approach, Fourie (2006a; 2006b) cites Hirschman's (1958) definition of infrastructure as capital goods that produce public services. Infrastructure often has some characteristics of a public good, mainly being non-excludable and the existence of positive externalities (Fedderke and Garlick, 2008). These are not, however, necessary characteristics of infrastructure. In some cases, infrastructure could include public goods that are not necessarily infrastructure, such as military equipment and non-public goods that are infrastructure; these can be in the form of privately owned transport infrastructure (Fourie, 2006a).

According to Srinivasu and Srinivasa-Rao (2013), infrastructure can simply be defined as the stock of basic facilities and capital equipment essential for productive activity and the functioning of a country. It is referred to as an "umbrella" term for numerous activities and named as "Social Overhead Capital", "Economic Overheads", "Overhead Capital" and "Basic Economic Facilities" (Snieska and Simkunaite, 2009: 17; Srinivasu and Srinivasa-Rao, 2013: 82 – 83; World Bank, 1994: 2). Hirschman (1958) argues that an activity can be labeled as part of infrastructure if, amongst others, it cannot be imported, it facilitates a great variety of economic activities, it is provided by public agencies, or by private agencies subject to public control and if it is technically indivisible (Srinivasu and Srinivasa-Rao, 2013). Although there is no consensus on how infrastructure should be defined, a common feature of all the definitions is the idea that infrastructure refers to capital goods provided with a long-term perspective, and comprising strong public involvement (Baldwin and Dixon, 2008; Chetty, 2007; Prud'homme, 2004; Rietveld and Bruinsma, 1998; Snieska and Simkunaite, 2009).

2.2.2 Different forms of Infrastructure Investment

Economists and urban planners distinguish between two components of infrastructure, namely, economic and social infrastructure (Fourie, 2006b; Snieska and Simkunaite, 2009). They define economic infrastructure as infrastructure that promotes economic activity, such as, roads, highways, electrical lines, railroads, airports, seaports, telecommunications, electricity, water supply and sanitation (Fourie, 2006a; 2006b). Social infrastructure, however, has to do with the human capital aspect of an economy. It is believed to be infrastructure that promotes health, educational and cultural standards of the population, which includes schools, universities, libraries, clinics, hospitals, parks and statues (DBSA, 1998; Fedderke and Garlick, 2008; Fourie, 2006a; 2006b; Snieska and Simkunaite, 2009).

2.2.3 Importance of Infrastructure Investment

According to the literature, infrastructure is essential for the development of any economy and is an important driving force to achieve rapid and sustainable economic growth. The effects of infrastructure on economic growth are given below.

2.2.3.1 Infrastructure and Transaction Costs

Infrastructure investment can be beneficial to the economy by reducing transaction, trade and transportation costs, thus improving competitiveness (Gjini and Kukeli, 2012; Heymans and Thome-Erasmus, 1998; Kessindes, 1993; Prud'homme, 2004; Snieska and Simkunaite, 2009; Srinivasu and Srinivasa-Rao, 2013). High transaction, trade and transportation costs expose the domestic private sector or firms to competition from international firms which are (in most cases) more established, thus leaving domestic firms vulnerable and unable to compete internationally. Infrastructure lowers transaction costs by facilitating flows of information and goods, and interactions between markets (Bertoldi, 2010; Gjini and Kukeli, 2012; Hassen, 2000; Kessindes, 1993). Adequate quantity and reliability of infrastructure are key factors that enable countries to compete in international trade (World Bank, 1994).

2.2.3.2 Infrastructure and Economic Linkages

According to Bertoldi (2010) and Hassen (2000), infrastructure investment creates the potential for economic linkages. It does this by enabling the private sector, individuals and government to respond to new types of demand in a variety of places and to enlarge markets (Prud'homme, 2004; Srinivasu and Srinivasa-Rao, 2013). Ondiege, Moyo and Verdier-Chouchane (2013) argue that building roads and installing transmission lines that connect rural communities to the national networks helps individuals, entrepreneurs and communities to participate in income-generating activities – these roads give them access to markets and connect them to the economy. Access to infrastructure services could improve capacity for producing goods and services in communities, create access to employment hubs and encourage private sector investment by creating better conditions for doing business (Gjini and Kukeli, 2012; Hassen, 2000; Heymans and Thome-Erasmus, 1998; Kessindes, 1993).

2.2.3.3 Infrastructure and Efficiency

Infrastructure is considered a factor of production that complements other inputs, allowing firms to lower their production and input costs (Fedderke and Garlick, 2008; Fourie, 2006b; Kessindes, 1993). Because of this direct impact on private activity, infrastructure supports industries within an economy and could also guide private sector investment (Fedderke and Garlick, 2008; Gjini and Kukeli, 2012; Kessindes, 1993). Industrial production requires infrastructure inputs through good and low transportation and electricity costs, as well as the availability of a skilled labour force to reduce production costs and induce production and profitability (Srinivasu and Srinivasa-Rao, 2013). Infrastructure is also believed to improve the productivity of other inputs in the economy (Fedderke and Garlick, 2008; Fourie, 2006b).

2.2.3.4 Infrastructure and Social Linkages

Infrastructure investment enhances human capital through the provision of educational, housing and health facilities to the general population (Kessindes, 1993; Prud'homme, 2004), thus leading to better health, skills and reduced vulnerability of the poor (Bond, 1999; Heymans and Thome-Erasmus, 1998; Srinivasu and Srinivasa-Rao, 2013). In such an instance, the most important point is that the quality of life and productivity of the population depends significantly on the availability and ability to access infrastructural facilities (Baldwin and Dixon, 2008; Prud'homme, 2004; Snieska and Simkunaite, 2009; World Bank, 1994). Infrastructure investment also provides employment opportunities. Large infrastructure projects are typically highly labour intensive, leading to the creation of jobs during the construction and maintenance operations (Bertoldi, 2010; Bond, 1999; Hassen, 2000; Kessindes, 1993). Moreover, the construction of infrastructural facilities involves significant spending, therefore increasing aggregate demand (Fedderke and Garlick, 2008).

2.2.3.5 Infrastructure and Geographical Factors

According to Snieska and Simkunaite (2009), infrastructure enables geographical concentration of economic resources and provides wider markets for output and employment. It helps determine spatial development patterns. Geographical factors are important determinants of the type of infrastructure required and efficiency of infrastructure investment (Fourie, 2006). According to Heymans and Thome-Erasmus (1998), infrastructure can adversely affect the natural environment, however, these effects of infrastructure are containable, provided that adequate systems for environmental management are in place. Although it is widely agreed that infrastructure investment is beneficial, the World Bank (1994: 19 – 20) stresses that it is important to note that:

"…economic impact of infrastructure investment varies not only by sector but also by its design, location, and timeliness. The effectiveness of infrastructure investment whether it provides the kind of services valued by users .... depends on characteristics such as quality and reliability, as well as on quantity. Matching supply to what is demanded is essential. Finally, the efficiency with which infrastructure services are provided is also a key to realizing potential returns".

2.2.4 Factors Affecting Investment in Infrastructure

While investment in infrastructure influences a variety of different factors discussed in the previous subsection, these and other factors also tend to have a reverse impact on infrastructure investment (Fourie, 2006b). A decision to invest in infrastructure for the private sector is based on expected profits and the degree of uncertainty or confidence associated with expectations (Chetty, 2007). According to Baldwin and Dixon (2008), Egert, Kozluk and Sutherland (2009), Prud'homme (2004) and World Bank (1994), government's role in infrastructure provision stems from the recognition of infrastructure's economic and political importance, a belief that problems with the supply technology require a highly activist response by governments, the nature of market failures and the need for government to address these market failures. These authors argue that governments intervene in the provision of infrastructure to prevent under-provision and non-provision with the composition of infrastructure investment depending largely on the immediate needs of a country. According to Fedderke and Garlick (2008), there is a theoretical argument holding that growth and rising output levels may also affect infrastructure investment decisions.

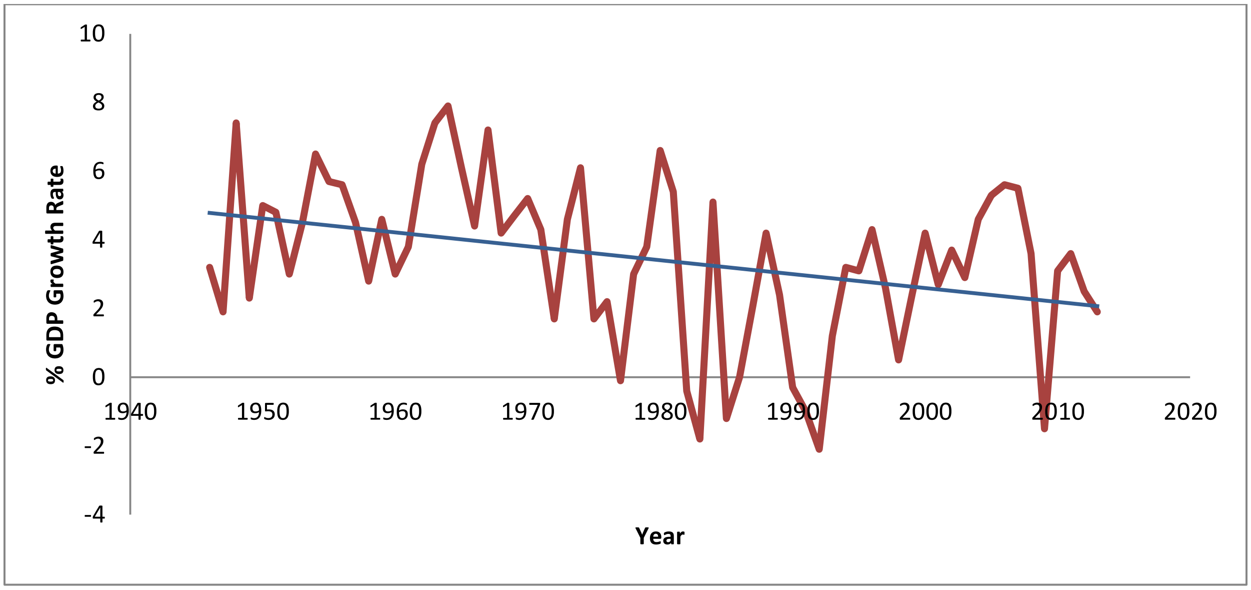
2.3 Infrastructure Investment in South Africa

This section explores infrastructure investment in the country. Subsection 2.3.1 gives a detailed account of economic and infrastructure trends over the years. Subsection 2.3.2 briefly highlights historical economic events that have led to infrastructure development in South Africa, and seeks to explain events behind the trends in the first sub-section. In the last subsection, the government's economic policy is reviewed.

2.3.1 Review of the South African Economy and Infrastructure Investment

The South African economy is arguably riddled with poverty, poorly located and insufficient infrastructure, persistently high rates of unemployment and low growth rates. Despite these economic challenges, South Africa has performed well for most of the post-1994 period by global standards (Presidency, 2014). While a growth rate of 1.9 per cent was recorded in 2013, recent economic growth outlook projections by the World Bank (2014a) and International Monetary Fund (IMF) (2014), show that it is likely to increase to rates between 2.0 per cent and 2.3 per cent in 2014. Based on the South African Reserve Bank (SARB) online statistics, the GDP growth rate has been gradually declining over time as shown by the dark blue linear trend line in Figure 2.1.

Figure 2.1: South African Real GDP Growth Rate, 1950 – 2013



Source: Generated by the researcher, SARB data.

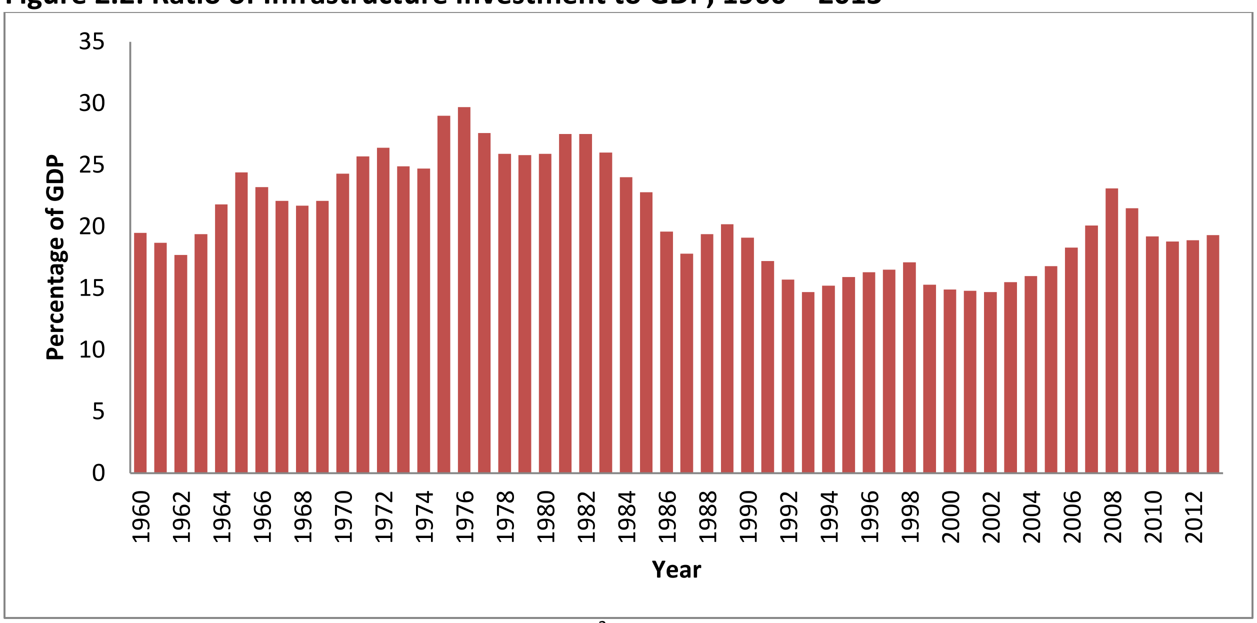
From Figure 2.1, the performance of the South African economy from 1950 to 2013 can be assessed within the framework of five sub-periods: 1950 - 1964; 1965 - 1980; 1981 - 1996; 1997 - 2006 and 2007 - 2013. From the 1950 to 1964 period, the economy exhibits a positive trend (see Figures A1-A5 in Appendix A), with an average growth of 5.02 per cent per year, representing a short-term economic boom within the entire long run period (1950 - 2013) assessed. During this sub-period, the rate rose from a minimum of 2.85 per cent in 1958 to a maximum growth of 7.9 per cent in 1964. In the second sub-period (1965 - 1980), the economy began to show signs of a decline in the growth rate with average growth of 4.1 per cent. When plotted, the sub-period trend line exhibits a sharp fall in the growth rate.

For the third sub-period (1981 and 1996), the South African economy grew by 1.5 per cent per year on average, exhibiting a much steeper slide in the growth rate relative to previous sub-periods. A graphical analysis of the sub-period reveals a very weak positive trend line. The trend line for the (1997 - 2006) sub-period however, shows a rapid rise in the GDP growth rate. The economy, from the long run trend perspective, indicates the beginning of an economic recovery from 1997 to 2006 at an average growth rate of 3.5 per cent. The positive trend of the 1997 -

2006 sub-period was, however, short-lived, as in the fifth sub- period (2007 - 2013), the economy fell back into a slump, and grew at an average of 2.6 per cent.

To remedy the downward-sloping economic growth trend, the South African government has identified infrastructure investment as an area of eminent significance and has dedicated vast resources towards its development (Mbanda and Chitiga, 2013; Perkins *et al*., 2005). In recent years, government has sought to accelerate public infrastructure spending, while also encouraging greater private-sector investment (National Treasury, 2012). The ratio of infrastructure investment to GDP, used to evaluate the performance of infrastructure investments (Kumo, 2012), was recorded at 19.3 per cent in 2013. Although it is below the recommended level of 25 per cent[1] for sustained economic growth, it is a significant increase relative to the 14.7 per cent ratio recorded in 1993, twenty years earlier. The South African performance in infrastructure investment as given by the ratio of the former to GDP is demonstrated in Figure 2.2 and 2.3.

Figure 2.2: Ratio of Infrastructure Investment to GDP, 1960 – 2013



Source: Generated by the researcher, own calculations[2] - SARB data.

[1] According to the NPC (2014), the accepted average for infrastructure investment, as a ratio of gross fixed capital formation to GDP, is 25 percent for developing countries.

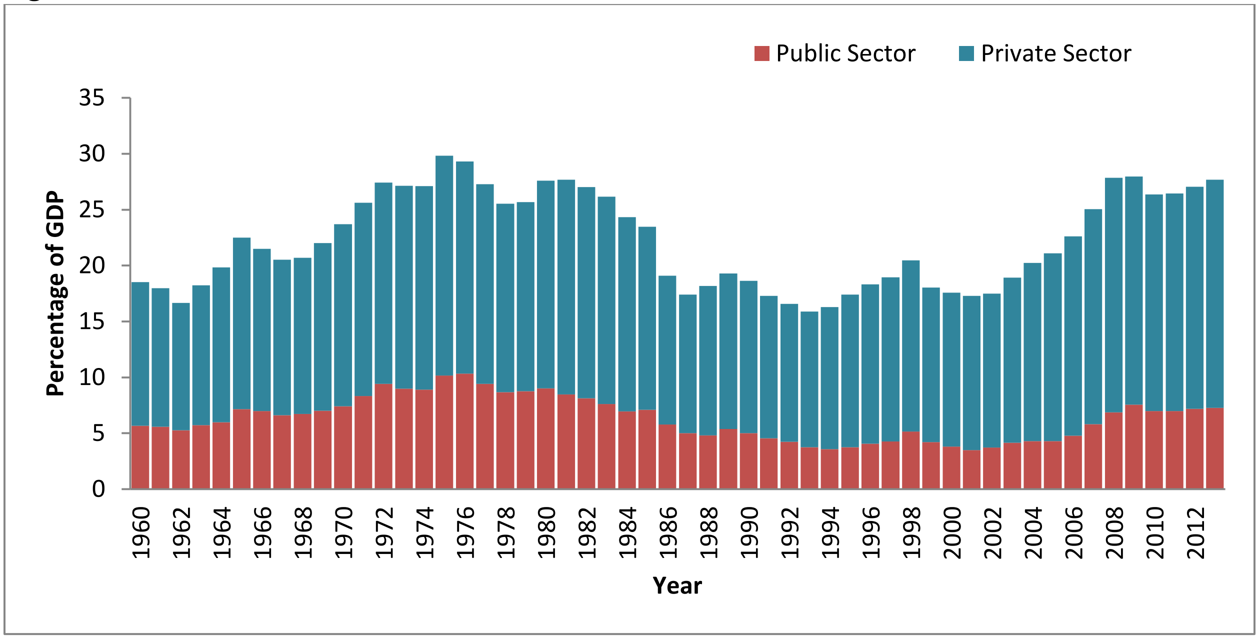
[2] See Appendix A for calculations.

Based on Figure 2.1, the ratio of gross infrastructure to GDP from 1960 to 2013 can be assessed within four distinct sub-periods. The first sub-period can be regarded as the sub-period of infrastructure investment boom and corresponds to 1960 - 1976. During this sub-period, the ratio of infrastructure investment to GDP shows a consistent upward trend (see Figures A6-A9 in Appendix A), with an average of 23.2 per cent per year. The second sub-period, 1977 - 1993, can be regarded as the period of infrastructure investment slowdown as the ratio was 22.1 per cent on average. Noticeably, the ratio fell drastically from 27.6 per cent in 1977 to 14.7 in 1993, exhibiting a strong negative sub-section trend.

The third sub-period, 1994 - 2008, can be deemed the sub-period of economic infrastructure investment recovery in South Africa, with an average ratio of 16.7 per cent. From 1994, the infrastructure investment ratio gradually recovered, rising from 15.2 per cent to 23.1 per cent in 2008. From 2009, which represents the beginning of the fourth sub-period, the ratio trend declined to a lower overall average of 19.5 per cent. Thus, the ratio fell from a maximum of 21.5 per cent to 19.3 per cent in 2009 and 2013 respectively. For a distribution of the ratio between the public and private sector see Figure 2.3 below: [3]

[3]The graph and statistics differ slightly from the ones generated in the Presidency (2014) and the National Treasury (2012) (2013).

Figure 2.3: Public and Private Sector Infrastructure Investment as share of GDP, 1960 – 2013

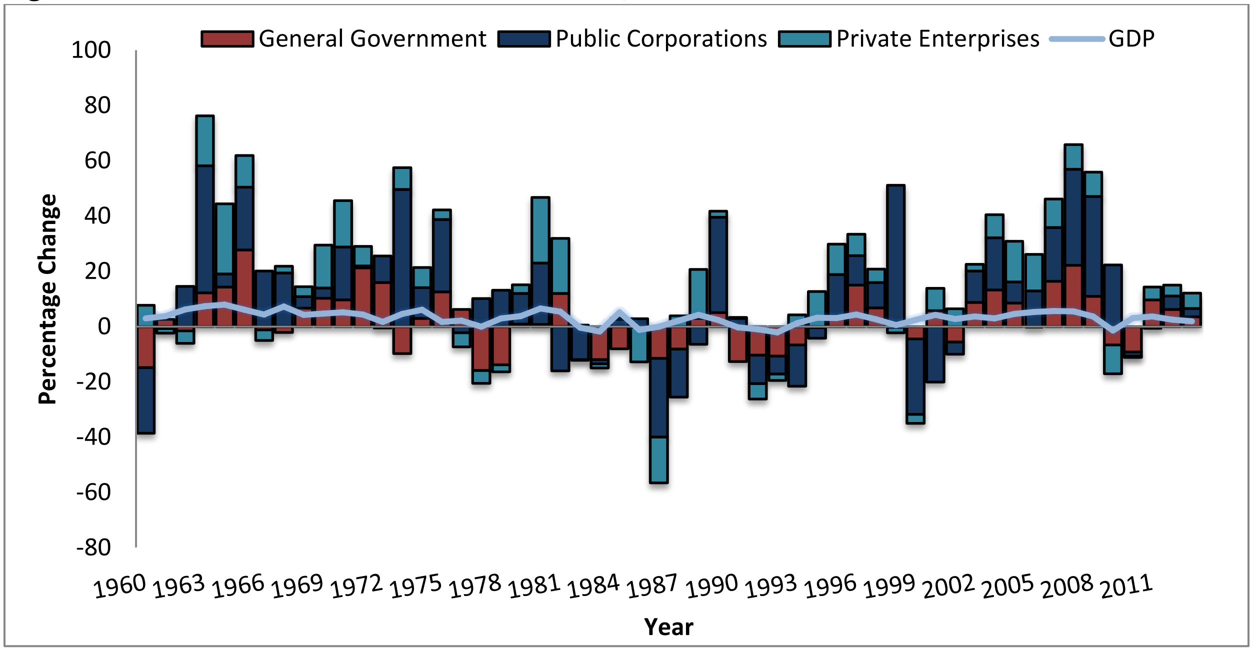


Source: Generated by the researcher, own calculations - SARB data.

The share of the public sector in gross infrastructure investment in the pre-1994 period averaged 45 per cent and 55 per cent for the private sector (see Figure A10, Appendix A). The proportion of distribution for the public sector weakened during the post-1994 period, averaging approximately 30 per cent for the public sector and 70 per cent for the private sector. Interestingly, the share of public sector infrastructure investment rose from roughly 28 per cent in 1994 to a high share of 36 per cent in 2013. The rise in the share of public sector investments signals the South African government's renewed interest in infrastructure development.

Although public sector real infrastructure investment growth rate has fluctuated over the years, its commitment to expand and maintain existing infrastructure is observed in Figure 2.4. From close observation it is evident that the public sector tends to invest more during economic boom periods and less so when the economy contracts. Public sector infrastructure investment has again gained momentum in recent years. According to the National Treasury's (2014) projections, growth in real gross infrastructure investment is expected to increase to 6 per cent in 2016, in line with the global and domestic outlook.

Figure 2.4: Contribution to Investment Growth, 1960 – 2013



Source: Generated by the researcher, own calculations - SARB data.

The National Treasury (2014), has declared its intention to continue setting up various economic and social infrastructure programmes in order to stimulate economic growth and employment creation. The private sector investment will also be supported through low real interest rates, reduced infrastructure red tape and high capacity utilisation. Over the next three years, public infrastructure and maintenance spending is estimated to exceed R844 billion, as shown in Table 2.1.

Table 2.1: Public Sector Infrastructure Expenditure, 2010/2011 - 2016/2017

R billion	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
		Outcomes			Estimates		
Energy	52.2	67.1	75.1	80.6	72.3	65.5	50.6
Water and sanitation	14.6	19.2	22.6	32.4	36.5	36.9	38.5
Transport and logistics	68.6	70.1	69.5	78.6	99.6	120.0	127.5
Other economic services	12.0	11.5	8.9	13.0	15.2	14.2	12.8
Health	6.7	7.7	9.7	9.8	10.5	11.3	11.6
Education	6.2	7.8	9.8	12.1	13.5	13.6	14.0
Other social services	12.8	15.7	10.7	13.8	12.5	13.0	15.9
Justice and protection services	3.8	2.8	4.4	4.9	4.9	5.0	6.5
Central government services	3.0	6.5	6.9	7.3	7.9	8.4	9.3
Total	**180.0**	**208.3**	**217.7**	**252.6**	**272.9**	**287.8**	**286.6**
National departments	7.2	6.6	9.6	11.4	14.1	14.3	16.7
Provincial departments	39.1	43.4	36.4	41.8	42.6	45.5	46.6
Local government	30.9	33.2	41.7	55.2	58.3	61.8	63.5
Public entities[1]	9.4	15.4	14.1	16.4	21.5	23.7	24.4
Public private partnerships	7.3	10.7	2.6	3.0	3.1	3.3	3.5
Public enterprises[1]	86.0	98.9	113.4	124.8	133.4	139.1	132.0
Total	**180.0**	**208.3**	**217.7**	**252.6**	**272.9**	**287.8**	**286.6**

1. Public entities are financed by capital transfers from the fiscus and public enterprises are financed from combination of own revenue, borrowings and private funding

Source: The National Treasury Budget Review (2014).

In Table 2.1, recent projections of public sector infrastructure spending between economic and social infrastructure is presented. Economic infrastructure investment is the largest component of the public infrastructure programme, as shown by estimated energy, transport and logistics, and water and sanitation expenditures. Spending on social infrastructure is estimated to be on the rise, with gradual increases in health and education expenditures in the next three years. There is certainly great dedication by the public sector to expand investment in infrastructure. However, to fully comprehend the country's interest in infrastructure development and economic events that have inspired different kinds of infrastructure developments, it is essential to explore its economic history.

2.3.2 Brief Infrastructure Development History

This subsection gives a brief highlight of the economic conditions that have inspired different kinds of infrastructure developments throughout the years. Following the previous subsection's structure, the history of South African infrastructure development is divided into four distinct periods, namely: the agricultural era, the mineral revolution, the industrial revolution and socio-economic transformation.

2.3.2.1 The Agricultural Revolution: 1650s – 1850s

The formal economy in South Africa began after the arrival of Dutch settlers at the Cape in 1652, whose initial intention was to establish a refreshment station that provided water, meat and other necessities to the Dutch East Indian Company ships sailing to Indonesia (Cilliers and Fourie, 2012; Feinstein, 2005; Wickins, 1983a). Prior to the arrival of the settlers, the economy of what was to become South Africa was dominated by subsistence agriculture and hunting, in line with Rostow's (1959) *traditional society* stage of growth discussed in section 2.1.The company wished to supply its ships with necessities through direct cultivation, importation and trade with the Khoi. However the company soon realised that these methods were not providing enough surplus and released a few employees to pursue cultivation activities by growing wheat, grain and later grapevines and breed livestock on the slopes of Table Mountain and surrounding areas (Cilliers and Fourie, 2012; Feinstein, 2005; Mason, 2003; Wickins, 1983b).

The 1657 to 1795 period marked the development of the Cape colony as more permanent settlers and slaves migrated into the country and moved to the interior. The settlers, however, encountered barriers to inland penetration as there were no roads (merely tracks) and no rivers had been bridged (Solomon, 1983). The predominant sector during this period was agriculture and economic activity quickened with increased production in wine, fresh fruit, maize, sugar and meat. The exportation of raw materials also grew, due to high levels of wool production, (Feinstein, 2005), making this period consistent with Rostow's (1959) *preconditions for take-off* stage of growth. During this period, infrastructure development was centred in Cape Town and areas in its close proximity as it was the country's economic hub. Infrastructure development was mainly targeted towards the agricultural sector, most notably, transport infrastructure to aid with the movement of produce to and from ports and the central hub for trade and exports. Formal construction of roads, harbours, railway, was carried out during this period (Perkins *et al*., 2005; Solomon, 1983).

2.3.2.2 The Mineral Revolution: 1860s – 1910s

The discovery of diamonds in the Orange Free State and gold in the Transvaal in 1867 and 1884, respectively, transformed the economy and attracted significant foreign interest. The mineral revolution led to further migrations of diverse nationalities into the interior of the country for business ventures and work (Webb, 1983). While diamonds and gold held centre stage, coal (which was discovered later) was supplied to gold mines and came to be of crucial economic importance and led the way to electricity generation (Iliffe, 1999). According to Feinstein (2005) and Nattrass and Seekings (2010), the agricultural and mining sectors contributed significantly to the economy's growth, employment creation and the export market. This period is also consistent with Rostow's (1959) *preconditions for take-off* stage of growth.

Infrastructure took centre stage during this period, with the discovery of diamonds and gold bringing significant infrastructure developments as more economic hubs emerged. This infrastructure boom was for the purpose of improving poor transportation and communication services. According to Perkins, *et al*., (2005), the discovery of diamonds and gold played an important role in the early development of the country's railway infrastructure. National network linkages were created through expansion of public facilities including roads, rail, ports and communication networks (Iliffe, 1999; Perkins, *et al*., 2005). Mining output and exports grew substantially owing to large capital and infrastructure investments during that period (Fedderke and Simkins, 2009).

2.3.2.3 Industrial Revolution: 1920s – 1970s

Manufacturing gained momentum between 1920 and 1970 through the upsurge in industrial activity such as mechanical assembly and repair, cement, chemicals, textile and cotton (Feinstein, 2005; Fedderke and Simkins, 2009; Iliffe, 1999). This characteristic of the economy makes this stage consistent with Rostow's (1959) *take-off* stage of growth. During economically sluggish years (1910s - mid-1930s), the government built its capacity to intervene in almost every aspect of the economy. The government also formulated an industrial policy and intervened when private investors were unable or unwilling to commit the necessary capital (Hanival and Maia, 2010; Faulkner and Loewald, 2008; Moll, 1991; Nattrass and Seekings, 2010). The Great Depression in the 1930s extensively reduced agricultural output as the demand for diamonds and agricultural exports fell. However, South Africa quickly recovered with assistance from the rise in the gold price and, consequently, output expanded and more jobs were created (Feinstein, 2005). The Second World War provided further stimulus to local industries due to less import competition.

In 1948, the National Party government was elected which introduced the policy of segregation that brought explicit racial discrimination which directly and deliberately affected job opportunities, the educational system, social benefits and earnings, making the distribution of income extreme (Nattrass and Seekings, 2005). Racial discrimination triggered persistent political unrest, reaching extreme heights from the 1960s. Consequently, economic sanctions were imposed on South Africa by the international community after the 1970s, affecting economic growth and investment in South Africa tremendously (Hanival and Maia, 2010). There were substantial infrastructure developments during this period to support industrialisation (Hanival and Maia, 2010).

The government took ownership and extended responsibility for railways, operated the transport system and expanded electricity supply (Nattrass and Seekings, 2010). Roads were extended and improved, while air travel was introduced (Perkins *et al*., 2005). Although there was significant growth in terms of infrastructure investment, provision of basic services such as clean water, sanitation, refuse collection, reliable and affordable transport and electricity was not even and fair throughout the country; areas occupied by black South Africans were poorly serviced (Presidency, 2014; Savage, 2008).

2.3.2.4 Socio-Economic Transformation: 1980s to Present

The late 1970s and the beginning of the 1980s saw the South African economy benefit from the gold price rise. However, a downward trend immediately followed due to the return of the gold price to lower levels, political instability and the imposition of financial sanctions (Faulkner and Loewald, 2008; Fedderke and Simkins, 2009). The economy was under severe pressure from the mid-1980s with slowing economic growth, a high budget deficit, low foreign exchange reserves and disinvestment (Presidency, 2014). It became apparent to the government that economic conditions were unsustainable and in the late 1980s negotiations commenced to deal with political pressures.

A new democratically elected government came into power in 1994 and revised and developed socio-economic policies with the intention to address declining growth rates, poorly located infrastructure, inequalities, unemployment and poverty brought by Apartheid (Reitzes, 2009). Apartheid had left most South Africans with limited access to basic social and physical infrastructure (Ncube, Shimeles and Verdier-Chouchane, 2012; Nnadozie, 2013) and post-1994 infrastructure programmes sought to allay social infrastructure backlogs. These programmes, such as the Reconstruction and Development Programme (RDP) of 1994 and the Growth, Employment and Redistribution (GEAR) of 1996, sought to provide access to basic services through infrastructure networks provision to the historically marginalised and poor population. Additional housing, health and educational facilities were constructed, while, electricity grids and water networks were extended in previously underserviced areas (Hanival and Maia, 2010; National Treasury, 2012; Perkins *et al*., 2005).

More recently, infrastructure investment has been directed towards stimulating economic activity and it has been identified by the Accelerated and Shared Growth Initiative of South Africa (ASGISA) of 2006, the New Growth Path (NGP) of 2011 and the National Development Plan (NDP) of 2012 as one of the key economic growth and employment creation drivers (Hanival and Maia, 2010; Mbanda and Chitiga, 2013; Reitzes, 2009; Savage, 2008). In the years leading up to the 2010 International Federation of Association Football (FIFA) Soccer World Cup, there was a huge rise in the construction sector to meet new stadia and transportation infrastructure. Moreover, additional expansions of the country's electricity and water and telecommunications networks were carried out (Hanival and Maia, 2010; Mbanda and Chitiga, 2013, National Treasury, 2012). This period is characterised by both the *take-off* and the *drive to maturity* elements of Rostow's (1959) stages of growth.

2.3.3 Economic Policy

While South Africa's economic policy is guided by the need to stimulate economic growth and address the high rates of unemployment, poverty and inequality, immediate post-1994 policies placed substantial weight on redistribution and social inclusion as an approach for the country to realise its inclusive growth objectives. More recently, policies have taken different approaches. While ASGISA has been macro-oriented, the NGP and NDP have sought to achieve a labour-absorbing growth path. These recent strategies are concisely discussed below.

2.3.3.1 ASGISA

The ASGISA, which presented initiatives to sustain higher and shared growth, had an objective to halve poverty and the unemployment rate by 2014. This target came from the identification of the following binding constraints on South Africa's escalating unemployment rate:

- Volatility and level of the currency.
- The cost, efficiency and capacity of the national logistics system.

- Shortage of suitably skilled labour.
- Barriers to entry, limits to competition and limited new investment opportunities.
- The regulatory environment and the burden on small and medium businesses.
- Deficiencies in state organisation, capacity and leadership.

In order to overcome these challenges and reduce unemployment to 15 per cent, the ASGISA specified that the South African economy needed to grow at an average rate of five per cent between 2004 and 2014. The subject areas through which growth acceleration was to be achieved were identified as being:

- Infrastructure programmes.
- Industrial investment strategies.
- Education and skills development.
- Eliminating the second economy and supporting small, medium, micro enterprises (SMMEs).
- Macroeconomic policies and implementation.
- Governance and institutional interventions.

2.3.3.2 NGP

The NGP was adopted as a framework for economic policy and the country's employment creation strategy. It responded to the 2008-2009 global economic crisis and identified high levels of unemployment, inequality and poverty as core challenges. The NGP targets the generation of five million new jobs by 2020 and identifies five job drivers:

- Substantial public investment in infrastructure.
- Targeting more labour-absorbing and cost-reducing activities across the main economic sectors such as the restructuring of land reforms to support smallholder schemes with comprehensive support around infrastructure, marketing and finance; accelerating exploitation of mineral reserves; refocusing the beneficiation strategy to support

fabrication; supporting manufacturing activities; and strengthening measures to expand the tourism infrastructure and services.

- Taking advantage of new opportunities in the knowledge and green economies by supporting energy efficiency and renewable energy; public employment and recycling schemes; stronger programmes, institutions and systems to diffuse new technologies to SMEs and households; greater support for research and development; and tertiary education to reduce the cost of and improve access to broadband.
- Leveraging social capital in the social economy and the public services through including assistance with marketing; bookkeeping; technological and financial services; training; increasing state procurement from and service delivery through organisations in the social economy.
- Fostering rural development and regional integration through infrastructure, including housing investments and economic development initiatives.

2.3.3.3 NDP

The NDP presents an exhaustive socioeconomic strategy to increase employment, alleviate poverty and inequality and improve living standards of the population by the year 2030. The plan recognises that South Africa is in a low growth and middle-income trap due to low levels of competition, high unemployment rates, low savings and poor skills. It also recognises that in order to combat these issues, it needs to raise employment and growth rates sufficiently enough to enable the population to attain an acceptable standard of living and minimise equality. To achieve this, the plan offers the following three intertwined interventions:

- Raising employment through faster economic growth.
- Improving the quality of education, skills development and innovation.
- Building the capability of the state to play a developmental, transformative role.

The plan is partitioned into three equally important phases. In the first phase (2012-2017), emphasis is given to infrastructure investment and employment creation by:

- Increasing high-skills supply and improving education output.
- Providing sufficient supply of energy and water.
- Intensifying research and development spending.
- Emphasising opportunities linked to existing industries.
- The improvement of the labour relations environment by means of employment strategies, programmes and incentives.

According to the National Planning Commission (NPC) (2012: 157), "South Africa should focus on diversifying the economic base" in the second phase (2018–2023). "This should include building the capacities required to produce capital and intermediary goods for the infrastructure programme and sub-Saharan Africa", while laying the foundation for intensive improvements in productivity and innovation. In the years leading up to 2030, the plan emphasises a knowledge economy, where innovation and improved productivity are strongly heightened. The plan envisions the country to have an improved quality of life, low levels of inequality and high levels of skilled labour by then.

The preconditions of the NDP revolve around:

- Intensifying commercial transport, telecommunications, energy, and water.
- Enhancing the quality of health and education and ensuring safer communities.
- The development of sustainable human settlements and complementary low-cost infrastructure.
- Strengthening the capabilities of the workforce.
- Promoting the expansion of global market share in domestic and foreign markets.
- Playing a more fundamental role in regional development.
- Strengthening public-service capabilities and the governance of state-owned enterprises.

Notably, the NDP complements the NGP by emphasising the creation of an environment conducive enough to enable faster growth and employment through government investment, microeconomic reforms that lower the costs of production and living, competitive and equitable wage structures, and the effective removal of constraints to investment in specific sectors. According to the plan, by 2030, the unemployment rate should be at a low rate of six per cent. To reach this target, 11 million jobs need to be created and employment scenarios in the plan suggest that most new jobs are likely to be generated in domestic-orientated businesses, with small and medium-sized firms being the main employment creators. Because the economy needs a thriving private sector, the plan sets out to improve the environment for doing business by putting in place measures to ascertain investment confidence such as policy certainty, regulatory reforms and support, competitive infrastructure delivery, efficiency of public services and the quality of labour.

The plan projects a 2.7 per cent rise in real GDP and per capita GDP increase to approximately R110 000 per person in 2030. The plan also aims by 2030, to achieve a 30 per cent rate of investment to GDP and 10 per cent for public sector fixed capital formation to GDP, which is consistent with ratios during high-growth phases in other countries. High rates of investment, especially in infrastructure, are essential to foster rapid growth and employment through the ability to improve economy-wide efficiency and cost structures, providing the population with the means to improve their own lives and boost their incomes and support industries.

Owing to the fact that the economy also requires a capable and suitably skilled workforce for sustained growth and employment, the plan suggests that efforts be taken to ensure the development of the capabilities of the workforce on a broad scale, ranging from competitive earnings, employment incentives, and programmes to promote investment in skills and education. The plan clearly outlines the basis for improving the quality of education, skills, health, mixed housing strategies and more compact urban development to assist citizens' access to public spaces and facilities; work and business opportunities through infrastructure, spatial planning and better quality public service. This enables active economic participation by the majority of the population, allowing them to acquire income and improve their standards of living, thus reducing poverty and inequality within society.

2.3.3.4 Synthesis

While the ASGISA and NGP were part of the developmental state framework adopted by the current administration whose perception is based on the notion that government intervention drives growth, the NDP recognises the role of the private sector in achieving growth. The NDP is sensitive to market forces and has received much support from the private sector. Similarly to the ASGISA and the NGP, the NDP recognises infrastructure investment as an avenue for both economic and social progress. The ASGISA and other economic policies initiated during President Thabo Mbeki’s term in office centred on achieving economic growth by building a competitive macro-environment, the post-Mbeki regime is more a worker-oriented development approach to growth. Evidently, the South African government is moving away from a consumption spending approach towards a more investment spending approach, where citizens are economically active in development in order to achieve the desired growth levels – thus, enabling South African citizens to improve their own living standards. Theoretically, this perspective is in line with the Keynesian and endogenous growth theories, specifically Barro’s (1990) growth model.

2.4 Conclusion

This chapter covered relevant growth theories that make reference to capital investment and its effects on growth. Additionally, the chapter gave an account of the conceptual literature behind infrastructural links to growth and an overview of infrastructure investment in South Africa. Interestingly, while most historical periods in section 2.2.3 were consistent with Rostow’s (1959) stages of growth, it appears the South African economy has elements of both the *take-off* and the *drive to maturity* stage. While the country has one of the highest living standards relative to many emerging economies, high consumption and a strong mining sector, *take-off* still needs to be concentrated towards the development of citizens, and that is what government policy sought to achieve. Barro’s (1990) model represents the core theoretical background for this dissertation and from it, appropriate variables required for the econometric analysis are chosen.

CHAPTER THREE
EMPIRICAL LITERATURE REVIEW

3.0 Introduction

According to Romp and de Haan (2007) empirical research on the relationship between public capital and growth should provide answers to whether an increase in public capital stock fosters economic growth and what the net effect of more infrastructure is. Because empirical literature on the infrastructure-growth relationship is immense and thereby making it impossible to give an exhaustive account, this chapter, in line with the main objective of this research and the recommendation by Romp and de Haan (2007), reviews a series of empirical studies that employ production and cost function theoretical frameworks to develop models that were analysed using a variety of statistical modelling methodologies. While providing illustrative examples of studies conducted to investigate the impact of infrastructure investment on economic growth, this chapter gives attention to studies involving both single equation and multi-equation methodologies which use data from both single and across numerous countries.

The chapter is organised as follows: section 3.1 gives an international perspective of empirical findings of the effects that infrastructure impose on the growth of different economies; section 3.2 highlights existing studies conducted in South Africa; in section 3.3, a discussion on both reviews is given.

3.1 An International Perspective

The relationship between infrastructure investment and economic growth has been a major research topic since the publication of Aschauer's (1989) seminal paper which found public investment in infrastructure to be an important source of economic growth (Calderon and Serven, 2010; Gramlich, 1994; Prud'homme, 2004; Sanchez-Robles, 1998). Aschauer (1989) initiated a study on the impact of infrastructure investment on output productivity growth in the United States (U.S.) using annual data from the year 1949 to 1985. He employed the Ordinary Least Squares (OLS) method against variables including productivity, output, private capital and indices for public capital stock, and found a strong positive relationship between public capital and productivity with high elasticity coefficients of output with respect to government capital, ranging between 0.38 to 0.56 per cent, implying that a 1 per cent increase in public capital would raise output by a range of 0.38 to 0.56 per cent.

As additional empirical research was conducted on the subject matter, Aschauer's (1989) work received support from academics such as Munnell (1990a) and Lynde and Richmond (1993) who also found a positive link between infrastructure investment and growth. However, Aschauer's (1989) findings also spurred some disagreements. While some academics argued that although there is evidence of positive output effects of government capital, the magnitude of these effects is generally much smaller than that reported by Aschauer (1989). Others found no empirical evidence of any impact of infrastructure investment on growth. Subsection 3.1.1 briefly discusses earlier studies (pre 2000) conducted internationally. In section 3.1.2, recent international studies are reviewed.

3.1.1 Earlier Studies

3.1.1.1 National Studies

Munnell (1990a) explores whether changes in the amount of non-military public capital, private capital and labour explain changes in output in the U.S between 1949 -1987. Making use of OLS approaches, she finds that public capital positively and significantly contributes towards output growth, with elasticity ranging from 0.31 to 0.39.

Building on earlier work, Munnell (1990b) explores the impact of public capital on output, employment growth, and private investment at the national and regional level for the period 1970 to 1986. Assuming a Cobb-Douglas production-type model where private capital, labour and the stock of public capital are functions of output, her regression results confirm that public capital has a significant positive impact on the level of output. She found that a one per cent increase in public capital would raise output by 0.15 per cent, which is much smaller than the estimates found in Aschauer (1989) and Munnell (1990a). By further examining the impact of various components of public capital on output by disaggregating public capital, Munnell (1990b) finds that capital such as highways and streets, water and sewer systems, other structures and equipment yields a statistically important relationship, while schools and hospitals, appear to have no direct impact on private output.

Contrary to Munnell (1990a, 1990b), Tatom (1991) finds public capital to be insignificant when re-estimating the regression from Aschauer (1989) by employing the variables in first differences and including a control variable for oil prices, suggesting spurious results in Aschauer's (1989) work. Holtz-Eakin (1992) also finds that there is no role for public infrastructure capital on output in the U.S. from 1969 to 1986. When employing OLS, instrumental variable (IV) and generalised method of moments (GMM) estimation techniques on private and public capital, labour and output the results suggest that the effect of public capital on output is negative and significant when controlling for fixed and state specific effects. This finding supports arguments by Holtz-Eakin and Schwartz (1995) who found that the capital stock effect on output is not statistically different from zero in the U.S. For an African country analysis, Ghali (1998) arrives at a similar conclusion when investigating the long run effects of public investment on private capital formation and economic growth in Tunisia using annual data on GDP, private and government investment over the period 1963 – 1993, and using the vector error correction model (VECM) framework. Ghali (1998) finds that public investment has a negative impact on economic growth. He also finds strong evidence suggesting that government investment causes growth.

Wylie (1995) estimates translog and Cobb-Douglas production functions for the goods-sector to examine the role of infrastructure in Canadian economic growth and productivity for the period 1946 – 1991. In the study, real output is assumed to be a function of goods-sector fixed capital, infrastructure fixed capital stock, time as a proxy for technical change and the unemployment rate as a proxy for business cycle effects on labour productivity, per hour worked. Using OLS techniques, Wylie (1995) finds total infrastructure capital stock to be a significant contributor to output, with a productivity elasticity of 0.52. When dividing the total infrastructure capital variable into core (air, rail, water, motor, urban and suburban transport; pipelines; toll highways, bridges and warehousing; grain elevators; and electric power and gas distribution), service (capital stock in trade; finance, insurance and real estate; broadcasting; telephone system; and commercial services) and public infrastructure components, he finds public infrastructure to provide the greatest contribution to productivity.

Mitra, Varoudakis and Veganzones (1998), explore the effects of infrastructure on manufacturing industries' total factor productivity (TFP) and technical efficiency (TE) in Indian states for the period 1976 – 1992 using 12 disaggregated infrastructure indicators of what they categorise as physical (roads and rail), social (education and health) and economic infrastructure (Banks and credit). They also make use of a Cobb–Douglas production function model consisting of annual indicators for value added, capital and labour inputs in the industry and controlling for regional, time and shock effects. Results of the study confirm a positive impact of physical and social infrastructure on the long run level of productivity of Indian manufacturing industries. Interestingly, social infrastructure, approximated by the education and health variables, shows the greatest impact on industrial TFP growth. They conclude that productivity, efficiency and, therefore, competitiveness depend on infrastructure.

Similar results are found in the Netherlands by Sturm, Jacobs and Groote (1999) who study the output effects of infrastructure investment for the period 1853 - 1913. Making use of a vector autoregressive (VAR) framework to estimate models comprising GDP, infrastructure capital formation and capital formation in machinery and equipment, infrastructure investment is found to have a strong positive and significant effect on output. A Granger causality test suggests a unidirectional relationship between infrastructure and GDP.

3.1.1.2 Cross-Countries Studies

In a paper that investigates the long run consequences of infrastructure provision on per capita income for a panel of countries over the 1950 to 1992 period, Canning and Pedroni (1999) find strong evidence of long run effects running from infrastructure to income levels. Variables employed in the study are GDP per worker, infrastructure as measured by kilometres of paved road per capita, kilowatts of electricity generating capacity per capita and the number of telephones per capita. For the purpose of the study, Canning and Pedroni (1999) conducted unit root and cointegration tests and also performed a conventional Granger causality analysis. Findings show that the effect of infrastructure on growth varies across countries with strong evidence of long run impacts of infrastructure on GDP per capita in a large number of countries. By pooling these cross-country effects, they find evidence that for telephones and paved roads the sign of the infrastructure effect on growth varies across countries, being zero on average, with a positive effect in some countries and a negative effect in others. There is also evidence that the effect of paved roads is positive in less developed countries. For electricity generating capacity, their findings support a shared positive effect in every country, however, this positive effect is more robust in developed countries. Causality between infrastructure and income seems to appear in some countries but not in others, but a large percentage of countries studied exhibited strong evidence in favour of a bi-directional causal link.

Findings by Canning and Pedroni (1999) are supported by an earlier study by Easterly and Rebelo (1993) who found that the share of public investment in transport and communication, health, education and housing and urban infrastructure is positively correlated with growth when examining the statistical association between measures of fiscal policy, level of development and the rate of growth in cross-section of countries for the 1970 - 1988 period. They also find evidence suggesting that causality between the two variables in question runs from infrastructure to growth.

Garcia-Mila, Mcguire and Porter (1996), however, find conflicting evidence when using disaggregated indicators for physical infrastructure between 1970 and 1983. This negative relationship was also found in other cross-country studies for example by Pritchett (1996) and Devarajan, Swaroop and Zou (1996). Notably, Devarajan *et al*., (1996) find either a negative or insignificant relationship between public capital, transport and communication and health and education investment and economic growth for a group of developing economies.

In a paper that sets out to examine the role of public capital on the growth rate of output using a cross-country approach, Sanchez-Robles (1998) finds a negative relationship between infrastructure and output when using expenditure on infrastructure as a percentage of GDP as proxy for infrastructure. However, when an index of physical capital units is used as an indicator for infrastructure endowment and investment instead of monetary value, a positive impact of public capital on the growth rate of output is observed.

3.1.2 Recent Studies

This subsection reviews recent (post-2000) studies dedicated to exploring whether public infrastructure investment fosters economic growth. Due to the large volume of studies conducted recently in other countries, Table 3.1 is used to summarise findings, econometric techniques and the infrastructure components used in different studies.

Table 3.1: Summary of Recent International Studies

Author(s)	Country, Sample, Specification and Estimation Method(s)	Infrastructure Variable(s)	Findings
Ahmed, Abbas and Ahmed (2013)	• Pakistan • 60 year period • Dynamic computable general equilibrium (CGE) model	Aggregate Infrastructure capital stock.	There is a positive infrastructure impact on GDP growth. Infrastructure has a crowding-in effect on private investment.
Albala-Bertrand and Mamatzakis (2007)	• Chile • 1960 - 2000 • Translog cost function	Total gross fixed capital formation and disaggregated physical capital stock: electricity, transport and telecommunication.	Infrastructure capital is cost saving and contributes to total factor productivity (TFP).
Babatunde, Afees and Olasunkanmi (2012)	• Nigeria • 1970 - 2010 • Simultaneous equation regression: IS-LM-balance of payment model • Three stage least squares (3SLS) methods	Infrastructure capital stock.	Infrastructure investment has a significant and positive effect on economic growth with a bi-directional causal link.
Badalyan, Herzfeld and Rajcanova (2014)	• Armenia, Turkey and Georgia • 1982 - 2010 • Panel unit root tests, cointegration analysis; dynamic ordinary least squares (DOLS); fully modified OLS and VECM approaches	Public Infrastructure Investment: gross fixed capital formation.	Overall strong positive and statistically significant short and long run relationship between infrastructure investment and economic growth - the causal link is bi-directional.
Belloc and Vertova (2006)	• 7 highly indebted African countries • 1970 - 1999 • Unit root and cointegration tests, VECM, impulse response and variance decomposition	Public investment.	A positive impact of public investment is observed on output in six out of seven countries. Infrastructure crowds-in private investment.
Bom and Ligthart (2014)	• OECD countries • Cobb-Douglas production function	Public capital stock.	Public investment increases output.
Bougheas, Demetriades and Mamuneas (2000)	• 119 countries • 1960 - 1989 • Growth regressions • OLS and IV estimation techniques	Physical Infrastructure stock: length of roads and telephone main lines. Human Capital: secondary school enrolment rate.	Significant positive relationship between infrastructure and long run economic growth. The secondary school enrolment rate is also found to be positive and significant.
Calderon and Serven (2002)	• 101 countries • 1960 - 1997 • Cobb-Douglas production function • OLS and GMM approaches	Physical infrastructure capital stock: electricity generating capacity, road length and the number of main telephone lines. Human capita: number of years of secondary schooling.	Positive and significant output contribution of all infrastructure indicators and human capital.

Author(s)	**Country, Sample, Specification and Estimation Method(s)**	**Infrastructure Variable(s)**	**Findings**
Calderon and Serven (2008)	• Sub-Saharan Africa • 1960 - 2005 • GMM-IV system estimator	Physical capital stock index: total telephone lines (fixed and mobile), electric power generating capacity and the length of the road network. Human capital: secondary school enrolment.	Infrastructure development has a robust positive impact on long run growth. Human capital was found to be statistically significant and positive.
Demetriades and Mamuneas (2000)	• 12 OECD countries • 1972 - 1991 • Cost function	Public capital Stock: Gross fixed capital formation.	Public infrastructure has a positive long run effect on output.
Dash and Sahoo (2010)	• India • 1970 - 2006 • Production Function • Two-stage least squares (2SLS), DOLS and VECM approaches	Index of physical infrastructure capital stock: per capita electricity power consumption, energy use, telephone lines (main and cellular), rail density, air freight transport and paved roads stock. Human capital: Infant mortality rate, health and education expenditure.	Economic and social infrastructure has a positive and significant impact on output. There is unidirectional causality running from both economic and social infrastructure to output growth.
Demurger (2001)	• China, 24 regions • 1985 - 1998 • Growth equation • 2SLS, fixed effects (FE) and random-effects (RE) methods	Infrastructure stock: transport and telecommunication indicators. Human capital: secondary education and Physical capital stock: transport and telephone infrastructure indicators.	Transport and telecommunication infrastructure and human capital have a positive impact on growth.
Egert, Kozluk and Sutherland (2009)	• 24 OECD countries • 1960 - 2005 • Time series and panel analysis. DOLS, pooled mean group (PMG) and GMM approaches	Physical infrastructure capital stock per capita: roads, rail, motorway, electricity generation and telecommunication. Human capital: years of schooling.	There are mixed results on contributions of infrastructure and human capital on long run output across countries. However, an overall assessment reveals a robust positive link between the variables.
Esfahani and Ramirez (2003)	• 75 countries • 1965 - 1995 • Cobb-Douglas production function • IV/2SLS estimation	Growth rates of physical capital stock: telephones and power production per capita.	Infrastructure has a substantial, positively and significant impact on GDP growth.
Estache, Perrault and Savard (2012)	• Sub-Saharan Africa • Cobb-Douglas production function • Static CGE estimation	Infrastructure investment: unproductive infrastructure, roads, electricity and telecommunication.	There are mixed results on the impact of infrastructure on growth. A closer inspection shows an overall positive effect on GDP from roads, electricity and telecommunication spending and not much effect from other infrastructure spending.
Fedderke and Kaya (2013)	• Turkey • 1987 - 2006 • PMG estimator and VECM cointegration methods	Physical capital stock: roads, rail, ports, electricity and telecommunication. Human capital (as control variable): average years of schooling.	On average, there is statistical and economic significance of infrastructure on productivity growth. Human capital is statistically insignificant in explaining growth.

Author(s)	Country, Sample, Specification and Estimation Method(s)	Infrastructure Variable(s)	Findings
Ferreira and Araujo (2007)	• Brazil • 1960 - 1996 • Correlation matrix, cointegration and VAR analysis	Physical infrastructure capital per capita: paved roads, telephone lines electricity generation capacity.	Productivity impact of infrastructure is significant and large in both the short and long run. Infrastructure has a crowding-in effect on private investment.
Gutierrez (2005)	• 6 Latin American countries • 1970 - 2002 • Growth accounting approach • OLS techniques	Investment expenditure.	Public investment has an insignificant impact on output growth.
Heintz, Pollin and Garret-Peltier (2009)	• USA • 1951 - 2006 • Production function • Autoregressive-distributed lag (ARDL) model	Price indices for physical/core Infrastructure capital stock.	A long run relationship exists between public capital and private productivity. Infrastructure has a crowding-in effect on private investment.
Herranz-Loncan (2007)	• Spain • 1850 - 1935 • Production function • Cointegration, VAR techniques	Aggregate and disaggregated physical infrastructure capital stock: transport and communication networks.	Investment in local scope Infrastructure has a positive impact on the economy, while returns to investment in large nation-wide networks were not significantly different from zero during the period.
Jayme Jr, da Silva and Martins (2009)	• Brazil, regions • 1986 - 2003 • Panel data model • OLS, (FE) and (RE) panel estimation	Share of infrastructure, transportation, energy and communication expenditures to total expenditure.	There is a positive and significant relationship between public infrastructure expenditures and macroeconomic performance.
Kamps (2006)	• 22 OECD countries • 1960 - 2001 • Cobb-Douglas production function - Pooled regression model • OLS, Unit root and cointegration tests	Public capital stock: gross fixed capital formation.	An average elasticity of output with respect to public capital is 0.2, positive and statistically significant in many countries in a pooled data analysis. Elasticity is much higher in time-series models, ranging from 0.37 to 0.85
Kamara (2007)	• 19 Sub-Saharan African countries • 1980 - 1995 • ARDL, PMG and GMM approaches	Physical Infrastructure stock and infrastructure index: total length of roads, electricity generation and, number of fixed line and mobile telephone subscribers. Human capital: average years of schooling.	There is positive and significant impact of physical and human capital on output with elasticity ranging between 0.22 and 1.34, 0.37 to 0.63 and 0.38 for individual infrastructure indicators, human capital and the index, respectively.
Kustepeli *et al.*, (2012)	• Turkey • 1970 - 2005 • Granger causality and Cointegration analysis	Investment in highway transportation infrastructure and highway length.	There is no evidence of a long run positive relationship between highway infrastructure expenditures and economic growth. There is no causal link between infrastructure and growth.
Mallick (2002)	• India • 1950 - 1995 • Production function • VAR estimation techniques	Public capital: Investment expenditure. Human capital: education level.	Economic growth is influenced largely by public investment and human capital.

Author(s)	Country, Sample, Specification and Estimation Method(s)	Infrastructure Variable(s)	Findings
Mamatzakis (2003)	• Greece • 1960 - 1995 • Translog Cost Function • 3SLS estimation	public capital stock in ports, railways, motor vehicles and roads, irrigation canals, electrical and communication facilities.	Public infrastructure is cost saving and capable enhances productivity growth. Infrastructure has a crowd-in effect on private investment.
Mastromarco and Weitek (2006)	• Italy, 20 regions • 1970 - 1995 • Stochastic frontier model	Physical public capital stock (core infrastructure): transport, electricity and communication, and non-core infrastructure: public buildings, hospitals, reclaimed land and others.	Overall public capital is positively associated with technical efficiency. Core infrastructure is found to positively stimulate efficiency, while non-core infrastructure exhibited mixed results.
Milbourne, Otto and Voss (2003)	• 74 countries • 1960 - 1985 • Cobb-Douglas production function • OLS and IV approaches	Public investment as share of GNP, total and disaggregated into transport, agriculture, education, health, housing and industry.	Mixed results per estimation method. Steady state model and IV show an insignificant contribution to growth by public spending while OLS results show the contrary.
Moreno, Lopez-Bazo and Artis (2003)	• Spain, regions and 12 manufacturing sectors • 1980 - 1991 • Translog cost function	Physical Infrastructure capital stock: transportation and communication. Net monetary stock of core infrastructure: transport, water and sewage facilities, and urban structures.	Public investment is found to reduce costs and increase efficiency.
Nketiah-Amponsah (2009)	• Ghana • 1970 - 2004 • Aggregate output accounting framework • OLS and Granger causality estimation	Infrastructure Investment: fixed capital formation. Human Capital: health and education expenditure.	Public infrastructure and health spending are significant determinants of economic growth. Education expenditure has no significant impact on growth. Economic growth Granger-causes expenditure on infrastructure.
Pooloo (2009)	• Mauritius • 1970 - 2006 • Production function • VAR and VECM analysis	Physical infrastructure stock: paved road length and telephone lines. Human capital: secondary school enrolment ratio.	Infrastructure is a significant determinant of economic growth with output elasticities ranging between 0.14 and 0.36. Human capital also has a significantly positive impact on economic growth. Infrastructure crowds-in private investment.
Rodriguez-Pose, Psycharis and Tselios (2012)	• Greece, 51 regions • 1978 - 2007 • FE, OLS approaches	Public investment expenditure and disaggregated public investment expenditure.	There is a positive and significant association between public (physical) infrastructure investment, human capital and regional growth in both the short and long run.
Sahoo, Nataraj and Dash (2012)	• China • 1975 - 2007 • Cobb-Douglas production function • ARDL, GMM and VECM approaches	Physical infrastructure index (electricity power consumption, energy use, telephone density, rail density, air transport and paved road) and social infrastructure: education and health.	Infrastructure and human capital have a significantly positive impact on growth with output elasticity of infrastructure varying between 0.28 and 0.36 and from 0.39 to 0.62 respectively. There is unidirectional causality from infrastructure development to output growth and bi-directional causality between economic growth and public investment.

Author(s)	Country, Sample, Specification and Estimation Method(s)	Infrastructure Variable(s)	Findings
Snieska and Simkunaite (2009)	• Latvia, Estonia and Luthuania • 1995 - 2007 • OLS methods	Physical infrastructure stock: paved road length, telephone lines and sanitation.	Mixed results between different infrastructure indicators and growth.
Vidyattama (2010)	• Indonesia, 26 regions • 1985 - 2005 • Growth equation • GMM estimation techniques	Physical infrastructure stock: length of roads per capita. Human capital: average year of schooling.	Infrastructure and human capital have a significant and positive effect on income.
Wang (2002)	• 7 East Asian countries • 1979 - 1998 • OLS and generalised least squares (GLS) methods	Physical public infrastructure stock: water electricity and transport, storage and communication.	Growth in public capital is significant and positive in explaining the variations in production growth rates in five of seven countries. Infrastructure crowds-in private investment.
Yu and Mi (2012)	• China • 1988 - 2007 • Cobb-Douglas production function • OLS approaches	Physical Infrastructure capital stock: electricity, gas and water, the management of water and the telecommunication, transportation, postage.	Physical infrastructure development contributes positively to Chinese economic growth, with a positive and statistically significant output elasticity of 0.29.

Source: Compiled by the researcher.

Table 3.1 gives a summary of recent studies on the infrastructure-growth relationship and from it two striking conclusions can be drawn. Firstly, within the wide range of international scientific literature reviewed, the effect of infrastructure on growth is inconclusive. However, a majority of the studies do draw a positive link between infrastructure and growth. Secondly, the direction of causality between economic growth and infrastructure also varies. While some studies find unidirectional causality that runs from infrastructure to growth, others find bi-directional causality, implying that infrastructure and growth have a feedback effect. However, Kustepeli *et al*., (2012) finds no causal link between the two variables. Thirdly, infrastructure appears to crowd-in private investment (see section 3.3 for a detailed discussion).

3.2 A South African Perspective

The infrastructure-growth relationship has not received substantial attention in South Africa. According to Fedderke and Garlick (2008), earlier studies done on the subject in South Africa emerged from the mid-1990s, when Abedian and Van Seventer (1995), Coetzee and Le Roux

(1998) and the DBSA (1998) analysed the association between infrastructure investment and growth using OLS estimation techniques. In their study, Abedian and Van Seventer (1995) use public capital stock and GDP per capita as proxies for infrastructure investment and economic growth and find infrastructure to have a positive effect on growth, with output elasticities ranging between 0.17 and 0.33. Similarly, Coetzee and Le Roux (1998) make use of public sector infrastructure stock and GDP per capita variables and obtain a positive output elasticity of 0.30.

The DBSA (1998) employs a Cobb Douglas production function specification to examine the impact of infrastructure on output for the period 1967 – 1996. After controlling for stochastic time trends and capacity utilisation, the report finds a robust positive relationship between public sector infrastructure investment and growth, with output elasticities between 0.25 and 0.30 (Fedderke and Garlick, 2008). The study also finds strong crowding-in effects of infrastructure on private sector investment through the employment of the Engle-Granger cointegration estimation method (Fedderke *et al*., 2006).

In two separate seminal studies analysing the long term trends in the development of South African economic infrastructure between 1875 and 2001, Fedderke *et al*., (2006) and Perkins *et al*., (2005) find that infrastructure significantly drives GDP growth through direct and indirect channels when using VECM and Pesaran, Shin and Smith (PSS) (1996, 2001) ARDL approaches, respectively. Findings suggest bi-directional causality between output and economic infrastructure investment. Moreover, Fedderke *et al*., (2006) find that the elasticity of economic growth with respect to infrastructure investment ranges between -0.06 and 0.20, assuming a 0.06 elasticity at the mean value of investment. For the analysis of both studies, a database established by Perkins (2003) was utilised for various infrastructure indicators:

- Economic infrastructure: gross fixed capital formation in infrastructure and fixed capital stock of infrastructure
- Railways: open railway lines, locomotives, coaching stock, goods stock, carrying capacity of goods stock, passenger journeys and revenue - earning traffic
- Roads: total distance, paved distance, passenger vehicles and commercial
- Ports: cargo handled

- Air travel: passengers carried by South African airways and international passengers passing through South African airports
- Telecommunications: fixed phone, mobile and total phone lines
- Electricity generated

Bogetic and Fedderke (2005) investigate the direct and indirect impact of infrastructure on growth for the 1970 to 1997 period. The study employs the VECM framework on infrastructure measures from Perkins' (2003) database, output, the net export ratio, industry concentration, skills ratio of labour force, ratio of research and development (R&D) expenditure per capita and urbanisation indicators. The study finds that infrastructure influences productivity in South Africa directly as a factor of production and less via the TFP channel. The two measures of economic infrastructure, gross fixed capital formation and fixed capital stock, exhibit both a negative and positive relationship to productivity, respectively. They argue that the negative association between gross fixed capital formation and productivity suggests crowding out effects in respect to private sector labour productivity.

In a study that explores the impacts of economic and social infrastructure on economic growth in South Africa, Kularatne (2006) uses the PSS ARDL and VECM methods to examine the association between infrastructure, gross value added (GVA) and private investment expenditure. Variables used in the study include gross value added per capita, private investment rate, economic and social infrastructure, skills ratio, interest rate, corporate tax and the savings rate. The study creates indices of economic infrastructure using roads and railway and, an index of social infrastructure using schooling. Findings of the study indicate that expenditure on both economic and social infrastructure has a positive and significant effect on growth. According to the results, increase in the investment rate of social infrastructure has a direct effect on GVA, with output elasticities of 0.06, while the economic infrastructure effect is indirect and the economic infrastructure investment rate has a multiplier effect of 1.02 on GVA per capita through private investment. According to the findings, GVA responds to private investment with an elasticity of 2.5, and the private investment rate responds to economic infrastructure spending with an elasticity of 0.02. The author also finds existence of a feedback effect or bidirectional effects on net economic infrastructure investment from per capita GVA and private investment of 10.70 and 0.59 per cent, respectively, suggesting a crowding in of private investment.

Mabugu *et al.*, (2009) provide an analysis of the impact of increasing public infrastructure investment in South Africa. A CGE model of the economy was developed and used to run and quantify the effects of ten per cent simulated increases in water, health, electricity, communications, and roads and transport spending above the indicated baseline. Findings of the analysis reveal that increases in public infrastructure investment, above those budgeted for, increases GDP. In another study, Ngandu, Garcia and Arndt (2010) analyse the economic impact of planned infrastructural investment programme on the South African economy using a multiplier analysis, multiplier decompositions, and structural path analysis. Making use of the social account matrix (SAM) for South Africa from 2003, the analysis results show that planned infrastructure programmes stimulate production activities and households at all income levels.

More recently, Mbanda and Chitiga (2013) perform a dynamic CGE analysis to investigate the impacts of increasing public economic infrastructure investment on economic growth and employment in South Africa, financing infrastructure investment through a government deficit, direct tax on firms and thirdly, a combination of both. Variables used for the model capture factors such as economic infrastructure, economic growth, unemployment, the wage rate, labour demand, formal and informal labour and spill over effects. Findings of the study reveal that increasing public infrastructure investment has an overall positive impact on the economy. The study indicates that increasing public infrastructure investment also increases, among other things, GDP and employment in South Africa regardless of which method is used to fund infrastructure investment increases. The study further finds that private investment suffers crowding out effects.

In a study that examines the relationship between government expenditure and economic growth for the period 1980 to 2011, Gadinabokao and Daw (2013) find that public capital does not contribute to growth in South Africa. The study uses OLS regression, cointegration, error correction model (ECM), and Granger causality techniques to perform the analysis on variables including GDP, total general government expenditure, and gross fixed capital formation by general government on construction works as proxy for public capital. Estimation results show that the coefficient of -0.02 for public capital has no impact on economic growth in the short run. However, in the long run, public capital is found to have a statistically significant negative relationship on economic growth. There is sufficient evidence to suggest a unidirectional causal link that runs from public capital to economic growth. These results imply that a crowding out effect is present.

Kumo (2012) finds a bi-directional relationship between economic infrastructure investment and economic growth when conducting a pairwise Granger causality test between economic growth, economic infrastructure investment, and employment in South Africa for the period 1960 to 2009 using bivariate VAR, VECM and ARDL approaches. The variables in question were economic infrastructure investment as measured by total public sector fixed capital formation, economic growth as measured by GDP, and public and private sector employment. A long and short run analysis with additional variables through the use of ARDL approaches indicates the presence of a steady-state long run equilibrium relationship between economic growth, economic infrastructure, formal employment and exports and imports of goods and services. Kumo (2012) concludes that economic infrastructure drives the long run economic growth and employment in South Africa; however, contrary to Mbanda and Chitiga (2013) and Gadinabokao and Daw (2013), he finds evidence of a strong private sector investment crowd-in effect as a result of economic infrastructure investment.

Although there is a paucity of South Africa literature on the impact of infrastructure on growth, there is strong evidence of a positive infrastructure impact on growth in the studies reviewed. However, one cannot disregard the negative relationship found in Bogetic and Fedderke (2005) and Gadinabokao and Daw (2013) whose findings suggest that the impact of public sector infrastructure investment on growth varies in South Africa. Notably, South African literature finds both direct and indirect impact of infrastructure. Fedderke and Bogetic (2006) argue that such vague and contradictory results are possibly due to: the crowding out of private investment by public sector investment; non-linearities generating the possibility of infrastructure overprovision; the simultaneity between infrastructure provision and growth; the possibility of multiple channels of influence between infrastructure and productivity improvements. They show that by controlling for the possibility of endogeneity in infrastructure estimation eliminates almost all evidence of unclear impacts of infrastructure and results in a positive and economically meaningful impact of infrastructure capital on TFP.

3.3 Synthesis

There is a plethora of literature, specifically, international scientific work on the impact of infrastructure investment on economic growth. From the international and South African review, it is quite evident how mixed the findings are on the subject matter, with a substantial number of studies that find a positive correlation between infrastructure investment and economic growth. While some studies report public infrastructure investment as having a favourable impact on economic growth, a few find no contributory role of infrastructure. Interestingly, within the body of literature that indicates a positive impact of infrastructure investment, there are also moderate differences in the magnitude of its impact, indicated by the extent to which growth responds to infrastructure investment.

Literature dedicated to examining the economic impact of both economic and social infrastructure is limited, with most studies leaning towards examining only the effect of economic infrastructure on growth. See for example, Estache *et al*., (2012), Esfahani and Ramirez (2003), Fedderke *et al*., (2006), Mbanda and Chitiga (2013), Moreno *et al*., (2003), Kumo (2012), Kustepeli *et al*., (2012) and, Yu and Mi (2012). Certain studies – specifically, Badalyan *et al*., (2014), Coetzee and Le Roux (1998), DBSA (1998), Demetriades and Mamuneas (2000), Gutierrez (2005), Rodriguez-Pose *et al*., (2012), Sturm *et al*., (1999) - examine the broad infrastructure indicator that encompasses both types of infrastructure. However, this method makes it almost impossible to determine the type of infrastructure that has the most impact on growth.

For those studies that consider both economic and social infrastructure[4], for instance, Bougheas *et al*., (2000), Dash and Sahoo (2010), Demurger (2001), Fedderke and Kaya (2013), Kularatne (2006), Munnell (1990b), Nketiah-Amponsah (2009), Pooloo (2009); the literature is not conclusive on their separate effects on growth, while there is general consensus that economic infrastructure plays a significant role in determining growth. However, the social infrastructure impact is not as clear-cut. For example, while Munnell (1990b) and Fedderke and Kaya (2013) find no social infrastructure role in economic growth, Kularatne (2006), Calderon and Serven (2002; 2008), Kamara (2007), Sahoo *et al*., (2012) find that social infrastructure has a positive and significant impact on growth, Nketiah-Amposah (2009), Milbourne *et al*., (2003) and, Mastromarco and Weitek (2006) find varied results depending on indicators used for the different classifications of social infrastructure. It is indisputable that the infrastructure-growth relationship has an important implication for policy, however, recognising and understanding the causal link between infrastructure investment and growth, and the effect that infrastructure has on private sector investment is just as essential for the purpose of understanding the complex interactions in an emerging economy like that of South Africa's, which will provide insights for other similar types of emerging market economies.

3.3.1 Causality

As noted by Gujarati (2004: 696), "although regression analysis deals with the dependence of one variable on other variables, it does not necessarily imply causation. In other words, the existence of a relationship between variables does not prove causality or the direction of influence". Such a statement may arguably imply that merely determining the relationship between infrastructure and growth may not be enough for policy purposes. In that regard, a review of the direction of causality is warranted.

[4] Human capital is considered social infrastructure in this context although not explicitly referred in that manner in most studies except, Dash and Sahoo (2010), Kularatne (2006) and, Sahoo *et al*., (2012).

For studies reviewed that consider causality in their analysis, the causal link between infrastructure an growth is mixed, however, there is a much stronger indication of a bi-directional causal link between these variables in both local and international studies (see, for example, Canning and Pedroni, 1999; Babatunde *et al*., 2012; Badalyan *et al*., 2014; Fedderke *et al*., 2006; Kumo 2012; Perkins *et al*., 2005). This finding implies that both these variables are a result of one another; as the economy expands, infrastructure investment will also rise, resulting in a further expansion of the economy. In contrast, Dash and Sahoo (2010), Gadinabokao and Daw (2013) and Sahoo *et al*., (2012) find evidence of a unidirectional causal relationship that suggests that it is infrastructure investment instead that causes economic growth, while Nketiah-Amponsah (2009) finds that economic growth Granger causes infrastructure investment. Interestingly, Kustepeli *et al*., (2012) find no causal link between them.

3.3.2 Crowding-in Vs. Crowding-out of Private Investment

Economic theory suggests that infrastructure investment may either complement or substitute private production. According to Belloc and Vertova (2006), public and private investment have a complementary relationship if infrastructure has a positive impact on private sector investment, in which case, the crowding-in hypothesis holds. However, should infrastructure investment adversely affects private investment, the crowding-out hypothesis would hold, implying that public and private capital are substitutes. International studies reviewed find evidence that infrastructure investment crowds-in private investment, see for example, Ahmed *et al*., (2013); Belloc and Vertova (2006); Ferreira and Araujo (2007); Heintz *et al*., (2009); Mamatzakis (2003); Pooloo (2009) and Wang (2002). However, for South African studies, the crowding-in effect does not appear to hold as strongly. While findings by Fedderke and Bogetic (2006), Kumo (2012) and Kularatne (2006) show evidence of a crowding-in effect, Bogetic and Fedderke (2005), Mbanda and Chitiga (2013) and Gadinabokao and Daw (2013) find that infrastructure investment crowds-out private sector investment.

According to Fedderke and Garlick (2008), Gramlich (1994), Romp and de Haan (2007) and Yu and Mi (2012), mixed results on the subject matter can be attributed to methodology issues such as: the use of different data (regional vs. national); infrastructure definitions; difficulty in the measurements and selection of variables; varying estimation techniques; development stages of economies; and different geographic scales of analysis. These issues are discussed below.

3.3.3 Methodological Issues

As noted in the previous chapter, there is no consensus on the definition of infrastructure and this very fact makes the analysis of infrastructure effects on the economy a challenge. According to Gramlich (1994), most econometric studies on infrastructure have used the narrow public infrastructure definition which only incorporates public sector economic infrastructure as an explanatory variable. The exclusion of social infrastructure and the contribution by the private sector variables is said to be mainly due to difficulties that arise in efforts to measure and distinguish between human capital investment expenditure from consumption spending and the infrastructure investment contribution from the private and public sector investments, as well as simply because of the unavailability of relevant data.

Another challenge in such an analysis is the measurement technique used to capture the public infrastructure investment variable. One of the commonly used indicators for infrastructure is public sector capital stock in monetary terms; see Ahmed *et al*., (2013), Belloc and Vertova (2006), Gadinabokao and Daw (2013), Kamps (2006) and, Kumo (2012). Pritchett (1996), Sanchez-Robles (1998) and Gramlich (1994) argue that there are several problems with using monetary values to calculate the stock of public capital as prices for infrastructure capital vary widely across countries and may give little indication of the efficiency of public sector infrastructure investment. This implies that public capital stock series constructed on the basis of investment series will tend to be overvalued (Romp and de Haan, 2007). In addition, Estache and Garsous (2012) argue that the use of public capital underestimates the impact of infrastructure.

Given these measurement problems when defining infrastructure and using monetary expenditure value problems, many recent studies have employed some physical measure of infrastructure when analysing its impact on economic growth. These studies have used proxies such as the number of kilometers of paved roads, kilowatts of electricity generating capacity, and the number of telephones to capture economic infrastructure and indicators such as years of schooling and secondary and primary school enrollment rate for social infrastructure; see Bougheas *et al*., (2000), Calderon and Serven (2002; 2008), Egert *et al*., (2009), Estache *et al*., (2012), Perkin *et al*., (2005), Sahoo *et al*., (2012) and Vidyattama (2010). However, Romp and De Haan (2007) argue that simple physical measures do not provide clarity, particularly on infrastructure investments made by the public and private sector. Moreover these measures do not correct for quality. For example, Munnell (1990b) explains that the lack of impact of social infrastructure on growth could possibly be due to an indicator problem, noting that the stock of buildings devoted to, say, education may not be the best indicator of the quality of educational services and instead that teachers' salaries, could be a better measure.

According to Fedderke and Garlick (2008), varying results are also heavily dependent on statistical techniques that control for the possibility of a bi-causal relationship between infrastructure and productivity. In the absence of these controls, a substantial number of these measures and indicators have insignificant or negative relationships to productivity measures. Estache and Garsous (2012) argue that the magnitude of the impact of infrastructure will depend on the development stage of a country, the type of infrastructure that is invested and the stock of existing infrastructure. They argue that for a developing country, the return on infrastructure investment is expected to be higher relative to that of a developed economy. Similarly, the geographical characteristic of regions and countries is also as important and could help determine the type of infrastructure needed for growth stimulation.

3.3.4 Theoretical Framework Model Issues

In most of the literature it is normally assumed that public sector infrastructure capital enters the aggregate production function, generally written as a Cobb-Douglas function, as an input. According to Romp and de Haan (2007), an alternative would be to incorporate public infrastructure provision into the production function as part of the technological constraint that determines total factor productivity. A major problem in estimating a production function is argued to be the potential for reverse causation. Munnell (1992) suggests that this shortcoming can be overcome by correcting for stationarity, testing for cointegration and conducting causality tests. Other approaches that have been followed include estimating panel models, estimating simultaneous equation models, and using IV and GMM. A few studies also present cost function models and more recently, the VAR framework has been widely used by academics to examine the contribution of infrastructure to economic growth (Kamps, 2006).

3.4 Conclusion

This chapter undertook a critical review of scientific literature on the impact of infrastructure on growth internationally and in South Africa. Empirical literature suggests that the estimates of the impact of infrastructure investment on economic growth are mixed. A majority of the literature states that there is a positive impact, while some argue against such a finding due to evidence of either a negative or insignificant impact. Since causality between infrastructure and growth, and the reaction of the private sector to infrastructure investment also bears important policy implications, conclusions on these factors were also reviewed. From this review, it was established that the causal link between infrastructure and growth varies. However, there is a much stronger indication of a bi-directional causal link between infrastructure and growth in both local and international studies. In terms of the impact of investment in infrastructure on private investment, international literature suggests that there is a crowding-in effect, but for the South African case, evidence on the effect of infrastructure on private investment varies.

As noted in the review, infrastructure-related literature is limited on South Africa. There are still issues that have not been entirely addressed, such as consideration of the impact of both economic and social infrastructure on growth and private investment, and their causal relationships. The analysis of these issues is crucial due to their implication for policy and achieving the development goals set out in the NDP for 2030. To bridge these gaps, this research follows closely the work of Kumo (2012) and Sahoo *et al*., (2012) and extends the econometric techniques and adapts some of the economic variables employed.

CHAPTER FOUR

METHODOLOGY AND MODEL SPECIFICATION

4.0 Introduction

As outlined in chapter one, the main objective of this study is to provide a comprehensive assessment of both the short and long run impact of government economic and social infrastructure investment on South African economic growth for the period 1983 to 2013. The study does so by analysing annual time series data using EViews 8 and Microfit 5.0 statistical software packages.

In light on the study's objective, this chapter discusses relevant statistical estimation concepts, techniques and the econometric specification of the models to be estimated in chapter five. This chapter is presented in two sections that cover time series statistical estimation methodology and model specification. Under section 4.1, subsection 4.1.1 gives an account of the issues surrounding stationarity, including its definition, spurious regression issues, the procedure for stationarity testing and various types of stationarity tests. Subsection 4.1.2 presents the concept of cointegration analysis. Subsection 4.1.3 explores vector autoregressive modelling techniques, followed by the vector error correction model discussion in subsection 4.1.4. In subsection 4.1.5, an account of the autoregressive distributive lag modelling approach is given.

The model specification of the study is given in section 4.2, which provides an outline of the theoretical framework, presents and describes the variables selected for estimation in chapter five and, their respective sources. Lastly, data issues and transformation are discussed.

4.1 Time Series Methodology

Unlike cross-sectional observations, which are collected at the same point in time, time series data is not independent of time. These observations encompass different values for different time periods (Koop, 2013). In detailed illustrations, Enders (2010) presents the fundamental facts of economic time series data to be:

- Most of the time series have a clear trend.
- Some series seem to wander.
- Any shock to a series displays a high degree of persistence.
- The volatility of many series is not constant overtime.
- Some series share comovement with other series.

According to Gujarati (2004), these properties of the time series data pose several challenges for statistical analysis, such as spurious regressions and autocorrelation. Hence, prior to the statistical analysis of this dissertation, statistical properties underlying the data generating process are explored.

4.1.1 Stationary and Nonstationary in Time Series

Theoretically, a time series is a collection of random variables ordered in time called a stochastic process (Gujarati, 2004; Maddala and Lahiri, 2009). A stochastic process whose mean, variance and autocovariance are constant over time is said to be weakly stationary. In a basic data generating process, suppose the current value of Y depends on its preceding value Y_{t-1} and a white noise error term (random shock) μ_t that is normally distributed with zero mean and variance σ^2, thus:

$$Y_t = \rho Y_{t-1} + \mu_t \tag{4.1}$$

From equation (4.1), conditions of weak stationarity hold when:

Mean: $E(Y_t) = \mu$ (4.2)

Variance: $\text{var}\,(Y_t) = E(Y_t - \mu)^2 = \sigma^2$ (4.3)

Autocovariance: $\gamma k = E[(Y_t - \mu)(Y_{t+k} - \mu)]$ (4.4)

where $E(Y_t)$, and var (Y_t) are constant and finite and (Y_t, Y_{t+k}) are constant for all t and all $k \neq 0$. Another way of describing a stochastic process is to specify the joint distribution of the variables. A stochastic process whose joint probability distribution does not change when shifted in time is defined as being strictly stationary. Under this form of stationarity, parameters such as the mean and variance, if present, also do not change over time or follow any trend. These conditions are given as:

Mean: $E(Y_t) = \mu$ (4.5)

Variance: $\text{var}\,(Y_t) = E(Y_t - \mu)^2 = \sigma^2$ (4.6)

Autocovariance: $\gamma(t_1, t_{1+k}) = \text{cov}\,(Y_{t1}, Y_{t1+k})$ (4.7)

where $k = 0$, the autocovariance is σ^2. Therefore, a time series is said to be strictly stationary if the joint distribution of n observations $Y(t_1), Y(t_2), \ldots, Y(t_n)$ is the same as the joint distribution of $Y(t_1 + k), Y(t_2 + k), \ldots, Y(t_n + k)$ for all n and k.

According to Gujarati (2004), the weak definition of stationary often holds in practice and this dissertation will use this definition when referring to stationarity from here on. A stationary series allows for attainment of meaningful sample statistics crucial for predicting future behaviour. Although a stationary series is desirable, it is not uncommon to encounter a nonstationary time series. A stochastic process is nonstationary if it fails to satisfy any of the above-mentioned conditions. While a stationary time series returns to its mean and fluctuates around it with reasonably constant amplitude, a non-stationary series will have different means at different time segments.

A nonstationary time series is also characterised by a variance that is time-dependent and goes to infinity as time approaches infinity (Engle and Granger, 1987). Consequently, the variance of this variable will become infinitely large as time approaches infinity. Furthermore, the time series disturbances will be perfectly correlated over time, thus indicating the presence of autocorrelation. This will result in a variability of time series mean across the time and the length of the time lapse between the series returning to one of its original mean values. Notably, if the series in a model being investigated is found to be nonstationary, standard estimation techniques cannot be used. Two examples of a nonstationary series is the random walk model, (which can be distinguished into two types; a random walk without drift and a random walk with drift) and the deterministic trend process.

To highlight the principle of a random walk without drift, consider equation (4.8).

$$Y_t = Y_{t-1} + u_t \tag{4.8}$$

where, the current value of Y depends on its preceding value Y_{t-1} and a white noise error term (random shock) u_t with zero mean and variance σ^2. Assuming that the initial value of Y is Y_0, by successive substitution in equation (4.8), it can be shown that:

$$Y_t = Y_0 + \sum u_t \tag{4.9}$$

Therefore,

$$E(Y_t) = E(Y_0) + E(\sum u_t) = Y_0 \tag{4.10}$$

$$\text{var}(Y_t) = t\sigma^2 \tag{4.11}$$

In essence, the mean of Y is equal to its initial value, however, as the time horizon increases indefinitely, the variance of Y also increases indefinitely, making it a nonstationary stochastic process. For a random walk with drift, consider equation (4.12).

$$Y_t = \delta + Y_{t-1} + u_t \tag{4.12}$$

where δ is the drift parameter, an intercept in the random walk model and u_t is the white noise error term. For this type of random walk model, it can be shown in equations (4.13) and (4.14) that both the mean and the variance increase overtime, causing Y to drift away from its initial value and thus violating the conditions of stationarity.

$$E(Y_t) = Y_0 + \delta_t \tag{4.13}$$

$$\text{var}(Y_t) = t\sigma^2 \tag{4.14}$$

A deterministic trend process can be given as:

$$Y_t = \delta + \beta t + u_t \tag{4.15}$$

where u_t is the white noise error term. Under the deterministic trend process, the mean varies while the variance is constant. Nonstationary time series pose various analytical challenges. Firstly, the behaviour of these series can only be studied for the period under consideration. Therefore, it cannot be generalised to explain behaviour in other time periods, thus, rendering it useless for forecasting purposes (Gujarati 2004; 2011). Secondly, the estimation of nonstationary time series may also yield unreliable and spurious regression results (Gujarati 2004, 2011; Koop, 2013; Thomas, 1997). Spurious results arise due to various series exhibiting common long run trends and regression methodologies falsely ascribing these trends as being valid long run relationships between variables without there being any economically justifiable relationships between the series in question. In empirical results, such regressions are characterised by very high values of R^2 and a low Durbin-Watson d-statistic (Asteriou and Hall, 2007; Thomas, 1997). For these underlying reasons it is essential to test for stationarity before any empirical estimation is done to understand the underlying data generating process for application of the suitable methodology.

4.1.1.1 Stationarity Testing

Literature recognises three approaches in which stationarity of a time series can be tested, which are: (1) graphical analysis, (2) correlogram and (3) unit root analysis. This dissertation employs both graphical and unit root analysis testing in chapter five to test for stationarity.

4.1.1.1.1 Graphical analysis

Examining stationarity by means of plotting a time series and its accompanying correlogram before pursuing more formal methods of testing for stationarity is considered to be a prerequisite for any stationarity test as it gives an intuitive feel for the nature of the given series.

4.1.1.1.2 Unit Root tests

Unit root testing is the most commonly used formal approach to examining the nature of time series. Proposed by Dickey and Fuller (1979, 1981), this method involves checking for statistically significant differences of the parameter on Y_{t-1} from equation (4.8). Unit root tests are conducted by running a simple random walk regression such as the one in equation (4.1) for all the time series variables defined in a given econometric model. The aim of the test is to check whether ρ is equal to one (i.e., there is a unit root). The equation can also be written as in (4.16) and (4.17) when Y_{t-1} is subtracted from both sides.

$$Y_t - Y_{t-1} = (\rho - 1)Y_{t-1} + u_t \tag{4.16}$$

$$\Delta Y_t = \delta Y_{t-1} + u_t \qquad (4.17)$$

where $\delta = (\rho - 1)$ and Δ is the first difference operator. Equation (4.17) represents a random walk without a constant and trend. Dickey and Fuller (1979) proposed two substitute regression equations for testing the presence of a unit root:

1. Random Walk with drift: contains a constant but no trend

$$\Delta Y_t = \beta_1 + \delta Y_{t-1} + u_t \qquad (4.18)$$

2. Random Walk with a stochastic trend: contains both a constant and a trend

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + u_t \qquad (4.19)$$

where u_t is the white noise error term and t is the trend variable. One can test for the presence of a unit root, or its lack thereof, through the use of hypothesis testing.

The null and alternative hypotheses are presented as:

H_0: $\delta = 0$ or $\rho = 1$ (i.e., there is a unit root)
H_1: $\delta < 0$ or $\rho < 1$ (i.e., there is no unit root)

Alternatively, these hypotheses can also be written as:

H_0: Y_t is nonstationary (i.e., there is a unit root)
H_1: Y_t is stationary (i.e., there is no unit root)

After estimating equations (4.17), (4.18) and (4.19) using ordinary least squares (OLS), unit root hypothesis testing can be done by comparing the tabulated or electronically generated (by statistical packages) tau (τ) statistic, also known as the Dickey-Fuller (DF) test statistic or "t-

statistic", against the computed τ-statistic found by dividing δ or ρ coefficients by their respective standard errors to obtain $\tau\delta$ or $\tau\rho$. If the computed absolute value of τ exceeds the critical τ-statistic value, the null hypothesis $\delta = 0$ or $\rho = 1$ should be rejected in favour of the alternative, thus, the series is stationary or has no unit root. However, if the computed absolute value of τ does not exceed the critical τ-statistic value, the null hypothesis should not be rejected, thus, the series is nonstationary or has unit root (Gujarati, 2004; 2011). Notably, a more widespread set of critical values may be found in Mackinnon (1991), which is also used by numerous statistical packages, including EViews 8.

The DF test of unit root discussed above is conducted under the assumption that the error terms u_t were uncorrelated. In a case where the u_t are correlated, Dickey and Fuller (1981) extended their test procedure to suggest an augmented version of the test where extra lagged terms of the dependent variable are included in order to eliminate autocorrelation. Similar to the DF test, the three alternative regression equations for testing the presence of a unit root using the augmented Dickey Fuller (ADF) test are:

$$\Delta Y_t = \delta Y_{t-1} + \sum_{i=1}^{m} a_1 \Delta Y_{t-i} + \varepsilon_t \tag{4.20}$$

$$\Delta Y_t = \beta_1 + \delta Y_{t-1} + \sum_{i=1}^{m} a_1 \Delta Y_{t-i} + \varepsilon_t \tag{4.21}$$

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \sum_{i=1}^{m} a_1 \Delta Y_{t-i} + \varepsilon_t \tag{4.22}$$

where ε_t is a pure white noise error term and where $\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$, $\Delta Y_{t-2} = (Y_{t-2} - Y_{t-3})$, etc. The number of lagged differenced terms to be included is often empirically determined by either the Akaike Information Criterion (AIC) or Schwarz Bayesian Criterion

(SBC). As in the case of the DF test, the usual DF τ-statistic is also applicable to the ADF test for the unit root hypothesis testing method discussed.

Another unit root testing procedure that is commonly used is the Phillips-Perron (PP) test. Phillips and Perron (1988) argued that the ADF tests were inadequate for unit root testing in time series and proposed a nonparametric statistical method known as the PP test, which takes into account the serial correlation in the error terms without adding lagged difference terms. To illustrate the PP unit root testing approach, we revisit equation (4.17). Given equation (4.17), the PP test corrects the coefficient δ to account for the correlation in u_t. Thus, the PP test is a generalised version of the DF test statistic that takes into consideration the less restrictive nature of the error process. Just as in DF and ADF tests, the PP test can also be performed by including a constant, constant and trend or neither in a regression. Similarly, the asymptotic distribution of the PP τ-statistic is the same as that of the ADF τ-statistic for the unit root hypothesis testing method (Gujarati, 2004; 2011).

4.1.1.2 Remedial Measures

Owing to problems associated with nonstationary time series, it is very important to transform these series in order to render them stationary. The transformations required to make time series stationary depend on the nature of the series in question (Gujarati, 2004; 2011). If a nonstationary time series is found to contain a deterministic trend, the appropriate transformation method to render the nonstationary time series stationary would be to detrend the series by regressing it on time. Such a series is called a trend stationary process. If a nonstationary time series becomes stationary after differencing, the series is a difference stationary process. Additionally, if a time series is rendered stationary after differencing it once, it is said to be integrated at first order, denoted as $\mathrm{I}(1)$. An $\mathrm{I}(2)$ series contains two unit roots and would require to be differenced twice in order to induce stationarity, however, if it has to be differenced d times to make it stationary, it is said to be integrated of order d, denoted as $\mathrm{I}(d)$ (Asteriou and Hall, 2007; Verbeek, 2004). Consequently, a stationary time series is integrated of zero order (i.e., $\mathrm{I}(0)$) since it does not require any differencing (Gujarati, 2004; 2011). Notably, most empirical statistical methods are based on the assumption that time series data tend to have the property of being $\mathrm{I}(1)$ and upon first differences, are rendered stationary or $\mathrm{I}(0)$.

In light of the significance of stationarity testing, this study will make use of both the ADF and PP tests, however, in a case where the two tests are contradictory, the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test will be used as a confirmatory measure. Generally, the KPSS test is used to assess the null hypothesis that a time series is stationary and often gives results contrary to those of the unit tests with the unit root as a null (DF, ADF and PP tests) (Asteriou and Hall, 2007).

4.1.2 Cointegration

The preceding subsection highlighted the problems that can be incurred with the use of trended or $\mathrm{I}(1)$ time series due to spurious regressions. However, a significant exception arises when all the nonstationary series in a model have the same stochastic trend in common (Kennedy, 2008; Verbeek, 2004). In such a case, the series are said to be cointegrated and OLS regression of the model can be run without the possibility of encountering unreliable and invalid results caused by spurious regressions. The method of cointegration, first introduced by Granger (1981) and elaborated further by Engle and Granger (1987), enables researchers to find sense in estimating non-stationary variables as it specifies that although two (or more) series encompass stochastic trends, if they have a long run equilibrium, or relationship, they will move closer together over time and their differences will eventually stabilise, thus, forming a stationary series (Thomas, 1997). Therefore the spurious regression problem is resolved. Following Asteriou and Hall (2007) and Verbeek (2004), consider two individually $\mathrm{I}(1)$ series, Y_t and X_t, and suppose there is a linear combination of Y_t and X_t.

$$Y_t = \beta_1 + \beta_2 X_t + u_t \tag{4.23}$$

Taking the residuals:

$$\hat{u}_t = Y_t - \hat{\beta}_1 - \hat{\beta}_2 X_t \qquad (4.24)$$

If $\hat{u}_t \sim \mathrm{I}(0)$, i.e., stationary, then Y_t and X_t are cointegrated. Engle and Granger (1987) formally define cointegration by stating that time series Y_t and X_t are $I(d,b)$ where $d \geq b \geq 0$, denoted as Y_t, $X_t \sim CI\ (d,b)$, if Y_t and X_t are $\mathrm{I}(d)$ and there exists a vector (β_1, β_2), which gives a linear combination of Y_t and X_t, such that $\beta_1 Y_t + \beta_2 X_t \sim I(d-b)$. The coefficient vector (β_1, β_2), is called a cointegrating vector.

Asteriou and Hall (2007) and Enders (2010) argue that if Y_t and X_t are cointegrated of different orders then they are unbalanced and cannot be cointegrated. For example, if $Y_t \sim I(0)$ and $X_t \sim I(1)$ then their linear combination will be $I(1)$ for the reason that the behaviour of the $I(1)$ series (X_t) will dominate the behaviour of Y_t, a $I(0)$ series. According to Harris (1995), it is possible to have a mixture of different orders of integration in time series when estimating three or more series. In such a case, a subset of the higher order series must cointegrate to the order of the lower-order series.

Notably, the presence and lack of cointegration between time series variables have implications for the method that can be used to estimate the hypothesised model. In instances where all variables are stationary, $I(0)$, a simple vector autoregressive model (VAR) in levels can be used. In cases where variables are nonstationary and there is no cointegration, the variables can still be used in the VAR model provided that they are differenced to render them stationary before estimation. However, when variables are cointegrated, a vector error correction model (VECM) is the appropriate technique to employ. Should there be both $I(0)$ and $I(1)$ variables, then autoregressive distributed lag (ARDL) methods are used. Generally, most economic time series are $I(1)$ and modelled using VECM techniques. All three methods are discussed below.

4.1.2.1 Testing for Cointegration

According to Kennedy (2008), there are three methods within which cointegration can be tested, namely single equation, vector autoregressive, and error correction approaches. The single equation cointegration approach (which includes tests such as the autoregressive distributed lag bounds testing approach, the Engle-Granger and augmented Engle-Granger, the cointegrating regression Durbin-Watson, the dynamic ordinary least squares, the fully-modified ordinary least squares and canonical cointegrating regressions tests), typically checks for unit roots in the cointegrating regression residuals. The vector autoregressive approach alternatively determines the number of cointegrating relations and estimates the matrix of cointegrating vectors (Johnston and DiNardo (1997). Whereas the error correction approach examines the coefficient of the error correction term against zero, which is a condition of the Granger representation theorem.

According to Enders (2010), the three most important and popular procedures used to test for cointegration are the Engle-Granger (1987), Johansen (1988) and Stock-Watson (1988) methodologies. For the purpose of this study, the fully-modified ordinary least squares, canonical cointegrating regressions, dynamic ordinary least squares, Johansen and the autoregressive distributed lag bounds testing approaches will be used to determine whether a long run relationship exists in the proposed model.

4.1.2.1.1 The Engle-Granger (EG) and Augmented Engle-Granger (AEG) Tests

The main goal of the EG test is to determine whether the series being investigated are cointegrated by examining the properties of the residuals. Should the residuals be stationary, then the series are cointegrated. This test involves firstly verifying the order of integration of each time series variable via unit root testing, specifically the DF and ADF tests. Once this has been established and the variables are found to be integrated of the same order, the hypothesised long run equilibrium or relationship (given in equation (4.25), for example) is then estimated via OLS and the estimated residuals are retained and tested for stationarity. Equations (4.26) and (4.27) respectively present the DF and ADF test equations of the estimated residuals.

$$Y_t = \beta_1 + \beta_2 X_t + e_t \tag{4.25}$$

$$\Delta\hat{e}_t = a_1\hat{e}_{t-1} + v_t \tag{4.26}$$

$$\Delta\hat{e}_t = a_1\hat{e}_{t-1} + \sum_{i=1}^{n} \delta_i \Delta + w_t \tag{4.27}$$

where Δ represents the first difference operator, e_t is the residual from the cointegrating regression, and v_t and w_t represent the random error terms. As in the DF, ADF and PP tests, the hypothesis testing in the EG and AEG tests is conducted in the same manner. The null and alternative hypotheses are presented as:

H_0: $a = 0$ (i.e., no cointegration)
H_1: $a < 0$ (i.e., cointegration exists)

These hypotheses are tested by comparing the test statistic on the regression coefficient a, to a special set of critical values depending on the number of explanatory variables in the cointegrating regression computed by Engle and Granger (1987). If e_t is found to be $I(0)$ then H_0 is rejected in favour of H_1, thus Y_t and X_t are cointegrated.

The EG approach is praised for its simplicity, however, this method contains a few shortcomings (Asteriou and Hall, 2007; Gujarati, 2011; Koop, 2013; Maddala and Lahiri, 2009; Thomas, 1997). The EG approach has low power in finite samples and may be misleading if structural breaks are present in the data. Another problem of this approach is that an error made in the first step of the EG test is carried on to the second step, thus resulting in autocorrelation and therefore the long run relationship estimates will be biased in finite samples. These drawbacks can be addressed with the use of alternative approaches, some of which are employed by the study and discussed in the subsequent subsections.

4.1.2.1.2 The Fully Modified Ordinary Least Squares (FMOLS) Test

This cointegration method by Philips and Hansen (1990) assumes the existence of a single cointegrating vector and involves adjusting OLS estimates of both long run parameters and their associated t-values to accommodate for any bias owing to autocorrelation and endogeneity problems present in OLS residuals (Harris, 1995; Harris and Sollis, 2003; Phillips and Hansen, 1990). Consequently, the resulting estimator is asymptotically unbiased and has fully efficient normal asymptotical properties allowing for the use of standard Wald tests using asymptotic chi-square (χ^2) statistical inference (Belke and Czudaj, 2010). Following Belke and Czudaj (2010), consider the following (y_t, X_t') vector process:

$$y_t = X_t'\beta + D_t'\gamma_1 + u_{1t} \tag{4.28}$$

where y_t is the $I(1)$ dependent variable and X_t' denotes the stochastic regressors governed by $X_t = \Gamma_{21}' D_{1t} + \Gamma_{22}' D_{2t} + \varepsilon_{2t}$ with $\Delta\varepsilon_{2t} = u_{2t}$. Moreover, $D = (D_{1t}', D_{2t}')$ are the deterministic trend regressors and u_{1t} is error term with zero mean and covariance (Ω). The FMOLS estimator is therefore given by:

$$\hat{\theta}_{FMOLS} = \begin{bmatrix} \hat{\beta} \\ \hat{\gamma}_1 \end{bmatrix} = \left[\sum_{t=1}^{T} Z_t Z_t'\right]^{-1} \left[\sum_{t=1}^{T} Z_t y_t^{+} - T\begin{bmatrix} \hat{\lambda}_{12} \\ 0 \end{bmatrix}\right] \tag{4.29}$$

where $Z_t = (X_t', D_t')'$, $y_t^{+} = y_t - \widehat{\omega}_{12}\widehat{\Omega}_{22}^{-1}\hat{u}_2$ signifies the transformed data and $\hat{\lambda}_{12}^{+} = \widehat{\omega}_{12}\widehat{\Omega}_{22}^{-1}\widehat{\Lambda}_{22}$ represents the estimated bias correction term with the long-run covariance matrices $\widehat{\Omega}$ and $\widehat{\Lambda}$ and their respective elements, which are computed using $u_t = (\hat{u}_{1t}', \hat{u}_{2t}')'$.

4.1.2.1.3 Canonical Cointegrating Regressions (CCR)

The CCR estimation method, developed by Park (1992), is a non-parametric approach for statistical inference in a cointegrated model involving adjustments of the integrated processes using only stationary components to account for long run correlation between regressors and the error term. According to Han (1996), this method yields asymptotically efficient estimators and χ^2 inference. Drawing from equation (4.28), the CCR estimator is defined as:

$$\hat{\theta}_{CCR} = \begin{bmatrix} \hat{\beta} \\ \hat{\gamma}_1 \end{bmatrix} = \left[\sum_{t=1}^{T} Z_t^* Z_t^{*\prime} \right]^{-1} \sum_{t=1}^{T} Z_t^* y_t^* \tag{4.30}$$

where $Z_t^* = (X_t^{*\prime}, D_t')'$, $X_t^t = X_t - (\hat{\Sigma}^{-1}\hat{\Lambda}_2)'\hat{u}_t$ and $y_t^* = y_t - \left[\hat{\Sigma}^{-1}\hat{\Lambda}_2\tilde{\beta} + \begin{bmatrix} 0 \\ \hat{\Omega}_{22}^{-1}\hat{\omega}_{21} \end{bmatrix} \right]' u_t$ represents the transformed data. The $\tilde{\beta}$ coefficients are estimates of the cointegrating equation applying static OLS. $\hat{\Lambda}_2$ is the second column of $\hat{\Lambda}$ (the estimated bias correction term), and $\hat{\Sigma}$ denotes the estimated contemporaneous covariance matrix of the error terms.

4.1.2.1.4 The Dynamic Ordinary Least Squares (DOLS) Test

The DOLS test is another alternative to the EG approach suggested by Stock and Watson (1993). The test is a parametric method in which the lagged first difference terms are explicitly estimated (Saayman, 2010). It extends the cointegrating regression by augmenting the errors with leads, lags and contemporaneous values of the regressors (ΔX_t) (Saayman, 2010), such that the new cointegrating equation error term is orthogonal to the entire history of the stochastic regressor innovations (Belke and Czudaj, 2010). The DOLS results in a more powerful test for cointegration and gives unbiased estimates of the long-run relationship (Harris, 1995; Harris and Sollis, 2003). According to Belke and Czudaj (2010), this method assumes that the added q lags and r leads of ΔX_t (exemplified in equation (4.31)), completely eliminate the long run correlation between error terms, u_{1t} and u_{2t}.

$$y_t = X_t'\beta + D_t'\gamma_1 + \sum_{j=-q}^{r} \Delta X_{t+j}'\delta + v_{1t} \tag{4.31}$$

The DOLS estimator of the equation is hence given by $\hat{\theta}_{DOLS} = (\hat{\beta}', \hat{\gamma}_1')'$.

In all the above-discussed single equation approaches, when variables in a regression model are found to be cointegrated through the use of hypothesis testing (as demonstrated in subsection 4.1.2.1.1), the long run relationship between them can be estimated by the cointegrating regression. In these circumstances, OLS estimation would yield superconsistent estimators of the long run parameters (Enders, 2010). Conversely, a drawback of these approaches arises due to their lack of systematic procedures to separately estimate multiple cointegrating regressions when there are more than two variables in a model. According to Harris and Sollis (2003), assuming that there is only one cointegration vector when there actually is more than one, leads to inefficiency as only a linear combination of these vectors can be obtained.

4.1.2.1.5 The Johansen Test

Since having more than two variables in a model constitutes the possibility of having more than one cointegrating relationship, an approach that allows the simultaneous evaluation of multiple relationships is needed, and the Johansen approach does just that. This approach, developed by Johansen (1988) and extended by Johansen and Juselius (1990, 1992, 1994), tests for the cointegration rank for a VAR process via likelihood ratio tests. The Johansen cointegration approach imposes no prior restrictions on the cointegration space and allows hypothesis testing to be performed directly on the cointegrating relationships (Kennedy, 2008).

As with the EG approach, the Johansen test begins by verifying the order of integration of each time series variable under investigation through unit root testing. When all variables are found to be cointegrated of the same order, the next step is to select the optimal lag length, which is generated by either a battery of lag length criteria such as the AIC or SBC criteria in practice via a VAR model estimation. Thirdly, determining the appropriate model regarding the deterministic component in the multivariate system and determine the rank of the number of cointegrating vectors by using the likelihood ratio tests (Asteriou and Hall, 2007; Enders 2010).

Johansen (1988) proposes the trace and maximum eigenvalue likelihood ratio tests to determine the significance of these canonical correlations. These test statistics are formulated as:

$$\lambda_{trace}\,(r) = -T \sum_{i=r+1}^{n} \ln(1 - \hat{\lambda}_i) \tag{4.32}$$

$$\lambda_{max}\,(r, r+1) = -T \ln(1 - \hat{\lambda}_{r+1}) \tag{4.33}$$

where λ is the estimated value for the ith ordered eigenvalue from the long run coefficient matrix and T is the number of usable observations. The λ_{trace} statistic tests the null hypothesis that the number of cointegrating vectors is less than or equal to r (the number of cointegrating relationships) against an unspecified alternative hypothesis. Alternatively, the λ_{max} statistic tests the null hypothesis that the number of cointegrating vectors is r against an alternative of $r + 1$ cointegrating vectors. The further the eigenvalues are from zero, the more negative is $\ln(1 - \hat{\lambda}_i)$ and $\ln(1 - \hat{\lambda}_{r+1})$ and the larger the λ_{trace} and λ_{max} statistics, respectively. The trace test is believed to be superior as it can be adjusted for degrees of freedom and it is more robust to skewness and excess kurtosis.

For a mathematical illustration of how the Johansen approach works, assume that there are three endogenous $I(1)$ variables Y_t, X_t and W_t, of which the matrix notion for $Z_t = (Y_t, X_t, W_t)$ is:

$$Z_t = A_1 Z_{t-1} + A_2 Z_{t-2} + \ldots + A_k Z_{t-k} + \mathrm{u}_t \quad (4.34)$$

where Z_t is a $k \times 1$ vector for endogenous variables, A_i is a $k \times k$ matrix parameters and u_t is a vector of independently and identically distributed innovations with zero mean.
The vector error correction model (see the vector error correction model discussion on subsection 4.1.4) formulation for Z_t is given as:

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \Gamma_2 \Delta Z_{t-2} + \ldots + \Gamma_{k-1} \Delta Z_{t-k+1} + \Pi Z_{t-1} + \mathrm{u}_t \quad (4.35)$$

where $\Gamma_i = -(I - A_1 - A_2 - \ldots - A_k)$ $(i = 1,2,\ldots,k-1)$ and $\Pi = -(I - A_1 - A_2 - \ldots - A_k)$. This specification contains information on the short and long run adjustments to changes in Z_t. Thus, Γ_i are the 3×3 coefficient matrix describing the short run dynamic effects and Π is the long run multiplier that holds information regarding long run relationships. We can decompose $\Pi = \alpha\beta'$ where a will include the speed of adjustment to equilibrium coefficients, while β' is a matrix of long run coefficients such that the term $\beta' Z_{t-k}$ embedded in equation (4.35) represents up to $k-1$ cointegration relationships which ensure that Z_t converges to its long run equilibrium (Harris, 1995).

Asteriou and Hall (2007) and Harris (1995) state that if Π has a full rank (i.e., $r = n$ linearly independent columns), Y_t, X_t and W_t are $I(0)$. If Π has a reduced rank (i.e., $r \leq (n-1)$ linearly independent columns), there are $r \leq (n-1)$ cointegrating relationships. Lastly, when the rank Π is zero, which implies that there are no linearly independent columns, then there are no cointegrating relationships. Normally, Π has a reduced rank and when there are multiple cointegrating vectors, then there exists a cointegrating vector for each subset of $n - r + 1$

variables and the cointegrating vectors become slightly difficult to interpret. To demonstrate, assume that $r = 2$, the model in equation (4.35) becomes:

$$\Pi_1 Z_{t-1} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \\ a_{31} & a_{32} \end{bmatrix} \begin{bmatrix} \beta_{11} & \beta_{21} & \beta_{31} \\ \beta_{12} & \beta_{22} & \beta_{32} \end{bmatrix} \begin{bmatrix} Y_{t-1} \\ X_{t-1} \\ W_{t-1} \end{bmatrix} \tag{4.36}$$

thus,

$$= \begin{bmatrix} a_{11}ec_1 & a_{12}ec_2 \\ a_{21}ec_1 & a_{22}ec_2 \\ a_{31}ec_1 & a_{32}ec_2 \end{bmatrix} \tag{4.37}$$

where $ec_1 = (\beta_{11}Y + \beta_{21}X + \beta_{31}W)_{t-1}$ and $ec_2 = (\beta_{12}Y + \beta_{22}X + \beta_{32}W)_{t-1}$ are the two cointegrating vectors and their respective speed of adjustment terms are given by a_{11}, a_{12}, a_{21} a_{22}, a_{31} and a_{32}. Although widely used, this approach is also not without fault. The Johansen approach faces a drawback in that parameter estimates in one equation are affected by misspecifications in other equations.

4.1.3 Vector Autoregressive (VAR) Models

VAR methodology is frequently used in macroeconomic time series analysis due to its ability to handle simultaneous-equation models. According to Sims (1980), in instances where there is simultaneity among variables (i.e., variables in a model are explained by the variables they are used to determine), there should not be any distinction between endogenous and exogenous variables. Thus, all variables are treated as endogenous and each equation should have an equal number of regressors, leading to the development of the VAR approach (Asteriou and Hall, 2007; Gujarati, 2004; 2011; Verbeek, 2004). VAR is mainly used to establish the short run relationship among variables and, as noted in the previous sub-section this method is ideal to use if all variables are stationary. If some of the variables contain unit roots, then the ones with unit roots should be differenced and the resulting stationary variables can be used in a VAR model (Koop, 2013). Conversely, Sims (1980) argued against differencing nonstationary variables as it leads to a loss of co-movement information within the data. He added that differencing could be a futile exercise because the goal of VAR analysis is to examine interrelationships among variables and not the parameter estimates. Enders (2010) concurs with this notion only when a structural or primitive model is under investigation.

Following Enders (2010), assume that a model is made up of two $I(0)$ variables, Y_t and X_t, where Y_t is affected by current and past values of X_t and concurrently, X_t is affected by current and past values of Y_t, the bivariate equations model is given by:

$$Y_t = \beta_{10} - \beta_{12}X_t + \gamma_{11}Y_{t-1} + \gamma_{12}X_{t-1} + u_{Yt} \quad (4.38)$$

$$X_t = \beta_{20} - \beta_{21}Y_t + \gamma_{21}Y_{t-1} + \gamma_{22}X_{t-1} + u_{Xt} \quad (4.39)$$

where Y_t and X_t are stationary, and u_{Yt} and u_{Xt} are uncorrelated white noise terms. Both equations constitute a first-order VAR model since the longest lag is in unity. These equations are also said to be structural or primitive VAR equations as Y_t and X_t have simultaneous impacts on each other respectively, given by $-\beta_{12}$ and $-\beta_{21}$. Using matrix algebra, equations (4.38) and (4.39) can be written as:

$$\begin{bmatrix} 1 & \beta_{12} \\ \beta_{21} & 1 \end{bmatrix} \begin{bmatrix} Y_t \\ X_t \end{bmatrix} = \begin{bmatrix} \beta_{10} \\ \beta_{20} \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix} \begin{bmatrix} Y_{t-1} \\ X_{t-1} \end{bmatrix} + \begin{bmatrix} u_{Yt} \\ u_{Xt} \end{bmatrix} \quad (4.40)$$

or

$$\mathrm{B}Z_t = \Gamma_0 + \Gamma_1 Z_{t-1} + u_t \quad (4.41)$$

Because Y_t and X_t are correlated with their respective errors u_{Yt} and u_{Xt} in equations (4.38) and (4.39), they do not meet the standard estimation techniques requirement necessitating that the regressors be uncorrelated with the error term, and in order to be estimated, restrictions must be imposed. Suppose a restriction that $\beta_{21} = 0$ is imposed, which implies Y_t does not have a concurrent effect on X_t, B^{-1} is given by:

$$\mathrm{B}^{-1} = \begin{bmatrix} 1 & -\beta_{12} \\ 0 & 1 \end{bmatrix} \quad (4.42)$$

Premultiplying the original VAR by B^{-1} yields:

$$\begin{bmatrix} Y_t \\ X_t \end{bmatrix} = \begin{bmatrix} \beta_{10} - \beta_{12}\beta_{20} \\ \beta_{20} \end{bmatrix} + \begin{bmatrix} \gamma_{11} - \beta_{12}\gamma_{21} & \gamma_{12} - \beta_{12}\gamma_{22} \\ \gamma_{21} & \gamma_{22} \end{bmatrix} \begin{bmatrix} Y_{t-1} \\ X_{t-1} \end{bmatrix} + \begin{bmatrix} u_{Yt} - \beta_{12}u_{Xt} \\ u_{Xt} \end{bmatrix} \tag{4.43}$$

Consequently, estimating the system (4.43) using OLS yields:

$$Y_t = a_{10} + a_{11}Y_{t-1} + a_{12}X_{t-1} + e_{1t} \tag{4.44}$$

$$X_t = a_{20} + a_{21}Y_{t-1} + a_{22}X_{t-1} + e_{2t} \tag{4.45}$$

where $a_{10} = \beta_{10} - \beta_{12}\beta_{20}$; $a_{11} = \gamma_{11} - \beta_{12}\gamma_{21}$; $a_{12} = \gamma_{12} - \beta_{12}\gamma_{22}$; $a_{20} = \beta_{20}$; $a_{21} = \gamma_{21}$; $a_{22} = \gamma_{22}$. In equation (4.43), the $\beta_{21} = 0$ restriction allows shocks of both u_{Yt} and u_{Xt} to simultaneously affect Y_t, however, only u_{Xt} shocks affects the contemporaneous value of X_t. To obtain the VAR model in standard form, which requires no restriction for estimation, both sides of equation (4.41) are multiplied by B^{-1}, yielding equation (4.44) and (4.45) or simply:

$$Z_t = A_0 + A_1Z_{t-1} + e_t \tag{4.46}$$

where $A_0 = \mathrm{B}^{-1}\Gamma_0$, $A_1 = \mathrm{B}^{-1}\Gamma_1$ and $e^t = \mathrm{B}^{-1}u_t$.

It should be noted that the renditions presented above were accomplished on the basis of a bivariate first order VAR model purely for explanatory purposes. This study will, however, employ a five-variable second order VAR model given in subsection 4.2.

4.1.3.1 Impulse Response Function (IRF)

This study employs the impulse response function to graphically examine how economic growth reacts to infrastructure investment in the short run. The IRF inspects how the dependent variable in the VAR model reacts to shocks in the error terms. More generally, it demonstrates the path at which macroeconomic variables diverge from and converge to their equilibrium point within a specific period as shocks occur in the economy (Enders, 2010). What is desirable about the IRF is it allows for the response analysis of each shock to each variable in the model, holding other shocks and variables constant. To illustrate the IRF, consider the structural model analysed in the previous subsection. Following the work of Enders (2010) and writing equations (4.44) and (4.45) in matrix form, we get:

$$\begin{bmatrix} Y_t \\ X_t \end{bmatrix} = \begin{bmatrix} a_{10} \\ a_{20} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} Y_{t-1} \\ X_{t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \tag{4.47}$$

One must impose an additional restriction in order to identify the IRF through matrix algebra; hence equation (4.47) can be expressed in terms of e_{1t} and e_{2t}; and u_{Yt} and u_{Xt} sequences respectively as:

$$\begin{bmatrix} Y_t \\ X_t \end{bmatrix} = \begin{bmatrix} \bar{Y}_t \\ \bar{X}_t \end{bmatrix} + \sum_{i=0}^{\infty} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}^i \begin{bmatrix} e_{1t-i} \\ e_{2t-i} \end{bmatrix} \tag{4.48}$$

$$\begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} = [1/(1-\beta_{12}\beta_{21})] \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} u_{Yt} \\ u_{Xt} \end{bmatrix} \tag{4.49}$$

The moving average presentation of equations (4.48) and (4.49) can be written in terms of u_{Yt} and u_{Xt} sequences as:

$$\begin{bmatrix} Y_t \\ X_t \end{bmatrix} = \begin{bmatrix} \bar{Y}_t \\ \bar{X}_t \end{bmatrix} + \sum_{i=0}^{\infty} \begin{bmatrix} \Phi_{11}(i) & \Phi_{12}(i) \\ \Phi_{21}(i) & \Phi_{22}(i) \end{bmatrix} \begin{bmatrix} u_{Yt-i} \\ u_{Xt-i} \end{bmatrix} \tag{4.50}$$

or

$$Z_t = \mu + \sum_{i=0}^{\infty} \Phi_i \, u_{t-i}$$

(4.51)

The impact multipliers or impact response functions of the above-specified moving average equations are given by Φ_{11}, Φ_{12}, Φ_{21} and Φ_{22}. Thus, immediate responses of a unit change in u_{Yt} and u_{Xt} on Y_t are given by $\Phi_{11}(0)$ and $\Phi_{12}(0)$, respectively. Likewise, five year period responses of a unit change in u_{Yt-5} and u_{Xt-5} on X_t, would be given by $\Phi_{21}(5)$ and $\Phi_{22}(5)$, respectively. Therefore, after n periods, the cumulated sum of the effects of u_{Yt} on the X_t sequence is given as:

$$\sum_{i=0}^{n} \Phi_{21}\,(i)$$

(4.52)

Letting n approach infinity yields the long run multiplier:

$$\sum_{i=0}^{\infty} \Phi_{jk}^{2}\,(i)$$

(4.53)

Plotting the impulse response functions is a practical way of visually representing the behaviour on the Y_t and X_t series in response to various shocks. However, for a primitive model an estimated VAR is under-identified, thus there is a need to impose an additional restriction to the VAR system in order to identify the impulse responses by using the Cholesky decomposition, which EViews 8 software automatically generates.

4.1.3.2 Variance Decomposition

Variance decomposition is concerned with the conditional variance of the impulse response presented in the previous subsection. It assists with the interpretation of an estimated VAR model by explicitly specifying the proportion at which each variable's forecast errors can be explained by its own shocks against exogenous shocks to other variables in a regression model. Enders (2010) argues that while unrestricted VARs are expectedly overparameterised, it is of great significance to understand the properties of forecast errors in identifying interrelationships among variables in a regression model. Given the statistical efficacy of variance decomposition, the study will make use of it to examine how infrastructure investment impacts on economic growth. To demonstrate the theoretical underpinnings of this mechanism suppose that the matrix coefficients of A_0 and A_1 in equation (4.46) are known and we want to forecast the values of Z_{t+1} conditional on the identified value of Z_t. Updating the equation by one period, for illustration, (i.e., $Z_{t+1} = A_0 + A_1 Z_t + e_{t+1}$) and taking the conditional expectation of Z_{t+1} yields:

$$E_t Z_{t+1} = A_0 + A_1 Z_t \qquad (4.54)$$

Therefore, the one-step-ahead forecast error is given by $Z_{t+1} - E_t Z_{t+1} = e_{t+1}$. Consequently, if equation (4.51) in the previous subsection to conditionally forecast Z_{t+1}, the one-step-ahead forecast would be $\Phi_0 u_{t+1}$. According to Enders (2010), in instances where, say, u_{Yt} shocks from equation (4.51) does not explain any of the forecast variance of X_t at all horizons, then the X_t sequence is concluded to be exogenous. Thus, X_t sequence evolves independently of u_{Yt} and u_{Xt} sequences. However if u_{Yt} explains all the forecast error variance in the X_t sequence at all forecast horizons then X_t is endogenous.

4.1.4 Vector Error Correction Model (VECM)

The VECM is a special case of the VAR model that imbeds an error correction mechanism (ECM) term. The VECM is one of the most commonly used econometric methods. This could be attributed to the ECM's ability to resolve spurious regression problems, fitting easily into the general-to-specific approach to econometric modelling and embedding an adjustment process that prevents the errors in the long run relationship from increasing. As noted, if Y_t and X_t are cointegrated, there is a long run relationship between them and according to the Granger representation theorem, there exists a valid error-correction representation describing the short run dynamics of the data which pulls the equilibrium error back towards zero (Verbeek, 2004). Thus, it can be estimated using the Johansen (1991) VECM methodology.

Consider a VAR (p) model of $I(1)$ endogenous variables denoted by Z.

$$Z_t = \Phi_1 Z_{t-1} + \cdots + \Phi_p Z_{t-p} + \varepsilon_t \tag{4.55}$$

The VECM of equation (4.55) is given by:

$$\Delta Z_t = \Pi Z_{t-1} + \sum_{i=1}^{p-1} \Phi_i \Delta Z_{t-i} + \varepsilon_t \tag{4.56}$$

where Z_t is a $k \times 1$ vector for endogenous variables, Π is a $k \times k$ long run multiplier matrix Φ_i are $k \times k$ coefficient matrices describing the short run dynamic effects. p is the VAR order or lag length and ε_t is a vector of independently and identically distributed innovations with zero mean. ΠZ_{t-1} is the vector error correction mechanism which captures the long run relationship between variables and the short run adjustments consistent with the long run relationship. These short run adjustments represent the feedback or adjustment effect that shows how the system readjusts as a result of disequilibrium having occurred in the previous period.

As discussed on the Johansen (1988) cointegration approach, the presence of cointegration in equation (4.56) is tested by examining the rank of the Π matrix, through the use of the trace and maximum eigen value tests. The presence of a reduced rank of Π (i.e where the $\Pi = r < n$, where n is the number of variables), implies that there exists r cointegrating vectors. Thus, the matrix can be written as $\Pi = \alpha\beta'$, where a is the adjustment matrix describing the speed of adjustment to equilibrium coefficients, while β' is the long run matrix of coefficients and contains the r cointegrating vectors. The ΠZ_{t-1} term can be expanded to yield:

$$\Pi\, Z_{t-1} = \begin{bmatrix} a_{11} \\ a_{12} \end{bmatrix} [\beta_{11} \quad \beta_{12}] \begin{bmatrix} Y_{t-1} \\ X_{t-1} \end{bmatrix}$$

(4.57)

where β_{11} is normalised to equal one, which is the standard practice in estimating cointegrating relationships. This implies that the Y is treated as the dependent variable in its relationship with X. Thus β_{12} may be interpreted as the long run impact of X on Y. The adjustment coefficients (a_{11} and a_{12}) must be considered with respect to the long run cointegrating relationship which may be expressed in an ECM form as $\varepsilon = (Y - \beta_{12}X)_{t-1}$. Assuming that one variable in the Z_t matrix, say X, in the previous period increases by more than its cointegrating relationship (above its equilibrium) with Y, for equilibrium to be restored, the variables have to adjust in the next period. Thus, X must fall while Y increases in the next period.

4.1.4.1 Causality

As noted in the previous chapter, the existence of a relationship between variables does not prove causality or the direction of impact, thus, causality between variables must be separately determined. Simply put, a variable is said to be causal of another if it helps to improve the forecasts of the latter (Lutkepohl, 2004b). According to (Enders, 2010), a test for causality seeks to answer whether the lags of one variable are part of the other variable's equation. This study will employ the use of the Granger causality test developed by Clive Granger (1969).

4.1.4.1.1 Granger Causality Test

The notion behind Granger causality is that a variable, say X_t, Granger causes Y_t if past values of X_t can explain Y_t. Koop (2013) warns that this does not guarantee causality, but rather suggests the possibility of one. The Granger causality test for Y_t and X_t involves the estimation of the following VAR model:

$$Y_t = a_1 + \sum_{i=1}^{n} \beta_i X_{t-i} + \sum_{j=1}^{m} \gamma_j Y_{t-j} + e_{1t}$$

(4.58)

$$X_t = a_2 + \sum_{i=1}^{n} \theta_i X_{t-i} + \sum_{j=1}^{m} \delta_j Y_{t-j} + e_{2t}$$

(4.59)

where εY_t and εX_t are uncorrelated white-noise error terms. The first step of performing a formal Granger causality test, considering equation (4.58) is to regress Y on all lagged values of Y, excluding the lagged X terms (i.e., restricted regression):

$$Y_t = a_1 + \sum_{j=1}^{m} \gamma_j Y_{t-j} + e_{1t}$$

(4.60)

Once equation (4.60) has been estimated, its restricted residual sum of squares (RSS_r) is retained. The next step is to estimate equation (4.58) and retain its unrestricted residual sum of squares (RSS_{ur}). A check for coefficient significance is done through hypothesis testing with the null hypothesis stating that $\sum_{i=1}^{n} \beta_i = 0$, thus, X_t does not cause Y_t. To test the hypothesis, the F test is used, which is:

$$F = \frac{(RSS_r - RSS_{ur})/m}{RSS_{ur}/(n-k)}$$

(4.61)

If the computed F value $>$ the critical F value at the chosen level of significance, the null hypothesis is rejected, thus, X_t Granger causes Y_t. Since EViews 8 automatically generates the test, an estimation of equation (4.58) and (4.59) would yield a number of different causality outcomes. Firstly, there is unidirectional causality from X_t to Y_t (i.e., X_t Granger causes Y_t) if the lagged terms of X, (i.e., $\sum_{i=1}^{n} \beta_i$) are statistically significant and the lagged Y terms (i.e., $\sum_{j=1}^{m} \delta_j$) are not statistically significant. Alternatively, there is unidirectional causality that runs from Y_t to X_t if the lagged terms of Y in equation (4.59) are statistically significant and the lagged X terms in equation (4.58) are not statistically significant. If both X and Y terms are statistically significant in both equations then there is bi-directional causality between the two variables. However, when both X and Y terms are not statistically different from zero in equations (4.58) and (4.59), then Y_t to X_t are independent of one another.

4.1.5 The Autoregressive Distributed Lag Modelling Approach

In time series data, it is not uncommon to find that a dependent variable maybe be correlated with its own time lags and the time lags of the explanatory variable. This often necessitates the inclusion of both the dependent variable's lags and the explanatory variable's lag in the regression model. Such a regression is known as the autoregressive distributed lag (ARDL) model. The ARDL or bounds testing methodology of Pesaran and Shin (1998) and Pesaran *et al.*, (2001) modelling has the ability to incorporate both $I(0)$ and $I(1)$ variables, detect long run and short run coefficients of explanatory variables, and is suitable for small-sample analysis. Following Johnston and DiNardo (1997), the theoretical properties of the ARDL approach can be explored through the use of the following equation:

$$Y_t = m + a_1 Y_{t-1} + \beta_0 X_t + \beta_1 X_{t-1} + u_t \tag{4.62}$$

where residual term u_t is assumed to be white noise. This is an ARDL (1, 1) model as the dependent variable Y and the explanatory variable X are each lagged once. This equation implies a set of responses in Y to any given change in X. The immediate effect (or the impact multiplier) of a unit change in X is given by the coefficient β_0.

Inverting the lag polynomial in Y yields:

$$Y_t = (1 + a_1 + a_1^2 + \cdots)m + (1 + a_1 L + a_1^2 L^2 + \cdots)(\beta_0 X_t + \beta_1 X_{t-1} + u_t) \tag{4.63}$$

Thus, the current value of Y depends on the current and all previous values of X and u, therefore implying that the current value of X has an effect on the current and future values of Y. Partial derivatives taken from equation (4.62) are given as:

$$\frac{\partial Y_t}{\partial X_t} = \beta_0$$

(4.64)

$$\frac{\partial Y_{t+1}}{\partial X_t} = \beta_1 + a_1\beta_0$$

(4.65)

$$\frac{\partial Y_{t+2}}{\partial X_t} = a_1\beta_1 + a_1^2\beta_0$$

(4.66)

Summing up the partial derivatives yields $(\beta_0 + \beta_1)/(1 - a_1)$, which is the long run effect of a unit change in X_t provided the stability condition $|a_1| < 1$ holds.

4.1.5.1 The Autoregressive Distributed Lag Bounds Testing Approach to Cointegration Testing

Both the EG and the Johansen cointegration testing approaches discussed thus far deliberate on cases where the variables under investigation are integrated of order one. According to Pesaran *et al*., (2001), these approaches implicate a further degree of uncertainty when analysing level relationships between variables due to the need for pre-testing. Hence, Pesaran and Shin (1998) and Pesaran *et al*., (2001) proposed the bounds testing approach, which is applicable irrespective of whether the underlying regressors are purely $I(0)$, purely $I(1)$ or mutually cointegrated, to evaluate the existence of a relationship between variables in levels. Moreover, it is not necessary with this approach to establish the order of integration of regressors in question before testing the existence of a level relationship between regressors. Since there is a level relationship between these variables, the autoregressive distributed lag modelling approach is used for estimation.

Consider the following VAR (p) model:

$$Z_t = c_0 + \sum_{i=1}^{p} \emptyset_i Z_{t-i} + \varepsilon_t$$

(4.67)

where Z_t is a $k+1$ vector of variables Y_t and X_t, c_0 represents a $k+1$ vector of intercepts, while β denotes a $k+1$ vector of trend coefficients. p is the VAR order or lag length and ε_t is a vector of independently and identically distributed innovations with zero mean. To implement the bounds testing procedure, a conditional ARDL-ECM expression of equation (4.67) is given as:

$$\Delta Z_t = c_0 + \Pi Z_{t-1} + \sum_{i=1}^{p} \Gamma_i \Delta Y_{t-i} + \sum_{j=0}^{p} \gamma_i \Delta X_{t-j} + \varepsilon_t$$

(4.68)

where Δ is the difference operator, ΠZ_{t-1} represents $(\Pi_{YY} Y_{t-1} + \Pi_{XX} X_{t-1})$ and the long run multiplier matrix is written as $\Pi = \begin{bmatrix} \Pi_{YY} & \Pi_{YX} \\ \Pi_{XY} & \Pi_{XX} \end{bmatrix}$.

Given equation (4.68), the bounds procedure can be employed using the standard Walt test or F-statistic in a generalised DF type of regression used for testing the significance of lagged levels of the variables in an equilibrium correction mechanism regression (Pesaran *et al.*, 2001). The null and alternative hypotheses are as follows:

H_0: $\Pi_{YY} = \Pi_{XX} = 0$ (i.e., no cointegration)
H_1: $\Pi_{YY} \neq \Pi_{XX} \neq 0$ (i.e., cointegration exists)

Two sets of asymptotic critical values are provided in this approach where one set of critical values assumes that all the regressors included in the ARDL are $I(1)$, while the other assumes that the regressors are $I(0)$. For this procedure, if the computed F-statistic is below the lower critical bound, the null hypothesis of no cointegration cannot be rejected. If the F-statistic falls above the upper limit, the null hypothesis can be rejected, therefore confirming the presence of a long run relationship between the dependent variable and its regressors. Alternatively, if the computed F-statistic falls within the bounds, then the results are inconclusive and integration properties of the variables should be checked before further inference is made (Pesaran *et al.*, 2001). Once cointegration is established, the conditional long run model of Y_t can be estimated as:

$$Y_t = c_0 + \sum_{i=1}^{p} \Pi_i Y_{t-i} + \sum_{j=0}^{p} \Pi_i X_{t-j} + \varepsilon_t \tag{4.69}$$

where all variables are as previously defined. This step involves using lag selection criteria to determine the optimal structure for the ARDL specification of the short run dynamics. Finally, the short run dynamic coefficients can be obtained by estimating the conditional ECM in equation (4.68) using OLS.

4.2 Model Specifications

This subsection gives an account of the underlying theoretical framework of the study's model, specifies and defines the variables to be used and gives a description of data issues and the model's respective sources.

4.2.1 Theoretical Framework

In theory and practice, as discussed in chapter two, public infrastructure capital, has long been recognised as a significant factor of production. Public infrastructure can enter the aggregate production process either directly as an additional input or as part of the technological constraint that determines total factor productivity (Romp and de Haan, 2007; Sanchez-Robles, 1998). Romp and de Haan (2007) further argue that the manner in which infrastructure is incorporated into the production process will not make a difference provided the production model is estimated via a Cobb-Douglas function. Accordingly, this study adapts and extends Barro's (1990) theoretical framework to include labour as an additional input. The labour augmented production function is given as:

$$Y = f(K, G, L) \tag{4.70}$$

where Y, which denotes output, is a function of private capital K, public capital, G which comprises both physical and human capital and, labour L. The Cobb-Douglas production function form of equation (4.70) can be written as:

$$Y_t = AX_{1t}^{\beta 1}X_{2t}^{\beta 2}X_{3t}^{\beta 3}X_{4t}^{\beta 4}e^{ui} \tag{4.71}$$

where:

Y = Gross domestic product (GDP)

A = Intercept coefficient

X_1 = Private capital investment (PVT)

X_2 = Economic infrastructure investment (INF)

X_3 = Total employment (EMP)

X_4 = Expenditure on health and education (HE)

β_i = Exponential X_i coefficients

e^{ui} = Exponential error term

This econometric growth model is adapted from the work of Sahoo *et al*., (2012). The model has, to the best of the researcher's knowledge, not been used in any of the South African studies but it has close ties to those employed by Kularatne (2006); Kumo (2012) and Mbanda and Chitiga (2013). Specifically, while Kumo (2012) and, Mbanda and Chitiga (2013) incorporate indicators for economic growth, economic infrastructure and employment, (as is done in this study), their models do not include proxies for private investment and social infrastructure. Conversely, Kularatne's (2006) model does include all variables used by this study except for employment.

In order to satisfy the study's objective, equation (4.71) can be expressed in a natural log form as:

$$\mathrm{InGDP}_t = a_0 + \beta_1 \mathrm{InPVT}_t + \beta_2 \mathrm{InINF}_t + \beta_3 \mathrm{InEMP}_t + \beta_4 \mathrm{InHE}_t + u_t \tag{4.72}$$

The expected sign of estimators is $\beta_1, \beta_2, \beta_3, \beta_4 > 0$.

4.2.2 Model Estimation

In order to address the research hypotheses presented in the first chapter, estimation techniques discussed in the previous section are employed. For the purpose of this study, equation (4.72) is estimated using VAR, VECM and ARDL techniques. The dynamics between infrastructure investment and growth can be analysed using the following VAR(p) model:

$$\mathrm{In}Y_t = a_0 + \sum_{i=1}^{p} \theta_i \, \mathrm{In}Y_{t-i} + u_t \tag{4.73}$$

where Y_t is a $k \times 1$ vector for all five endogenous variables, i.e. GDP, private investment, economic infrastructure, employment and spending on health and education. a_0 represents the intercept coefficients, θ_i are $k \times k$ coefficient matrices for all regressors, p is the VAR order or lag length and u_t is a vector of independently distributed error terms. As noted from subsection 4.1.3, the above VAR model can only be estimated in that form if all variables are $I(0)$.

An impulse response function is employed for a graphical presentation of impulse reactions between GDP, private investment, economic infrastructure, employment and expenditure on health and education under the VAR model. Should the variables be either $I(1)$ or $I(2)$ and cointegrated, the VECM presentation of the model is given as:

$$\Delta \mathrm{In} Y_t = a_0 + \Pi \, \mathrm{In} Y_{t-1} + \sum_{i=1}^{p-1} \Phi_i \, \Delta \mathrm{In} Y_{t-i} + u_t \tag{4.74}$$

where Δ is the first difference parameter, Y_t is a $k \times 1$ vector for all endogenous variables, Π is a $k \times k$ long run multiplier matrix and Φ_i are $k \times k$ coefficient matrices describing the short run dynamic effects. Just as in equation (4.72), p is the VAR order or lag length and u_t is a vector of independently and identically distributed innovations with zero mean.

The ARDL specification is used as a confirmatory estimation technique to corroborate results of both VAR and VECM. The ARDL model of specification of the study can be presented as:

$$\begin{aligned}\Delta \mathrm{InGDP}_t = {} & a_0 + \sum_{i=1}^{p} \beta_{1i} \, \Delta \mathrm{InGDP}_{t-i} + \sum_{i=1}^{p} \beta_{2i} \, \Delta \mathrm{InPVT}_{t-i} + \sum_{i=1}^{p} \beta_{3i} \, \Delta \mathrm{InINF}_{t-i} \\ & + \sum_{i=1}^{p} \beta_{4i} \, \Delta \mathrm{InEMP}_{t-i} + \sum_{i=1}^{p} \beta_{5i} \, \Delta \mathrm{InHE}_{t-i} + \beta_{6i} \Delta \mathrm{In} GDP_{t-i} + \beta_{7i} \Delta \mathrm{InPVT}_{t-i} \\ & + \beta_{8i} \Delta \mathrm{InINF}_{t-i} + \beta_{9i} \Delta \mathrm{InEMP}_{t-i} + \beta_{10i} \Delta \mathrm{InHE}_{t-i} + u_t\end{aligned} \tag{4.75}$$

where Δ is a first difference operator and u_t is an identically and independently distributed white noise error terms.

A drawback in using production functions is the potential for reverse causality. To address these simultaneous bias issues in the model and ascertain the direction of causality between infrastructure investment and economic growth, the Granger causality test is conducted.

4.2.3 Model Diagnostic Inspection

The study applies several diagnostic checks to measure statistical adequacy of the specified models and examine whether the classical assumptions of the OLS are violated or not. These checks include tests for auto or serial correlation, non-normality, multicollinearity, heteroscedasticity and the stability and variability of the models investigated. F and t tests are used to test the significance of the variables and thereby address the study hypotheses.

4.2.4 Justification of Variables Selected

This study employs the use of GDP, private investment, economic and social infrastructure investment and employment to analyse the impact of infrastructure on economic growth. The motivation behind the choice of these variables is based purely on theoretical and empirical works discussed in chapters two and three, respectively. According to Fedderke and Garlick, (2008), economists naturally describe growth as a function of a variety of production inputs and argue that growth models vary with respect to the production inputs that each researcher regards as key determinants of aggregate output. Private capital, government infrastructure investment (economic and social) and employment are recognised both in theory and practice as major contributors to economic growth. As Barro (1990) emphasises, infrastructure is crucial for sustained economic growth. Thus, following his work, this study considers both economic and social infrastructure which, according to most literature, favourably contributes to growth through its ability to lower transaction and productions costs, create economic linkages and enhance human capital. All these indicators are argued to be key factors in any economy's wellbeing and have positive effects on economic growth and development, hence, they are included as exogenous variables that determine growth in this study. The variables chosen for this study are defined as:

4.2.4.1 Gross domestic product (GDP)

The total value of all final goods and services produced within South Africa. The series is published by the SARB under the code KBP6006Y, in millions of the South African Rand and deflated by the GDP deflator (2005=100). GDP is widely used as an indicator for economic growth as it captures the value of output produced and services rendered in an economy, giving a good indication of aggregate productive activity within it.

4.2.4.2 Private Investment (PVT)

This variable denotes the purchases of capital goods by the private sector. This variable is available as Gross fixed capital formation: Private business enterprises (Investment) (KBP6109Y) at the SARB statistics page. The series is captured in millions of the South African Rand and deflated by the GDP deflator (2005=100). Private investment, is a direct injection in the economy, which leads to direct production of goods and services performed and create job opportunities. Most studies have shown that this variable is an important growth input.

4.2.4.3 Government Economic Infrastructure (INF)

This variable is available as gross fixed capital formation: General government - economic infrastructure (Investment) (KBP6101Y) at the SARB statistics page. This series represents fixed investment in infrastructure, ideally defined as the purchase of economic capital goods by government. The series is captured in millions of the South African Rand and deflated by the GDP deflator (2005=100).

4.2.4.4 Total Formal Employment (EMP)

This series denotes the total number of people employed in the formal sector. Yearly data of the series covering the 1983 – 2007 period is obtained from Hodge (2009), who compiled the formal sector employment data from various sources from 1946 to 2007. The researcher updated the series to 2013 by averaging the quarterly data reported in various issues of the quarterly labour force surveys (QLFS) published by Statistics South Africa. The series is captured in millions and referred to in theoretical terms as labour and keeps the production side of the economy going.

4.2.4.5 Expenditure on Health and Education (HE)

An index on health and education expenditure is created to represent social infrastructure investment by government alternatively referred to by most studies and theories as human capital. Data on health and education expenditure is published by the SARB as KBP4374F and KBP4373F, respectively. This series is captured in millions of the South African Rand.

4.2.5 Data Sources and Transformation

Statistical data on GDP, aggregate public infrastructure, private and public investment, total employment and government expenditure on health and education were downloaded from the South African Reserve Bank (SARB) website (www.resbank.co.za), Hodge (2009) and various issues of the Statistics South Africa's (STATS SA) QLFS. All monetary value variables are in local currency (i.e., the South African Rand). Annual data used in the study ranges from 1983 to 2013. The researcher had initially projected the study to cover the 1960 to 2013 period, however, the unavailability of annual statistics for the desired periods on government expenditure on health and education data prompted an adjustment of the sample size. EViews 8 and Microfit 5.0 statistical software packages are used for analysis of the data.

4.2.5.1 Data Transformation

The data in the study is transformed as follows:

4.2.5.1.2 Annualisation of Data

Data on total formal sector employment from 2008 to 2013 is made available by STATS SA in quarterly frequency. In order to transform the data into annual values equivalent to all the time series variables to be used for analysis in the study, the following process is used:

$$\text{Annual Value} = \frac{\sum Q_i}{4} \tag{4.76}$$

where Q is the value of total employment in each of the four quarters.

4.2.5.1.3 Index Formulation

The study utilises an index for health and education spending to capture government investment in social infrastructure. This index is formulated by summing the values of both health and education expenditure for each time period under investigation to create one variable. The creation of this index allows the researcher to assess the effects of both variables as a collective, thereby ensuring the parsimony principle in the study's econometric model.

4.2.5.1.4 Natural Log Transformation

Natural log transformations on all variables are performed. The log transformation of variables, which compresses the scales in which variables are measured, is important as it allows for coefficients to be interpreted as elasticity values, thus enabling the researcher to interpret the percentage change between two variables. According to Gujarati (2004), such a transformation also reduces heteroscedasticity in the data. Moreover, log transformations remove nonlinearity and seasonal trends in time series data that can be interpreted as nonstationary by stationarity tests by stabilising the variance (Lutkepohl, 2004b).

4.3 Conclusion

This chapter has given a comprehensive account of the econometric methods and models that the study intends to utilise in the next chapter in order to evaluate the impact that infrastructure investment has on economic growth in South Africa and thereby address the objectives of the study highlighted in the first chapter. The type of data the study will make use of is time series and since this data encompass different values for different time segments, it poses spurious regression challenges which affect the validity of econometric results. This chapter discussed the importance of checking for stationarity when dealing with time series data and the respective stationarity tests to be employed in the study before estimation in order to avoid spurious results. A theoretical presentation of the cointegration concept and its tests were also discussed. The study will employ the Johansen cointegration, FMOLS, CCR, DOLS and the ARDL bounds test approaches in examining the existence of long run equilibrium in the study's econometric model. Accordingly, VAR, VECM and ARDL methods will be estimated and from these methods, short run relationships between economic growth and its proposed determinants can be established.

CHAPTER FIVE

EMPIRICAL ANALYSIS AND INTERPRETATION OF RESULTS

5.0 Introduction

This chapter has a twofold objective. Firstly it outlines the empirical approaches undertaken to quantify the interactions between economic and social infrastructure investment, private investment, employment and economic growth in order to understand the dynamics of the South African economy; and secondly it presents and interprets their findings. As earlier chapters have established, the primary focus of this empirical investigation is to probe the influence that government investment in infrastructure has on economic growth. The secondary hypothesis that the study wishes to test is the relationship between infrastructure investment, private investment and employment; and lastly, the direction of causation between infrastructure investment, private investment, employment and economic growth. To assess these interactions, multiple and single equation estimation techniques are employed, and hence, the chapter is organised as follows:

Section 5.1 presents preliminary examinations of the data utilised in the study in order to portray its basic features. Thus, the section presents basic descriptive statistical and graphical evidence to summarise the properties of the natural log-transformed indicators for economic growth, private investment, employment and, economic and social infrastructure investment. Section 5.2 is concerned with determining the order of integration, which is done through the use of the augmented Dickey Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests. The vector autoregressive (VAR) and vector error correction model (VECM) analysis processes and results are presented in section 5.3. Specifically, the section firstly estimates the short run relationships and causality between the variables by utilising the impulse response function (IRF) and the variance decomposition tests within the VAR framework. Secondly, the existence of a long run relationship among economic growth, infrastructure investment, private investment and employment is ascertained by the Johansen cointegration methodology. Accordingly, the VECM is estimated, allowing the researcher to determine the short run dynamics of the long run relationship and attain short run elasticity coefficients of the five-variable-model. The Granger causality tests are also used to ascertain the causal linkages between the variables under the VAR framework.

To verify the results obtained from the VAR and VECM, single equation estimation methods, namely the fully modified ordinary least squares (FMOLS), canonical cointegrating regressions (CCR), dynamic ordinary least squares (DOLS) and autoregressive distributed lag (ARDL) modelling techniques, are employed in section 5.4. In section 5.5, a discussion of overall findings is provided and conclusions concerning the study's hypotheses are drawn.

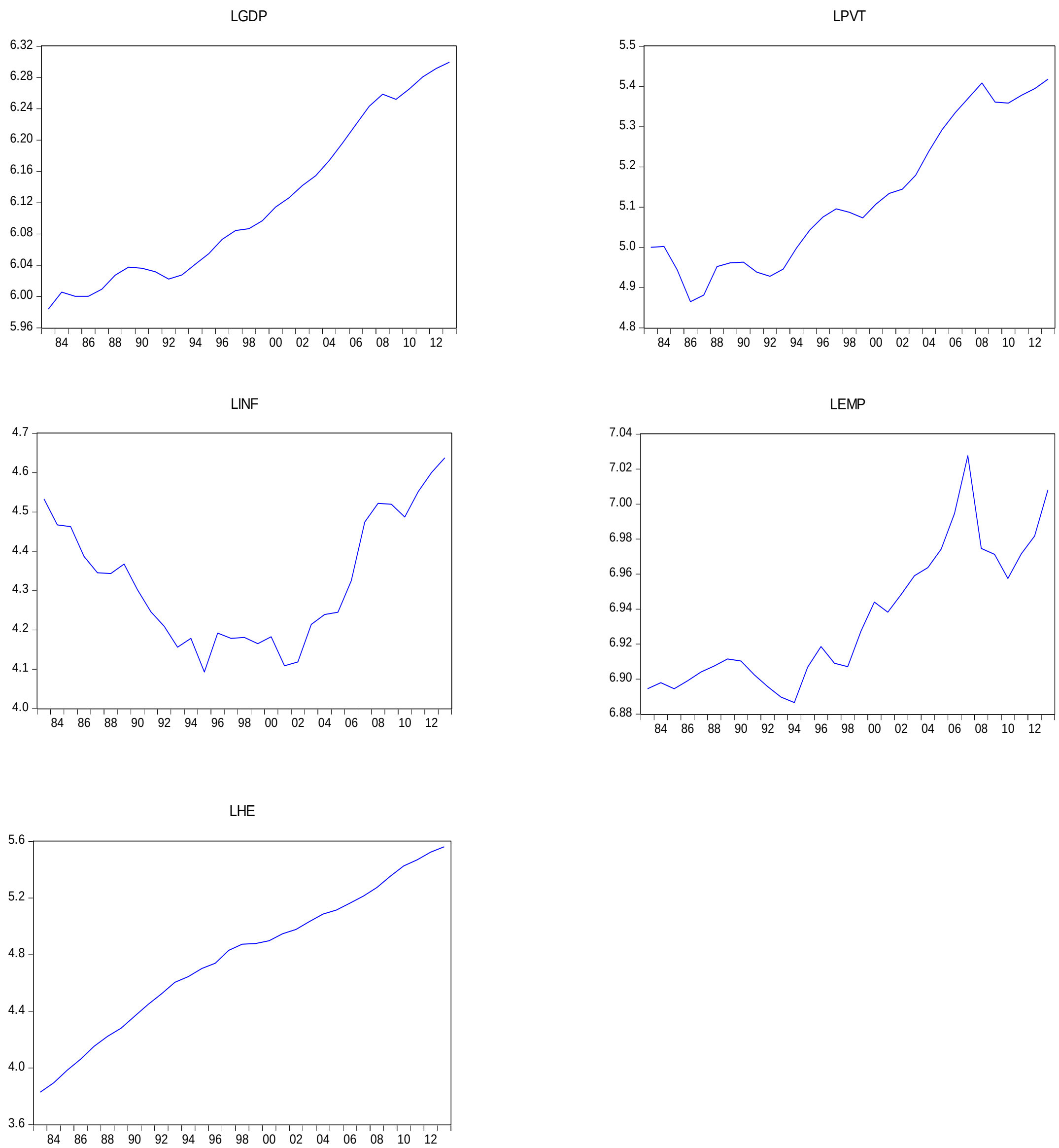
5.1 Description of Data

It is essential to carry out a preliminary inspection of the data series being investigated in order to understand the basic features of the data in a study before performing any empirical econometric analysis.

5.1.1 Graphical Analysis of Data

In order to provide a visual inspection of time series data used in this study, graphical plots of each series were constructed. Accordingly, Figure 5.1 displays plots for each of the variables against time in level form. A review of Figure 5.1 leads to the deduction that all the series are likely to be nonstationary and characterised by an upward trend, except for economic infrastructure (LINF), which appears to exhibit both upward (1983 - 2001) and downward (2002 - 2013) trends. In contrast to Figure 5.1, when the variables are plotted in first differences, stationarity is observed (see Appendix B1), and thus the variables most likely exhibit time-independent and mean-reverting tendencies inherently observed in stationary time series. However, to confirm the researcher's initial intuition, formal (statistically verifiable) stationarity tests are conducted in section 5.2 of this chapter.

Figure 5.1: Graphic Plots of Variables in Levels



Source: Generated by the researcher.

5.1.2 Descriptive Statistics

The data series' descriptive statistics, as presented in Table 5.1, point to a symmetrical distribution of economic growth (LGDP), private investment (LPVT), infrastructure (LINF), employment (LEMP) and social infrastructure investment (LHE). The distribution of the series can be determined by evaluating different statistical measures. Firstly, since the mean and median values are almost identical, and the values of skewness are very close to zero, the variables are normally distributed. The positive skewness in the distribution of LGDP, LPVT, LINF and LEMP indicate that their distributions are skewed to the right and therefore have longer right tails relative to their left tails. Consequently, the skewness value for LHE is negative and this implies that the distribution has a longer left tail compared to the right. The minimum and maximum estimates show that there are very little variations in the variables, implying stability in the series over the study period.

Table 5.1 Descriptive Statistics Results

	LGDP	LPVT	LINF	LEMP	LHE
Mean	6.117388	5.125237	4.323797	6.934768	4.777175
Median	6.086735	5.087366	4.302418	6.918607	4.874058
Maximum	6.299602	5.418358	4.638040	7.027676	5.562486
Minimum	5.984014	4.865033	4.092896	6.886604	3.828789
Std. Dev.	0.102801	0.180088	0.161762	0.039165	0.501351
Skewness	0.466906	0.358974	0.354587	0.637112	-0.269467
Kurtosis	1.772331	1.702389	1.807691	2.292983	2.064950
Jarque-Bera	3.073100	2.840692	2.485849	2.742880	1.504493
Probability	0.215122	0.241630	0.288539	0.253741	0.471307
Sum	189.6390	158.8824	134.0377	214.9778	148.0924
Sum Sq. Dev.	0.317044	0.972953	0.785004	0.046018	7.540582

Note: the number of observations $(n) = 31$.

Source: Estimation results.

The Kurtosis coefficient, which measures the thickness of the distribution tails, is meant to be three for a normal distribution. If it is less than three then the distribution is fat relative to being normally distributed. It is evident from Table 5.1 that the Kurtosis coefficients are well below the required level, therefore the results indicate fat or platykurtic distributions of the series. A more formal method of testing for normality is by means of the Jarque–Bera (JB) test statistic. The JB test is a test of the joint hypothesis that the skewness and Kurtosis coefficients are 0 and 3, respectively. Under the null hypothesis of normally distributed observations, the JB test statistic follows a chi-square χ^2 distribution with 2 degrees of freedom. Should the JB test statistic, in absolute value, be greater than the critical value of χ^2 at a chosen significance level, the null hypothesis may be rejected in favour of the alternative. Thus, if the computed probability (p) value of the JB test statistic is sufficiently low, which occurs when the value of the statistic is very different from 0, the hypothesis that the observations are normally distributed can be rejected. In the context of this study, the results of the JB test indicate that all series follow a normal distribution.

5.1.3 Correlation Matrix

The correlation matrix, given in Table 5.2, indicates the existence positive correlations between LGDP, LPVT, LINF, LEMP and LHE, thus in line with economic theory and consistent with the positive trends exhibited in the variables in Figure 5.1. Notably, there is a highly positive correlation between GDP, LPVT, LEMP, and LHE, which strongly suggests the existence of multicollinearity between the regressors in the model. Although the presence of multicollinearity affects the reliability of the coefficients' estimates, Dougherty (2001) argues that that does not imply that the model is misspecified as the regression coefficients remain unbiased and standard errors maintain their validity.

Table 5.2: Correlation Matrix Results

	LGDP	LPVT	LINF	LEMP	LHE
LGDP	1.000000	0.979938	0.444066	0.925581	0.940748
LPVT	0.979938	1.000000	0.459216	0.921316	0.902254
LINF	0.444066	0.459216	1.000000	0.420467	0.159379
LEMP	0.925581	0.921316	0.420467	1.000000	0.827340
LHE	0.940748	0.902254	0.159379	0.827340	1.000000

Source: Estimation results.

5.2 Stationary Tests

As discussed in the previous chapter, it is of great importance to formally test the stationarity, or examine the integration properties of all series data before estimation in order to avoid spurious results. Hence, to ascertain the order of integration of each variable that enters the multivariate model of this study, the ADF and the PP tests of stationarity are conducted.

From the graphical analysis of the data in the previous section, it is expected that most variables in this study are trended and nonstationary (i.e., have unit roots), but can be rendered stationary upon first differencing, i.e., $\mathrm{I}(1)$. For this study, the unit root testing procedure adopted a method that determines the significance of the restriction conditions in order to decide which deterministic component (if any) should be included in each series unit root equation. Hence, all three unit root equations (with a time trend and constant term, with constant and with no deterministic component) are estimated from the least restrictive condition to the most restrictive and stopping when a deterministic condition is found to be significant before proceeding to establish the order of integration for each variable. For example, if the trend in the first condition is found to be significant, the restriction is adopted for the unit root test for that particular variable. Should the trend be non-significant, the subsequent restriction (condition with only an intercept) is to be tested. Consequently, no restrictions are imposed if none of the deterministic conditions are found to be significant.

Table 5.3 reports the unit root test results of the ADF and PP test results, with the KPSS test being a confirmatory test measure in the case of inconclusiveness. As discussed in the previous chapter, both the ADF and PP tests are conducted on the null hypothesis that the data generating process has a unit root, while the KPSS test is used to assess the null hypothesis that a time series has no unit root. In performing the main tests (ADF and PP), if the computed test statistic value is greater than the critical value then the null hypothesis is rejected, hence, there is no unit root or nonstationarity. For the KPSS test, the computed test statistic value needs to be smaller than the critical value in order for its null hypothesis not to be rejected.

Table 5.3: Summary of Unit Root Test Results

Variable	Test	Lag	Restriction	t-Stat/ LM-Stat	Inference
LGDP	ADF	0	Constant, Linear Trend	-3.985998**	$I(1)$
	PP	3	None	-2.302182**	$I(1)$
	KPSS	4	Constant, Linear Trend	0.096513	$I(1)$
LPVT	ADF	1	Constant, Linear Trend	-4.432169*	$I(0)$
	PP	6	None	-2.767975*	$I(1)$
	KPSS	5	Constant, Linear Trend	0.131255	$I(1)$
LINF	ADF	0	Constant, Linear Trend	-5.600230*	$I(1)$
	PP	12	Constant, Linear Trend	-6.904006*	$I(1)$
	KPSS	4	Constant	0.227846	$I(0)$
LEMP	ADF	0	Constant, Linear Trend	-5.117829*	$I(1)$
	PP	12	Constant, Linear Trend	-6.109215*	$I(1)$
	KPSS	3	Constant, Linear Trend	0.124328	$I(0)$
LHE	ADF	0	Constant, Linear Trend	-3.729964**	$I(1)$
	PP	1	Constant	-3.145742**	$I(1)$
	KPSS	3	Constant	0.405657	$I(1)$

Notes:

- * and ** indicate statistical significance at 1% and 5% levels, respectively.
- The optimal lag lengths for the ADF tests are automatically determined by the Schwarz Information Criterion (SIC).
- The bandwidths for the PP and KPSS tests are automatically determined by the Newey West Bartlett Kernel selection.

Source: Estimation results.

Results in Table 5.3 indicate that both the ADF and PP tests do not reject the null hypothesis of the existence of a unit root when LGDP, LEMP, LINF and LHE are in levels. When these series were first-differenced, both tests found that no unit roots were present. For LPVT, the results from the main tests were not conclusive; hence the KPSS test was used to confirm the order of integration, where it was also found to be difference stationary. Overall, the results reported in Table 5.3 suggest that all variables are first difference stationary, thus $\mathrm{I}(1)$. This finding suggests there may be one or more cointegrating vectors between the variables and therefore, the model could be feasibly employed within the VECM framework.

5.3 VAR and VECM Estimation Processes

This section covers the vector autoregressive (VAR) and vector error correction model (VECM) analysis processes. Moreover, interpretations of the estimated results are provided.

5.3.1 Lag Length Selection

Prior to estimating a VAR or VECM it is standard practice to first determine the selection of unrestricted VAR order (p). The optimal number of lags to be included in the cointegration test and succeeding VAR or VECM model are identified by the Akaike, Schwarz and Hannan-Quinn information criteria, the sequential modified likelihood ratio, and the final prediction error tests as the VAR and VECM methodologies are sensitive to lag lengths. To determine the lag length, the unrestricted VAR is estimated with all variables in levels with a maximum number of lags, then reducing down by re-estimating the model for one lag less until zero (Asteriou and Hall, 2007). In each of these models, the values of the Akaike information criterion (AIC) and Schwarz information criterion (SIC) criterion and their respective autocorrelation, heteroskedasticity and normality diagnostics are analysed and the model that minimises AIC and, SBC and passes all diagnostic checks is selected as the one with the optimal lag length. Following Charemza and Deadman's (1992) recommendations for limited observations such as the ones used in this study, the maximum number of lags of this study was initially set at three, and sequentially reduced to two, which was found to meet the Gaussian conditions.

From the unrestricted VAR output, the lag order selection criterion is then generated, of which the results are presented in Table B1, Appendix B. Although a majority of the tests suggest the optimal lag in the model to be one in Table B1, this study utilised two lags as recommended by the AIC and FPE (i.e., the final prediction error test) since both these criteria have superiority when dealing with small observations (Acquah, 2010; Enders, 2010; Kilian, 2001). This finding suggests that a second order $(p = 2)$ VAR model is most appropriate, and therefore a first order $(p - 1)$ VECM can be estimated since EViews estimates the VAR model in level form and takes the first difference of the VAR variables to estimate the VECM (Lutkepohl, 2004b). Thus, under the VECM framework, one degree of freedom is lost, therefore reducing the lag order by one (Lutkepohl, 2004b). Thus, a second order $(p = 2)$ VAR in the VECM framework is estimated as a first order $(p = 1)$.

5.3.2 Stability of the VAR

The study used the Autoregressive (AR) roots test to examine the stability of the VAR(2) process and found that that no roots lie outside the unit circle, thus the stability condition holds, as shown in Table B2 and Figure B2, Appendix B. According to Johnston and DiNardo (1997) and Lutkepohl (2004b), if each root has a modulus less than one, all the endogenous variables in a VAR system will be $I(0)$ and therefore the variables to be estimated in the VAR model require no differencing. Since all the moduli in the AR table are strictly less than one, a VAR approach may be appropriate to estimate short run interactions in the dynamic model of this study. However, the highest modulus of 0.98 is also very close to one, suggesting that the Johansen VECM approach may also be successfully estimated to test for cointegrating effects. Given the results of the AR roots test, both the VAR and VECM are plausible models to consider, hence the approach this study takes is to estimate both the VAR and VECM in order to address the study's objective and hypotheses.

5.3.3 VAR Model Estimation

This subsection deals with the short run relationships and causality between the variables under the VAR framework, following the Cholesky ordering of: LGDP-LPVT-LINF-EMP-LHE. Incidentally, the study experimented with other orderings of the variables but settled for the above-specified ordering on the basis that the other permutations yielded implausible results for certain variables and did not provide significantly different results on most variables. The VAR (2) results are displayed in Appendix B, Table B3. The results of the study's impulse reaction function (IRF) and the variance decomposition under the estimated VAR (2) model are presented in subsections 5.3.3.1 and 5.3.3.2. The same VAR model is used for the Granger causality tests which are presented in subsection 5.3.4.

5.3.3.1 Impulse Response

The impulse response function (IRF) results of the specified VAR(2) model are presented in order to show the relationship between economic growth and its specified determinants (economic and social infrastructure investment, private investment and employment) and to enable the researcher to address the study's hypotheses. These results are shown in ten separate illustrations (Figures 5.2 to 5.11) below, covering a ten year period.

Figure 5.2: Response of LGDP to LPVT Innovation

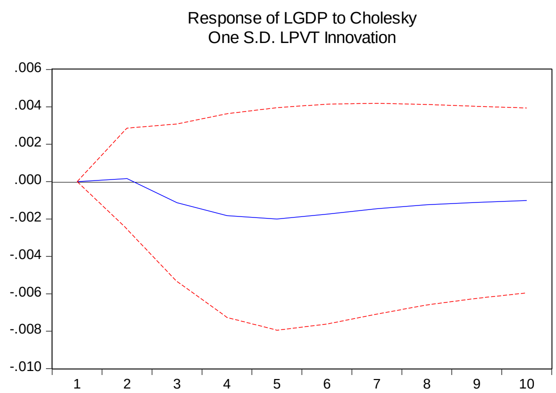


Figure 5.3: Response of LGDP to LINF Innovation

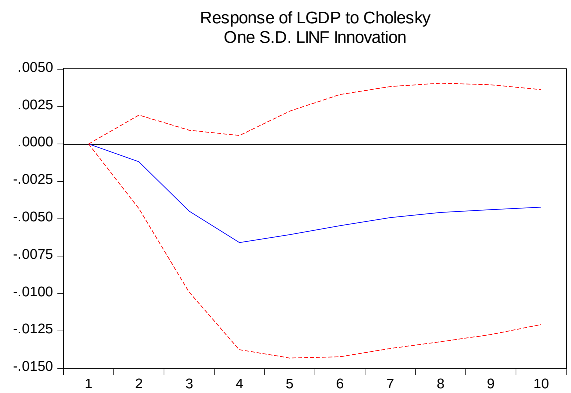


Figure 5.4: Response of LGDP to LEMP Innovation

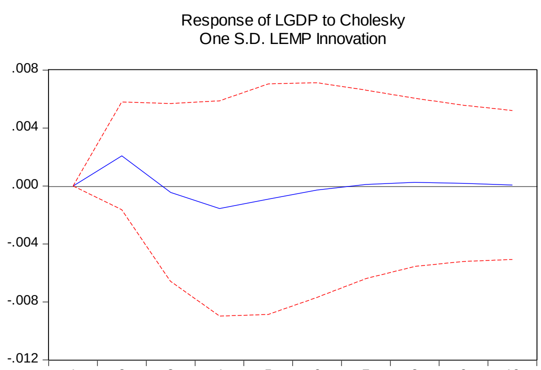


Figure 5.5: Response of LGDP to LHE Innovation

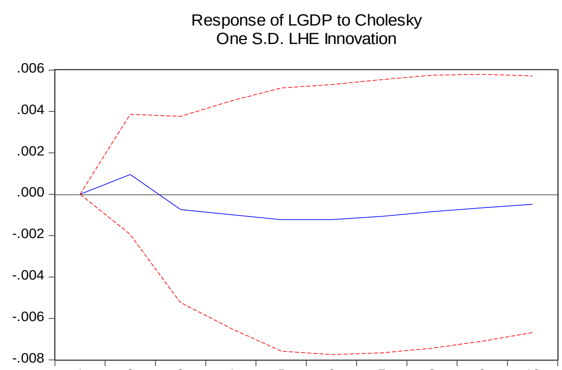


Figure 5.6: Response of LPVT to LINF Innovation

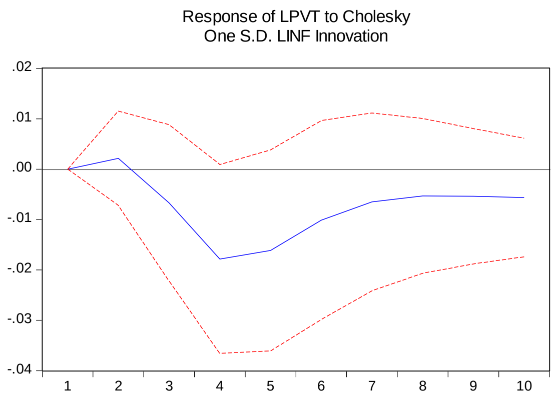


Figure 5.7: Response of LPVT to LHE Innovation

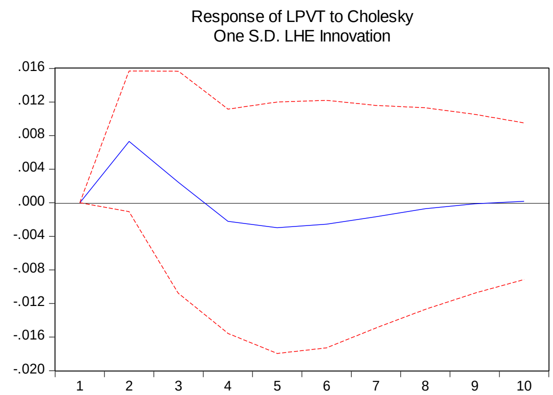


Figure 5.8: Response of LEMP to LINF Innovation

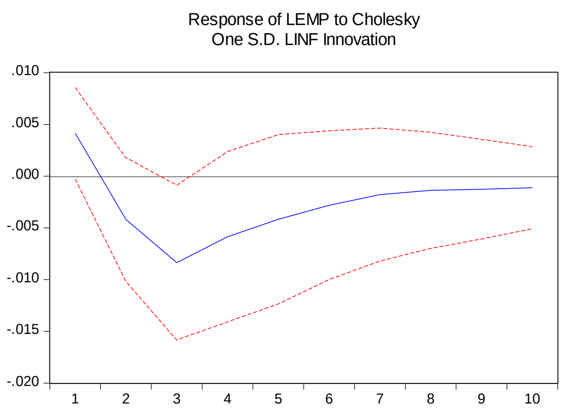


Figure 5.9: Response of LEMP to LHE Innovation

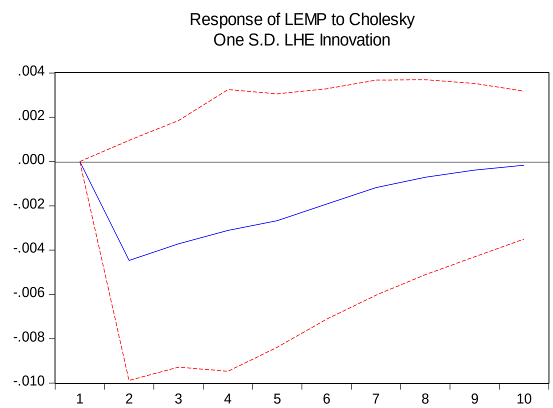


Figure 5.10: Response of LINF to LINF Innovation

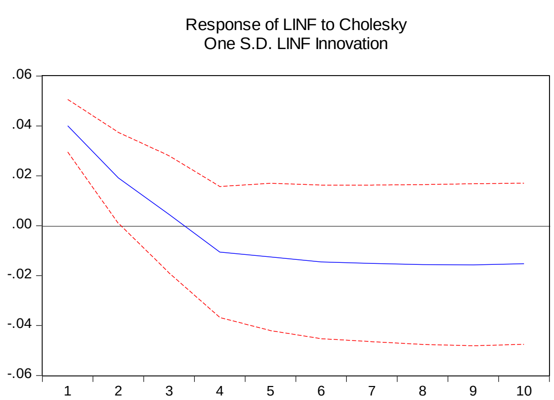
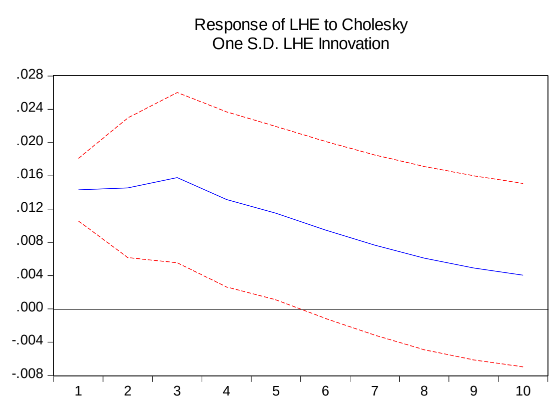


Figure 5.11: Response of LHE to LHE Innovation



In Figure 5.2, it is shown that economic growth does not respond to a 1 per cent standard deviation shock to private investment in the first year, which is then followed by a negative reaction of a very low magnitude of 0.0002 per cent from the beginning of the second year. Figure 5.3 shows that there is a low adverse impact on economic growth due to a 1 per cent positive disturbance in economic infrastructure investment. Specifically, this effect becomes less negative toward the fourth year and stays relatively constant for the rest of the forecast period. Hence hypothesis 1, which postulates a positive association between economic infrastructure investment and growth does not hold in the South African case in the short run. The results also show that an unexpected one-period shock to employment leads to an immediate spike in economic growth which then becomes negative after the second year and dissipates over time. A similar effect is observed in Figure 5.5 when there is an impulse shock to social infrastructure investment, the effect on economic growth is positive in the first two years but becomes negative thereafter. This finding suggests that some kind of positive relationship exists between growth and social infrastructure investment and therefore hypothesis 2 is confirmed.

When analysing the crowding-in and out of private investment by infrastructure, the results reported in Figures 5.6 and 5.7 suggest when there is a 1 per cent innovation in economic infrastructure investment, private investment responds instantaneously and positively, reaching an extremely low stable peak of 0.002 per cent in the second year and turns negative thereafter. A one unit shock to social infrastructure investment has a similar effect, with an elasticity of 0.007 per cent. Figure 5.7 shows that private investment responds positively to its one standard deviation shock followed by a rapid decline in the third year. Therefore, in respect to both forms of infrastructure investment, hypothesis 3 cannot be rejected as there appears to be evidence of crowd-in effects in the short run. While assessing the manner in which employment reacts to shocks to economic and social infrastructure investment (see Figures 5.8 and 5.9), the researcher discovers that the overall effect of infrastructure to employment is negative, however, the effects are negligibly low. Interestingly, both economic and social infrastructure instantaneously respond positively to their own unitary shocks and while the former becomes negative from the third year, the latter persists positively but at a decreasing rate over the 10-year horizon as shown in Figures 5.10 and 5.11, respectively. The above results show that while most of the effects are consistent with economic theory, the magnitudes are however, negligible. Implying that infrastructure investment in the South African setting does not produce significant results in the short run but is likely to be a long term phenomenon.

5.3.3.2 Variance Decomposition

The ten-year variance decomposition results of the VAR (2) system are presented in Tables B5 – B9 (Appendix B). Based on the variance decomposition of LGDP given in Table B4, it appears that economic growth is mainly driven by its own innovations, ascribing 100 per cent in the first year. From year three, economic infrastructure investment emerges as a significant driver of economic growth, increasing over time to a significant contribution of 25.53 per cent by the tenth year. Sahoo *et al*., (2012) also found an important role played by economic infrastructure in explaining the growth of GDP in the longer term. Furthermore, they find that growth in GDP is also largely attributed to private investment. However, this study finds that private investment, employment and social infrastructure investment do no play a significant role in explaining variations in economic growth as they only account for percentage averages of about 1.32, 1.28 and 0.71 respectively, throughout the entire ten-year forecast period. Hence, economic infrastructure investment is a key driver to fluctuations in economic growth in the longer term. Although these decompositions show that there is a relationship between economic infrastructure and growth, they do not demonstrate any signs of the interactions between these variables, hence the study’s first, second and third and hypothesis cannot be confirmed. This method is however useful in guiding the researcher to understand the dynamics of the South African economy in the context of identifying the main drivers behind the macroeconomic variables in question since 1983.

From Table B5, it is evident that private investment is largely affected by its own impulses and the impulses to economic growth in the first year, accounting for 39.20 and 60.79 per cent of the variations respectively. While the contribution of economic growth stays relatively constant, the contribution of private investment declines to 9.03 per cent by the end of the forecast period. Interestingly, shocks to economic infrastructure investment increasingly account for changes in private investment (with a contribution of 24.14 per cent by the tenth year), implying that the former plays a significant role in explaining fluctuation in the latter over time. As with the variance decomposition of LGDP, social infrastructure investment and employment make a negligible and unwavering contribution to private investment.

Table B6 reports that 99.22 per cent of the variance in economic infrastructure investment is due to its own shocks in the first year of the forecast period. However, from the fourth to the tenth year, this effect declines to an average of 28.59 per cent. Notably, shocks to economic growth increasingly explain changes in economic infrastructure investment throughout the entire forecast period, with a percentage impact of 63.50 per cent in year five to 66.87 per cent by the end of the forecast period. Conversely, private investment, employment and social infrastructure investment jointly contribute an average of 6.93 throughout the entire forecast period, strongly signalling very weak impacts of these variables on economic infrastructure investment.

Results in Table B7, show that the deviations in employment are generally a result of its own innovations from the immediate years of the forecast but declines gradually to an average contribution of 34.40 per cent. Other variables such as economic growth, economic infrastructure investment, private investment and social infrastructure investment explain the variations in employment by 29.69, 24.34, 3.62 and 7.93 on average, respectively. While economic growth appears to have the most impact on employment, private investment has the least impact according to the results. Notably, as the magnitudes of the effects of all the four variables to employment increase, the impact of its own shocks decline overtime. Hence in the longer term, economic growth, private sector investment, economic and social infrastructure investment explain employment in the South African economy.

Table B8 indicates that in year one of the forecast period, investment in social infrastructure is affected by its own innovations by 59.66 per cent and by shock to economic growth, private investment, economic infrastructure investment and employment contributing 16.46, 7.66, 19.49, 1.16 and 12.01 per cent, respectively. By the tenth year, changes in social infrastructure investment are seen to be largely attributed to its own shocks and shocks to economic growth. As these results demonstrate, economic growth contributes substantially to economic infrastructure investment, private sector investment and employment over the longer term. While economic growth also appears to drive social infrastructure investment, the results show that investment in social infrastructure is largely dependent on itself in both the short and long term. Given these findings, one would expect the direction of causality to run mainly from economic growth. The direction causality will be dealt with in section 5.3.4.

5.3.3.3 VAR Diagnostic Tests Results

Serial correlation, normality and Heteroscedasticity tests were performed to examine the statistical reliability and adequacy of the VAR model. As displayed in Table B9 (see Appendix B), at the given lag length the VAR model, contains residuals that are normally distributed and homoscedastic, however, the model fails the LM autocorrelation test.

5.3.4 The VECM Estimation

As reported previously, the AR roots test reveals that one of the roots has a value very close to one. This finding, together with the fact that all the series in the study's multivariate model are $I(1)$, shows that it is feasible to use the VECM method and test if a long run relationship exists between the series. For this purpose, the Johansen test of cointegration is applied. However, prior to generating the test, the appropriate model regarding the deterministic component in the multivariate system needs to be ascertained.

5.3.4.1 Deterministic Components

This step is concerned with determining whether an intercept and trend should be included in the model. According to Asteriou and Hall (2007) and Harris (1995), five different deterministic models (i.e., cases) can be considered:

- Case 1: No intercept or trend in the cointegrating equation(s) or VAR. This rarely occurs in practice since the intercept is needed in order to account for adjustments in the unit of measurements of the variables in the model.
- Case 2: Intercept but no trend in the VAR model. In this instance, the intercept is restricted to the long run model.
- Case 3: Intercept in the cointegrating vector with no trend in the cointegrating vector and VAR model. It is assumed that the intercept in the cointegrating equation is cancelled out by the intercept in the VAR, therefore leaving only one intercept in the short run.
- Case 4: Intercept in both the cointegrating equation and the VAR model, a linear trend in the cointegrating equation but not in the VAR model. In this model, no time trend exists in the short run.
- Case 5: Intercept and quadratic trend in the cointegrating equation, and an intercept and linear trend in the VAR model. This case is also not a plausible option as it is problematic to interpret in an economics standpoint.

Accordingly, Table 5.4, below, shows the five assumptions that can be made regarding the possible cointegrating relations that might exist among all the variables in the study's model.

Table 5.4: Summary of Test Assumptions

Data Trend:	Case 1: None	Case 2: None	Case 3: Linear	Case 4: Linear	Case 5: Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	3	3	2	1	1
Max-Eig	3	2	1	1	1

*Critical values based on MacKinnon-Haug-Michelis (1999)

Source: Estimation results

Within the context of Table 5.4, since cases 1 and 5 are deemed implausible for macroeconomic time series data in practice, the researcher focuses on the remaining options. For the remaining three cases, the results show strong evidence of the existence of a long run equilibrium relationship among all variables in the model. Specifically, when there are no restrictive conditions, such as in case 2, the trace and maximum eigenvalue tests confirm the existence of three and two cointegrating vectors, respectively. In case 3, the trace test suggests two cointegrating vectors while the maximum eigenvalue test finds only one. The one cointegrating vector found by the maximum eigenvalue test in case 3 is supported by both tests in case 4, which suggests strong evidence of only one cointegrating vector. Attempts were made to estimate cases 2 and 3, however they yielded implausible results (not reported), from an economic perspective as the coefficients for employment were unrealistically large in both cases. Case 4, which allows for both a linear intercept and trend in the cointegrating equation, is chosen as the appropriate model and, interestingly, conforms to the nature of the series, as discussed in the previous section. Thus, the study proceeded to estimate the Johansen cointegration test of the variables in levels based on case 4.

5.3.4.2 Cointegration Test Results

As previously discussed in chapter four, given that p is the number of variables and r is the rank (i.e., number of cointegrating vectors), the trace test statistic examines the null hypothesis that $r \leq p$ against the alternative. Conversely, the maximum eigenvalue statistic test tests the null hypothesis that the number of cointegrating vectors is r against an alternative of $r+1$ cointegrating vectors. For both tests, the null hypothesis can be rejected if the computed test statistics are greater than their critical values and thus, cannot be rejected should the computed test statistics be less than the critical values. These tests follow a sequential testing technique when ascertaining the number of cointegrating vectors (i.e., $r = 0, 1, 2, \dots, n-1$). For instance, if the null hypothesis of at most zero cointegrating vectors exist is rejected in favour of the alternative of at most one cointegrating vector, then the subsequent null hypothesis would test the presence of at most one cointegrating relationship against the alternative of at most two cointegrating relationships.

Accordingly, Table B10 (see Appendix B) reports the cointegration test results. As Table B10 shows, at 5 per cent significance level, the hypothesis of no cointegrating vector is rejected by both the trace and the maximum eigenvalue tests since their test statistics of 113.82 and 51.99 (respectively) are greater than their respective critical values of 88.80 and 38.33. The alternative hypothesis of the existence of a single cointegrating relationship was, however, not rejected since the trace statistic of 61.82 is less than the critical value of 63.87 and the maximum eigenvalue statistics of 28.01 is smaller than the critical value of 32.11. Hence, the analysis concludes that one long run cointegrating equation exists among LGDP, LPVT, LINF, LEMP and LHE and thus justifies the use of the error correction term (ECM) to show short run dynamics, which is then estimated via the α coefficients.

5.3.4.3 VECM results

The five-variable VECM results are presented in Table B11, Appendix B. The VECM results for each variable can be written in equation (4.74) form, from chapter four, and hence the VECM equation for LGDP can be expressed as:

$$\Delta LGDP_t = 0.005 - \mathbf{0.18}\,(-1.31 - \mathbf{0.01}t + LGDP_{t-1} + \mathbf{0.39}\,LPVT_{t-1} - \mathbf{0.16}\,LINF_{t-1} - \mathbf{0.81}\,LEMP_{t-1} - 0.07\,LHE_{t-1}) + 0.45\,\Delta LGDP_{t-1} + 0.017\,\Delta LPVT_{t-1} - 0.019\,\Delta LINF_{t-1} + 0.167\,\Delta LEMP_{t-1} + 0.002\,\Delta LHE_{t-1} \tag{5.1}$$

The magnitudes of the estimated long run equilibrium relationship coefficients for the variables in equation (5.1) or the error correction mechanism (ECM) term, as defined by the β vector $(-1.31 - \mathbf{0.01}t + LGDP_{t-1} + \mathbf{0.39}\,LPVT_{t-1} - \mathbf{0.16}\,LINF_{t-1} - \mathbf{0.81}\,LEMP_{t-1} - 0.07\,LHE_{t-1})$, prove to be plausible and have the correct negative signs except for private investment. Notably, the β coefficients have negative signs due to the ECM rendition of the equation, hence these coefficients must be interpreted as positive elasticities. The statistical significance of each of these coefficients can be determined by comparing the t-statistics in Table B11 against the t-critical values of 2.77, 2.05 and 1.70 respectively for 1, 5 and 10 per cent levels of significance, respectively. Additionally, emboldened coefficients in the VECM equations denote statistical significance.

According to equation (5.1), the long run coefficient for economic infrastructure investment of 0.16 is both statistically significant and consistent with economic theory and implies that if the government increases its economic infrastructure investment by 1 per cent, economic growth will also increase by a magnitude of 0.16 per cent in the long run, *ceteris paribus*. This result is consistence with the findings by Bougheas *et al*., (2000), Estache *et al*., (2012), Kularatne (2006), Kumo (2012), Mitra *et al*., (1998), Munnell (1990b), Perkins *et al*., (2005), Pooloo (2009), Sahoo *et al*., (2012) and Yu an Mi (2012), among others, whose coefficients range between 0.14 and 1.02 specifically for economic infrastructure investment. Thus, given a positive correlation between economic growth and economic infrastructure investment in the long run, hypothesis

1 cannot be rejected. However, in the short run, the correlation between the two variables given by the elasticity coefficient of (-0.019) is statistically insignificant, hence hypothesis 1 is rejected.

As anticipated, the social infrastructure coefficient also exhibits a positive relationship with economic growth, however this impact is not statistically significant. Social infrastructure investment's insignificance is also observed in Munnell (1990b) and Fedderke and Kaya (2013). The short run coefficient for social infrastructure investment of 0.002 is also not statistically significant, hence hypothesis 2 is rejected for both the short and long run. This is a puzzling result as it goes against economic theory and therefore warrants further examination.

Moreover, equation (5.1) shows that a percentage rise in employment causes a 0.81 per cent rise in economic growth. Not only is this coefficient highly significant, it is also realistic in the context of the South African economy being highly labour intensive. Conversely, private investment appears to affect economic growth inversely, with a 1 per cent rise in private investment leading to a 0.39 per cent decline in economic growth. This negative coefficient is statistically significant at the 1 per cent level, which strongly suggests that there is a negative influence of private investment on economic growth. It appears that no short run causality exists between the variables since the employment coefficient is negative. The private sector investment contribution findings do not conform to economic theory and need further investigation through other estimation methods, which are presented later in the chapter.

The LGDP short run adjustment coefficient (α adjustment coefficients) of the cointegrating equation -0.18 is statistically significant at the 10 per cent level and is of the correct sign, suggesting that on average, 18 per cent of the existing long run disequilibrium will be corrected yearly when economic growth rises above its long run relationship with the other variables, assuming the absence of other shocks. This can also be interpreted as: when economic growth rises above its long run structural average by 1 per cent in the previous period, it adjusts downward by about 0.18 per cent in the succeeding period, implying that it will take about 5.5

years for the full correction to happen. The VECM equations for LPVT, LINF, LEMP and LHE are given in equations (5.2) to (5.5).

$$\Delta LPVT_t = \mathbf{-0.04 - 1.40}\ (-1.31 - \mathbf{0.01}t + LGDP_{t-1} + \mathbf{0.39}\ LPVT_{t-1} - \mathbf{0.16}\ LINF_{t-1} - \mathbf{0.81}\ LEMP_{t-1} - 0.07\ LHE_{t-1}) + \mathbf{2.65}\ \Delta LGDP_{t-1} + 0.11\ \Delta LPVT_{t-1} - 0.11\ \Delta LINF_{t-1} + 0.31\ \Delta LEMP_{t-1} + \mathbf{0.42}\ \Delta LHE_{t-1} \quad (5.2)$$

Equation (5.2) suggests that private investment adjusts downwards by more than 1 per cent in the following period in response to economic growth having increased above its long run equilibrium with other cointegrating variables by 1 per cent in the previous period. This adjustment is highly significant, however the adjustment is towards the wrong direction since for equilibrium to be restored economic growth has to fall while all the other variables increase in the subsequent year due to its theoretically postulated positive relationship with growth. This implies that the private sector is disinvesting as a result of overproduction in the previous period, which is quite difficult to justify from an economic perspective. The short run coefficients of the equation suggest that only LGDP and LHE have a significant positive impact on private investment in the short run. This implies that causality runs from growth and social infrastructure investment to private sector investment, therefore explaining the negative relationship observed in the cointegrating equation $(-1.31 - \mathbf{0.01}t + LGDP_{t-1} + \mathbf{0.39}\ LPVT_{t-1} - \mathbf{0.16}\ LINF_{t-1} - \mathbf{0.81}\ LEMP_{t-1} - 0.07\ LHE_{t-1})$, between economic growth and private investment. Since there is evidence of crowding-in of private investment by social infrastructure investment, hypothesis 3 holds explicitly with respect to the social infrastructure component in the short run. Although statistically insignificant, the sign of the LINF coefficient suggests that there might be crowding-out of private investment by economic infrastructure in the short run.

The VECM equation (5.3), below, treats economic infrastructure investment as the dependent variable and according to the results, economic infrastructure investment does not adjust to its long run when economic growth oversteps its long run equilibrium relationship with the rest of the variables in the model. Additionally, the results also show that a 1 per cent rise in economic growth will result in a 4.61 per cent increase in infrastructure investment in the short run. All the other variables are insignificant in explaining infrastructure investment in a short term perspective; hence growth drives economic infrastructure investment.

$$\Delta LINF_t = -0.07 - 0.34\,(-1.31 - \mathbf{0.01}t + LGDP_{t-1} + \mathbf{0.39}\,LPVT_{t-1} - \mathbf{0.16}\,LINF_{t-1} - \mathbf{0.81}\,LEMP_{t-1} - 0.07\,LHE_{t-1}) + \mathbf{4.61}\,\Delta LGDP_{t-1} - 0.13\,\Delta LPVT_{t-1} - 0.11\,\Delta LINF_{t-1} + 0.60\,\Delta LEMP_{t-1} + 0.43\,\Delta LHE_{t-1} \tag{5.3}$$

$$\Delta LEMP_t = 0.03 + 0.09\,(-1.31 - \mathbf{0.01}t + LGDP_{t-1} + \mathbf{0.39}\,LPVT_{t-1} - \mathbf{0.16}\,LINF_{t-1} - \mathbf{0.81}\,LEMP_{t-1} - 0.07\,LHE_{t-1}) - 0.19\,\Delta LGDP_{t-1} + 0.07\,\Delta LPVT_{t-1} - 0.10\,\Delta LINF_{t-1} - 0.09\,\Delta LEMP_{t-1} - \mathbf{0.34}\,\Delta LHE_{t-1} \tag{5.4}$$

$$\Delta LHE_t = \mathbf{0.04} + 0.36\,(-1.31 - \mathbf{0.01}t + LGDP_{t-1} + \mathbf{0.39}\,LPVT_{t-1} - \mathbf{0.16}\,LINF_{t-1} - \mathbf{0.81}\,LEMP_{t-1} - 0.07\,LHE_{t-1}) - 0.33\,\Delta LGDP_{t-1} - 0.16\,\Delta LPVT_{t-1} - 0.11\,\Delta LINF_{t-1} + 0.05\,\Delta LEMP_{t-1} + 0.33\,\Delta LHE_{t-1} \tag{5.5}$$

The short run adjustment coefficients for LEMP (0.09) and LHE (0.36), as shown in equations (5.4) and (5.5), carry the correct signs but are not statistically significant and hence employment and social infrastructure investment do not have any bearing in the short run to assist economic growth to return to its long run equilibrium. Interestingly, while social infrastructure appears to crowd-out employment, it does not have any significant relationship with any of the variables in the system. Overall, short run coefficients - which also give the researcher information about short run causality - fail to show any feedback causality linkages between the variables, therefore hypothesis 4 is rejected on all accounts. The lack of a short run relationship between infrastructure, private investment and growth in the short run is understandable as these variables are more likely to have marginal economic impact on the economy in the long run. However, that should not be the case with respect to employment, hence an impulse response function and test for direction of causality are justified.

5.3.4.4 Impulse Response

The impulse reaction function (IRF) results are presented to allow analysis of the variables as per the study's hypotheses 1, 2 and 3, and these results are shown in eight separate illustrations given in Appendix B, Figures 5.12 to 5.17 below, over a ten year period.

Figure 5.12: Response of LGDP to LINF Innovation

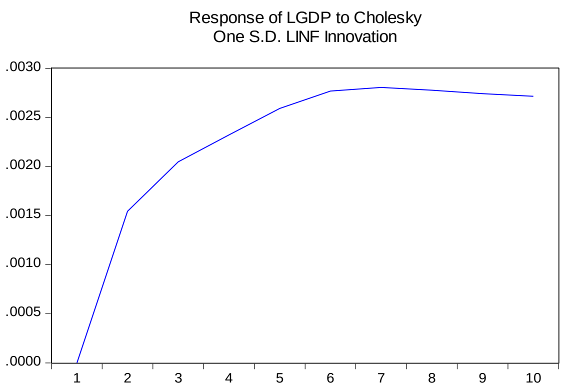


Figure 5.13: Response of LGDP to LHE Innovation

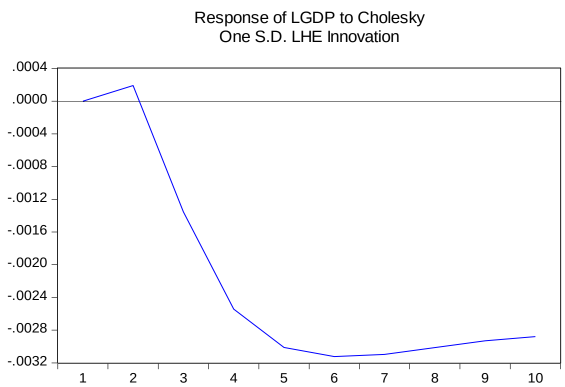


Figure 5.14: Response of LPVT to INF Innovation

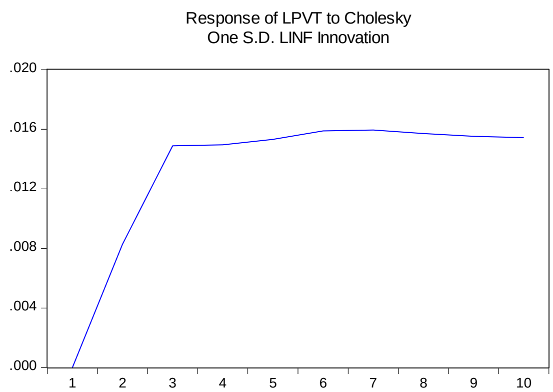


Figure 5.15: Response of LPVT to LHE Innovation

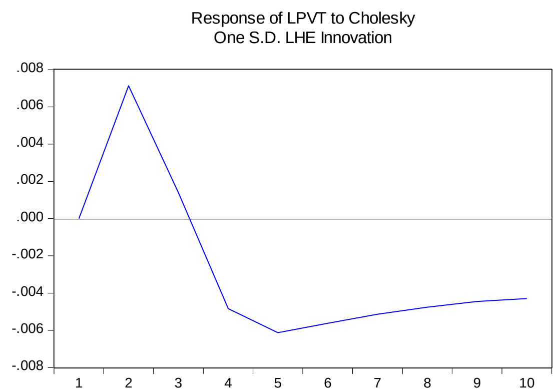


Figure 5.16: Response of LINF to LINF Innovation

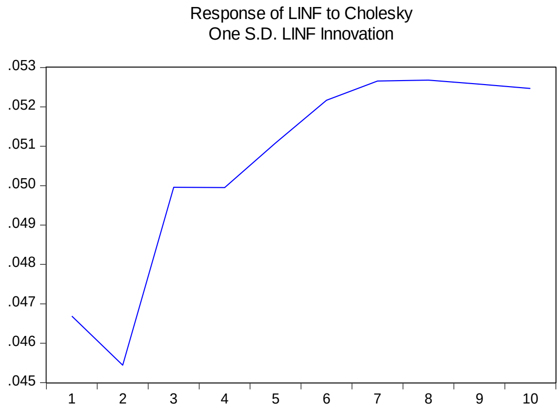
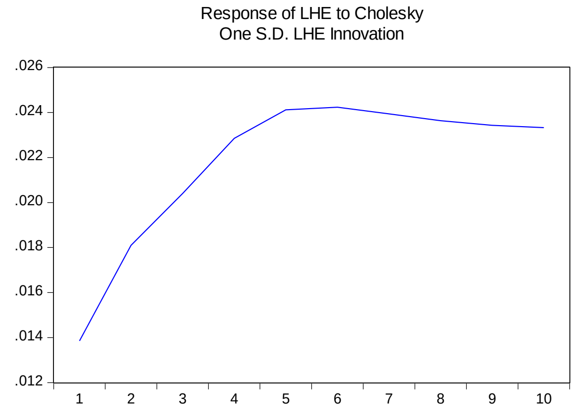


Figure 5.17: Response of LHE to LHE Innovation



In Figure 5.12, the response of economic growth to a one standard deviation shock in economic infrastructure investment is positive. Specifically, the results show that this positive impact is sustained at a constant rate from the second year of the ten year horizon. The results also show that an unexpected one-time positive shock to social infrastructure investment has an instantaneous but negligible positive effect on economic growth in the first two years but turns negative thereafter. Therefore, hypothesis 1 cannot be rejected for both the short and long run. However, with respect to social infrastructure investment and economic growth, hypothesis 2 only holds for a short term. When analysing the crowding in and out of private investment by infrastructure, the results suggest that when there is a 1 per cent innovation in economic infrastructure investment, private investment responds instantaneously and positively, reaching a stable peak of approximately 0.02 per cent in the second year, which is sustained throughout the 10 year period. A one unit shock to social infrastructure investment, however, does not have the same impact. Figure 5.15 shows that private investment responds positively to its one standard deviation shock up to the third year, after which it dissipates and becomes negative. Given these findings, the third hypothesis of the study is confirmed in the short run for both forms of infrastructure investment in question. In the long run, only economic infrastructure crowds-in private investment hence, hypothesis 3 is accepted. Interestingly, both economic and social infrastructure respond positively to their own unitary shocks and are persistent as shown in Figures 5.16 and 5.17, respectively.

5.3.4.5 VECM Diagnostic Tests Results

Diagnostic tests were carried out on the VECM model for serial correlation, normality and heteroscedasticity checks (see Appendix B, Table B12). Specifically, from the autocorrelation LM tests with the null hypothesis of no serial correlation between residuals at the given lag length, No serial correlation was found to exist in the specified model as the probability values of the tests are greater than 10 per cent, therefore the null hypothesis cannot be rejected. The Cholesky of covariance (Lutkepohl) normality tests, which are based on the null hypothesis that residuals are multivariate normal, are applied to check for normality of the model's residuals. The test results reveal that the residuals are normally distributed, thus, the null hypothesis is not rejected. Making use of the white heteroscedasticity (no cross terms) tests, residuals are found to be homoscedastic.

5.3.5 Granger Causality Tests

Given the possibility of multiple relationships and vagueness regarding the direction of causality between the series, VAR (2) Granger causality block exogeneity Wald tests were conducted. These tests inspect whether or not the null hypothesis of non-causality between the dependent and independent variable is significant at a given probability against the alternative hypothesis stating the presence of a causal relationship. The rejection and the lack thereof of the hypotheses are based on the chi-squared χ^2 test of the Wald criterion. Notably, the rejection of the null hypothesis implies that there is evidence of causality. In this study, the null hypothesis is rejected if the probability value of χ^2 is less than 10 per cent.

With reference to Table B13 (Appendix B), which presents the VAR (2) short run Granger causality results, the null hypothesis that LPVT, LINF, and LHE do not Granger cause LGDP cannot be rejected. These results confirm the short run results from the VECM and VAR-IRF. However, the null hypothesis that LEMP does not Granger cause LGDP is rejected at 5 per cent significance level. Interestingly, when studying reverse causality, the null hypothesis that LGDP does not Granger cause LEMP is also rejected, thus a bi-directional causal effect exists between economic growth and employment. In contrast, Kumo (2012) only finds a unidirectional causal link that runs from economic growth to public sector employment when accounting for a structural break in South African data. Importantly, LGDP also appears to Granger cause LPVT and LINF, thus implying a unidirectional causal relationship that runs from economic growth to private investment and economic infrastructure investment. Fedderke *et al.*, (2006), Kumo (2012) and Perkins et al., (2005) also found that economic infrastructure to responds to growth. Notably, no causal effects were detected between LGDP and social infrastructure investment, therefore social infrastructure and growth are strongly exogenous in explaining movements in economic growth and, vice versa. To assess the crowding-in and out of private investment by both economic and social infrastructure, their causal relationships are studied. The results suggest the absence of causal effects, from either direction, between infrastructure investment and private investment. Moreover, while bi-directional Granger causality is observed between employment and infrastructure, the results also show that a unidirectional causal relationship that runs from social infrastructure investment to employment. However, Kumo (2012) records a one way causal relationship that runs from private sector employment to economic infrastructure investment and a feedback effect with private employment. Hence, only hypothesis 4 with respect to economic infrastructure investment and employment cannot be rejected.

The VAR and cointegrating model results showed some economically consistent relationships between economic growth, infrastructure investment, employment and private investment. However, the VAR coefficients were small and negligible while private sector investment tended to produce incorrect signs both in the long and short run relationships in the VECM. Hence, there is a need to use alternative estimation methods.

5.4 Single Equation Estimation Methods

This section is concerned with the estimation of the FMOLS, CCR, DOLS and ARDL methods to confirm findings from the VAR and VECM regarding the nature of the long and short run relationship between economic growth private investment, economic infrastructure investment, employment and social infrastructure investment in South Africa.

5.4.1 Fully-Modified Ordinary Least Squares (FMOLS)

Table C1, Appendix C presents the results the estimated non-prewhitened Barlett kernel, Newey-West fixed bandwidth $= 40.000$ FMOLS model. Its cointegrating equation is summarised as:

$$LGDP = \mathbf{4.20} + \mathbf{0.01}\,t + \mathbf{0.07}\,LPVT + \mathbf{0.09}\,LINF + \mathbf{0.20}\,LEMP - \mathbf{0.08}\,LHE \quad (5.6)$$

The FMOLS results indicate that there is a highly significant and positive long run relationship between economic infrastructure investment and economic growth. Thus, a 1 per cent increase in economic infrastructure causes economic growth to rise by 0.09 per cent. This finding supports hypothesis 1. The observed negative coefficient of social infrastructure investment implies that a unitary increase in social infrastructure investment would result in a 0.08 per cent decline in economic growth, *ceteris paribus*. Hence hypothesis 2 does not hold. These elasticity coefficients are statistically significant at 1 and 5 per cent, respectively. As expected, private investment and employment also impacts on economic growth positively, with elasticity coefficients of 0.07 and 0.20, respectively. Overall, the FMOLS results confirm that a long run cointegrating relationship exists between economic growth and its regressors.

5.4.1.1 FMOLS Diagnostic Tests Results

In order to ensure reliability in the above-estimated FMOLS model, the diagnostics of the model must be examined. The very high value of R^2 indicates that variations in economic growth are fully explained by variations in economic and social infrastructure investment, private investment and employment in the long run. The Normality test (see Figure C1, Appendix C) reveals that the residuals are normally distributed.

5.4.2 Canonical Cointegration Regression (CCR)

Equation (5.7) below presents the long-run equilibrium equation obtained from the CCR estimation of the study's model (see Table C2, Appendix C) and shows that all the specified explanatory variables, save for social infrastructure, play a positive and highly significant role in driving economic growth in South Africa in the long run, hence there is cointegration among the variables.

$$LGDP = \mathbf{4.13} + \mathbf{0.01}\, t + \mathbf{0.06}\, LPVT + \mathbf{0.09}\, LINF + \mathbf{0.21}\, LEMP - \mathbf{0.08}\, LHE \tag{5.7}$$

The regression results show that increasing investment in economic infrastructure by 1 per cent will lead to a 0.09 per cent increase in economic growth at 1 per cent level of significance, everything else being constant. In contrast, a 1 per cent rise in social infrastructure investment causes economic growth to fall by 0.08 per cent and hence the results validate those reported by the FMOLS. LPVT and LEMP coefficients indicate that if private investment and employment individually increased by 1 per cent, then the South African economy would grow by 0.06 and 0.21 per cent, respectively. The signs of coefficients are consistent with economic theory, except that of social infrastructure investment, which suggests that it takes away from growth in the long run. Additionally, all coefficients are statistically significant at conventional significance levels.

5.4.2.1 CCR Diagnostic Tests Results

The overall model is significant with an excellent goodness of fit, indicating that about 99% of the variations in economic growth are explained by variations in economic and social infrastructure investment, private investment and employment. The results show that the CCR model's residuals are normally distributed (see Figure C2).

5.4.3 Dynamic Ordinary Least Squares (DOLS)

It is shown on Table C3 (Appendix C) that as the government dedicates more of its resources to develop economic infrastructure, the economy responds positively and significantly. The long-run equilibrium equation is given by:

$$LGDP\ = \mathbf{3.64} +\ \mathbf{0.01}\, t +\ 0.03\, LPVT\ +\ \mathbf{0.11}\, LINF\ +\ 0.28\, LEMP\ -\ 0.07\, LHE \tag{5.8}$$

Equation (5.8) suggests that a percentage increase in economic infrastructure investment would result in a 0.124 per cent boost to the economy, *ceteris paribus*. The long run coefficients for private investment, social infrastructure investment and employment of 0.03, 0.28 and -0.07 are all statistically insignificant, thus these variables do not have a long run relationship with growth. These results therefore confirm those attained from both the FMOLS and CCR approaches with regards to the statistically significant economic infrastructure investment's correlation to economic growth.

5.4.3.1 Diagnostic Checks

Given the R^2 value of 0.99 in Table C3, the model is a good fit. To ascertain the robustness of the model, tests for serial correlation, and normal distribution of residuals were applied. Presented in Appendix C, Figure C3, the results reveal that the residuals of the DOLS model are normally distributed.

5.4.4 Autoregressive Distributed Lag Model (ARDL)

The ARDL bounds F test procedure for cointegration testing examines the presence of a unique long run relationship among variables under the null hypothesis that no long run cointegrating vector exist between the series (i.e., $\beta_6 = \beta_7 = \beta_8 = \beta_9 = \beta_{10} = 0$) against the alternative that cointegration exists among the variables (i.e., $\beta_6 \neq \beta_7 \neq \beta_8 \neq \beta_9 \neq \beta_{10} \neq 0$). Under the ARDL bounds testing hypothesis testing approach, the null hypothesis can be rejected if the computed F-statistic is shown to be higher than the upper bound of the critical values. Accordingly, the null cannot be rejected if the computed F-statistic is lower, and if the computed F-statistic falls in-between the bounds, the test is inconclusive, therefore prior information about the order of integration of the variables is needed to make a decision. Similarly to the VECM approach, the existence of the cointegrating equation under the ARDL approach must be ascertained prior to analysing the long and short run relationships between the variables (Kayikci and Bildirici, 2014). The first step of the ARDL-bounds testing procedure is to determine the lag lengths on the first differenced variables from the unrestricted models, and for that purpose, this study makes use of the AIC. Thus, as recommended by the AIC, the ARDL (1, 1, 0, 0, 0) model is estimated and the F-statistics of the bounds tests results are given in Table 5.5.

Table 5.5: Bounds Test Results

F-statistic	$\alpha = 0.05$		$\alpha = 0.10$	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
5.0588	4.1977	5.5082	3.4682	4.6455

Notes: α denotes the level of significance.

Source: Estimation results.

The ARDL (1, 1, 0, 0, 0) bounds test in Table 5.5 suggests the existence of a cointegrating relationship between economic growth, economic infrastructure investment, social infrastructure investment, private investment and employment as the F-statistic is above the upper bound at 10 per cent level of significance. Thus, the null hypothesis of no cointegration between the series is rejected in favour of the alternative. The presence of cointegration is consistent with findings of Kularatne (2006), Kumo (2012) Perkins *et al*., (2005) and Sahoo *et al*., (2012) who also employ the ARDL method, as well as with the multi and single equation estimates conducted earlier in the study.

5.4.4.1 Long Run Coefficients Estimates

Once the existence of cointegration has been established, the long run equilibrium impacts of economic and social infrastructure investment, private investment and employment on economic growth can be discussed. The estimated long run coefficients are reported in Table C5, Appendix C. The results for the long run elasticity coefficients show that while economic growth responds positively and with reasonable magnitudes to private investment, economic infrastructure investment and employment as suggested by economic theory, social infrastructure investment has an inverse effect on economic growth. Hence, in the long run, when the government increases economic infrastructure investment by one per cent, the South African economy will grow by 0.07 per cent. This finding is consistent with Heintz *et al*. (2009) Kamara (2007), Kularatne (2006), Kumo (2012), Perkins *et al*., (2005) and Sahoo *et al*., (2012). Furthermore, the magnitude and the long run elasticity of economic infrastructure is found to be smaller compared to previous empirical estimates, with a range between 0.10 and 1.34 when using the ARDL method. Likewise, if investment in social infrastructure should increase by 1 per cent, the economy would contract by 0.17 per cent, thus, confirming results in FMOLS, CCR and DOLS methods discussed earlier. It is also observed that a 1 per cent rise in private investment and employment would cause a 0.16 per cent and 0.07 per cent rise in economic growth, respectively. All variables are statistically significant under the 5% level, apart from employment, which carries an insignificant coefficient, inferring that it has no bearing on economic growth in the long run. Given these findings, hypothesis 1 of the study holds while the second hypothesis is rejected.

5.4.4.2 Short Run Estimates

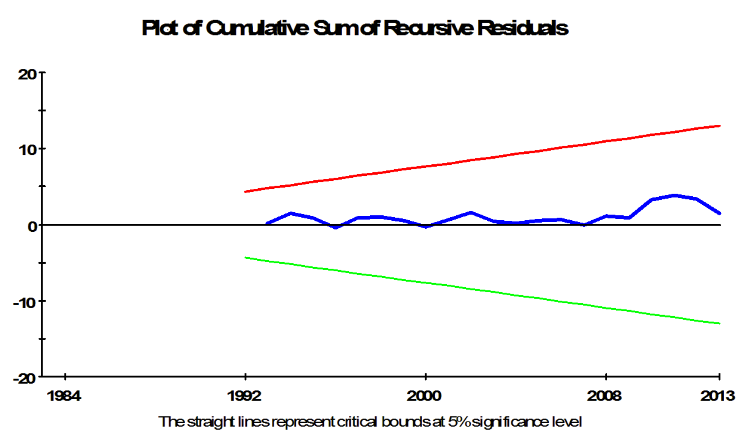
The ARDL (1, 1, 0, 0, 0) unrestricted error correction model estimates based on the associated long run coefficients are presented in Table C6, Appendix C. The results show that the lagged value of the ECM (-0.43) carries the correct (i.e., negative) sign and it is statistically significant at 1 per cent level. This suggests that approximately 43 per cent of the preceding year's disequilibrium in LGDP is corrected each year. Additionally, since the ECM is statistically significant, this further confirms the existence of a stable long run relationship among variables and implies causality from private investment, economic infrastructure investment, employment and social infrastructure investment to economic growth.

Interestingly, the results also show that, in the short run, economic infrastructure investment has a positive and statistically significant effect on economic growth with a magnitude of 0.03 per cent. This implies that economic infrastructure investment is an important determinant of economic growth in South Africa in the short run. This is consistent with the finding in Ferreira and Araujo (2007). Conversely, the results show that when government increases investment in social infrastructure by one per cent, economic growth would decline significantly by -0.08 per cent in the short run. This adjustment coefficient is interestingly highly significant, reinforcing the notion that social infrastructure investment takes away from growth in the short run. Therefore, hypothesis 1 is not rejected with regards to a positive relationship between economic infrastructure investment and growth in the short run. Accordingly, hypothesis 2, which assumes a positive correlation between social infrastructure investment and economic growth, is rejected. Private investment appears to have a positive and highly significant effect on the growth of the South African economy with an elasticity of 0.19. Based on the results, there is also a positive relationship between employment and economic growth, however its coefficient is statistically insignificant and therefore does not bring any effect on growth in the short run.

5.4.4.3 Results for Diagnostic Analysis

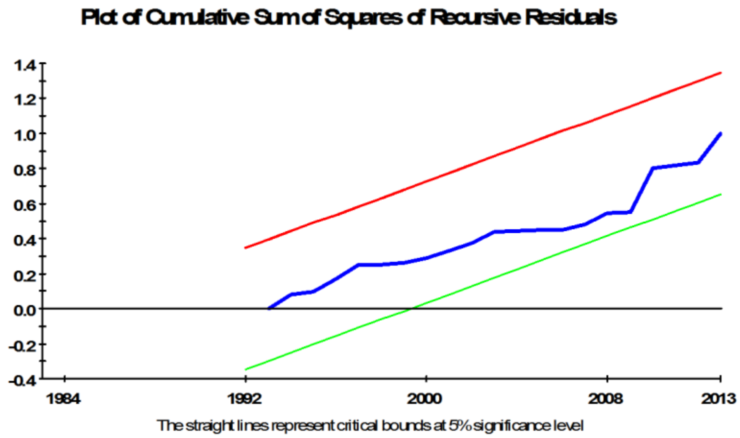
The underlying ARDL model's performance and goodness-of-fit indicate robust estimation results. With reference to Table C4, Appendix C, the ARDL model fits very well with a R^2 of 99 per cent. The overall model is also highly statistically significant based on the F-statistic. Evidently, the model meets the Gaussian conditions as it passes tests against serial correlation, functional form misspecification, heteroscedasticity and it is found to be normally distributed as shown in Table C7. The estimated ARDL model was also subjected to stability tests through the use of the recursive residuals (CUSUM) and cumulative sum of squares residuals (CUSUMSQ). Figure 5.18 (a and b) shows that the long run model coefficients are structurally stable as both plots remain within critical bounds of 5 per cent level of significance.

Figure 5.18 (a): Plot of Cumulative Sum of Recursive Residuals



Source: Estimation results.

Figure 5.18 (b): Plot of Cumulative Sum of Squares of Recursive Residuals



Source: Estimation results.

5.5 Discussion of Results

The core objective of this study was to provide an in-depth assessment of the impact of government economic and social infrastructure investment on economic growth in South Africa. Embedded within this objective was the need to ascertain firstly, the magnitude at which economic and social infrastructure investment individually affect growth both in the short and long run; secondly, the contribution by all the supporting variables (i.e., private investment and employment) towards achieving economic growth; thirdly, the impact of infrastructure investment on private investment; and lastly, the direction of causation among all the variables in the model.

To verify whether the study's hypotheses hold, the overall results obtained from all six estimation methodologies are discussed. In order to simplify the discussion and compare findings of the various methods used, a summary of short and long run coefficients of each explanatory variable on LGDP was constructed, see Table 5.6.

Table 5.6: Summary of Short and Long Run Relationships[5]

Variable	VECM		FMOLS	CCR	DOLS	ARDL	
	SR	LR				SR	LR
LINF	-0.019432	0.155299*	0.088600*	0.089032*	0.111227*	0.029564***	0.067197*
LHE	0.002136	0.065415	-0.081402**	-0.077443**	-0.067497	-0.075104*	-0.17071**
LPVT	0.016893	-0.392355*	0.065413**	0.062210**	0.028874	0.18993*	0.15868**
LEMP	0.167061	0.813914*	0.200850**	0.209997***	0.284666	0.031684	0.072016

Notes:

- SR and LR denote short and long run, respectively.
- *, ** and *** indicate statistical significance level at 1%, 5% and 10% respectively.
- α coefficients for both the VECM and ARDL models are not included in this table but are discussed under subsections 5.3.4.4 and 5.4.4.2, respectively.

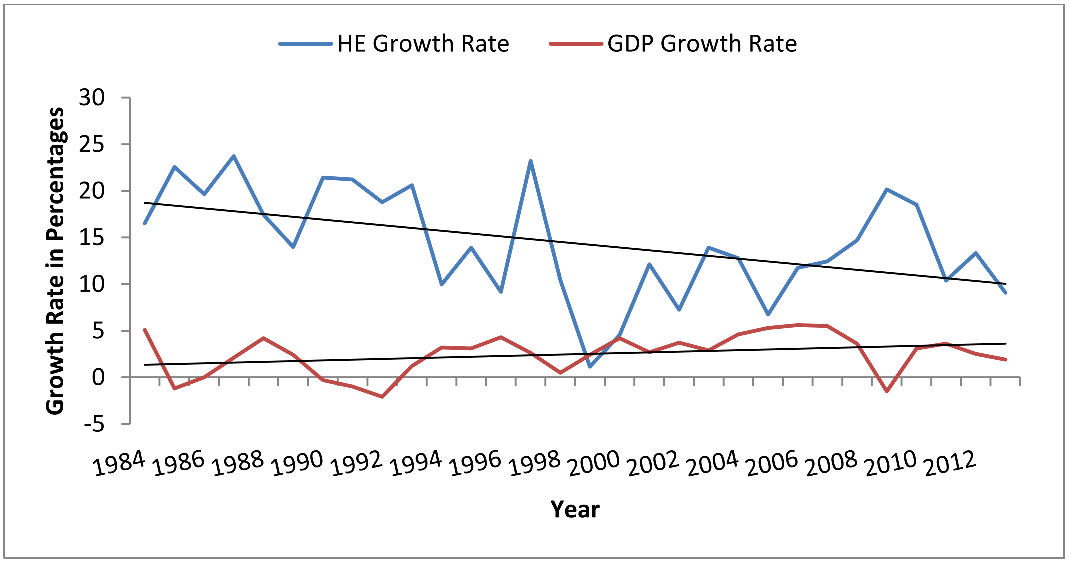
From the previous presentation of results, the researcher found that the VECM, FMOLS, CCR and ARDL methods strongly suggest the existence of a long run cointegrating relationship between economic growth, employment, infrastructure and private investment. From Table 5.6, it is observed that the short run elasticity (as given by the VECM and ARDL) estimates for economic infrastructure investment range between -0.02 and 0.03. While the ARDL estimate of 0.03 is significant at the 10 per cent level, the estimate obtained from the VECM is not statistically different from zero. The magnitude of the ARDL estimate is however too small to suggest any important short run economic growth contribution by economic infrastructure investment. These findings are plausible and make economic sense as infrastructure is provided with a long-term perspective and takes a long period of time to construct and to be channelled for productive use.

In the long run, economic infrastructure's role in growth is highly significant and carries elasticities that range between 0.07 and 0.16. Hence, economic infrastructure has a positive and statistically significant impact on economic growth in the long run. This finding is consistent with most empirical literature on the subject. The elasticity coefficients were also found to be of similar magnitudes to those of Fedderke *et al.*, (2006), Kumo (2012) and Pooloo (2009).

[5] VAR results are presented in the form of the IRF and variance composition and therefore could not be incorporated into the table.

There is strong evidence that social infrastructure investment has a negative impact on economic growth in both the short and long run, with magnitudes of -0.08 to 0.002, and -0.17 to 0.07, respectively. Overall the results of this study contradicts Kularatne (2006) reports an elasticity of 0.06 between economic growth and social infrastructure investment interaction. Although the negative effect found in this study is consistent with findings from Munnell (1990b), this result goes against economic theory. Seeing that most of the coefficients are significant, and bearing in mind the proxies used as indicators for this variable, the negative impact may be a reflection of the fact that despite low and negative real economic growth rates in the 1980s, especially when there were international sanctions against the apartheid government, social infrastructure spending - or health and education spending in this case - was kept at high levels. In post-apartheid South Africa, social infrastructure spending kept an upward momentum even though the economy's growth rate was on a declining path post 2007. Moreover considering an alternative perspective, although nominal figures of social infrastructure investment may have been increasing throughout the investigated period, the annual growth rates of such a spending have been declining. The GDP growth trend however appears to have been weakly positive, thereby showing evidence of a negative association between the two variables. This can be observed in Figure 5.19, (below).

Figure 5.19: Growth Rates of GDP and Expenditure on Health and Education (HE)



Source: Generated by the researcher, own calculations[6] - SARB data.

While the VECM suggests that an inverse relationship exists between economic growth and private investment in the long run, single equation methods find that the latter in fact favourably influences economic growth. Results from the single equation methods show that if private investment was to rise by 1 per cent, then the economy would expand within a range of 0.03 to 0.16 per cent in the long run. In the short run, the IRF under the unrestricted VAR system showed that economic growth responds positively to a surprise shock in private investment with a very insignificant magnitude. Moreover, coefficients of the VECM and ARDL suggest that a short run positive relationship may exist between the two variables.

Employment is found to significantly lead to growth in the long run by three out of the five methods employed, with elasticity magnitudes ranging from 0.20 to 0.81. In the short run, the IRF shows an instantaneous positive effect to economic growth which becomes negative after the second year. This result is validated by both the VECM and ARDL methods, which find the relationship between employment and growth to be positive but statistically insignificant in the short run.

[6] See Appendix A for calculations.

The IRF technique under both the VAR and VECM frameworks was very useful in allowing the researcher to test the third hypothesis in the short run. It was found that an unanticipated unit shock to economic and social infrastructure investment would crowd-in private investment. However, it should be noted that under the VAR framework, this effect is only temporary, over a longer period, the results showed that there is crowding-out of private investment. Also, even under the VECM framework, social infrastructure investment crowds-out private investment after the third year. These results do not conform to economic theory but are consistent with findings in Mbanda and Chitiga (2013) and Gadinabokao and Daw (2013) who find infrastructure investment to crowd-out private sector investment. Notably, the variance decomposition results revealed that private investment is largely driven by economic growth, alluding to the possibility of a crowd-in from growth instead of infrastructure. This was later corroborated by the VAR Granger causality tests which showed that there exists a unidirectional causal link that runs from economic growth to private investment.

To address the fourth hypothesis, and thereby ascertaining the direction of causality among the variables, the VAR Granger Causality test was generated. The Granger causality tests carried out supported findings by Nketiah-Amposah (2009) who finds unidirectional causality that runs from economic growth to economic infrastructure investment. No directional causal effect was found between economic growth and social infrastructure investment. This is understandable since these are merely short run causality linkages and results suggest these variables are a long run phenomenon. A bi-directional causal link between growth and employment, and employment and economic infrastructure investment is also observed.

Considering the overall results obtained, the following conclusions can be drawn:

- The researcher fails to reject hypothesis 1 in the long run but do so in the short run.
- Hypothesis 2 is rejected in both the long and short run.
- Hypothesis 3 holds for both economic and social infrastructure in the short run. However, in the long run, results are mixed.

- Hypothesis 4 is rejected for all variables except for the direction of causality between employment and economic growth, and employment and economic infrastructure investment.

5.6 Conclusion

This chapter provided an empirical analysis of this research study using EViews 8 and Microfit 5.0 statistical software packages. Preliminary examinations of the data were conducted and all the variables were found to be non-stationary in levels and stationary in first difference. The study estimated the IRF, variance decomposition and Granger causality tests under the VAR (2) system. The study also carried out cointegration analysis and IRF under a VECM (1) system. Due to implausible results exhibited by private investment and social infrastructure investment coefficients in both models, single equation estimation methods were estimated. Overall, the researcher found that a long run relationship exists between economic growth, infrastructure investment, private investment and employment. Findings from multiple equation methods reveal that while economic infrastructure investment is an important determinant of growth, its long-run impact on private investment is inconclusive. Private investment might be driven by economic growth rather than infrastructure investment but this will have to be investigated by future studies. Social infrastructure investment was found to crowd-out economic growth and investment by the private sector over a long period. Generally, single equation methods yielded more economically plausible results and they have unanimously supported the central thesis of this study that economic infrastructure investment is an important driver of economic growth over the long run horizon and so too is private investment and labour.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.0 Introduction

This chapter summarises the present study and gives policy recommendations based on the findings. The chapter consists of three sections. Section 6.1 presents the summary of the study and discusses the empirical findings. Policy implications and recommendations are laid out in section 6.2, while section 6.3 provides the study's strengths, weaknesses (limitations of study) and policy prescriptions. Section 6.4 outlines recommendations for future research.

6.1 Summary of the Study

As a policy instrument for economic growth acceleration, the South African government continues to invest in infrastructure, and following the Barro (1990) theoretical framework, this study attempted to assess the kind of effects such an investment has on the economy. The researcher carefully selected macroeconomic variables that have been considered in the econometric models for empirical analysis of the research study in this dissertation through statistical estimation techniques as guided by Barro (1990) and international studies, specifically that of Sahoo *et al*., (2012), in this area of study. These variables include GDP as an indicator for economic growth, general government gross fixed capital formation, economic infrastructure, government expenditure on health and education as proxies for economic and social infrastructure investment, respectively. Total formal employment and private business enterprises' gross fixed capital formation were used as proxies for employment and private sector investment. Specifically, the study set out to empirically quantify the impact of both economic and social infrastructure investment on economic growth in South Africa. The objective of the study centred around four hypotheses which were constructed to examine how key macroeconomic variables such as private investment, employment and growth have reacted to the impact of economic and social infrastructure investment between 1983 and

2013. Furthermore, through this study, the key determinants of growth in South Africa in both the short and long run were identified.

To achieve the study's objective and address the respective hypotheses, preliminary examinations of the data were conducted through the use of visual and unit root tests and all the variables were found to be non-stationary in levels and stationary in their first differences (i.e., $I(1)$). Both the unrestricted VAR and VECM techniques were estimated since the AR table used for establishing the stability of the unrestricted VAR at a lag length of 2 contained a root with a modulus of 0.98. Under the VAR framework the study estimated the IRF, variance decomposition and Granger causality tests which only consider short run relationships among the specified variables. The study proceeded to estimate a first order VECM, which takes into account both short and long run relationships. Due to implausible results exhibited by the wrongly-signed statistically significant coefficient of private investment and the insignificant but correctly signed coefficient of social infrastructure investment in the multi-equation setting the study opted for estimating single equations as well for confirmatory purposes. The single equation methodology on the whole revealed that private sector investment, infrastructure spending and employment do have plausible positive long run relationships to GDP growth, however, social spending tended to have a persistent statistically significant negative relationship to economic growth.

Overall the study found that economic and social infrastructure investment, private investment, employment and economic growth series were first-difference stationary and shared a long run relationship between the 1983 and 2013 period. Based on Barro's (1990) theoretical framework, other economic growth theories and most empirical work, economic and social infrastructure investment were expected to be a key determinant of economic growth and thus carry positive coefficients. Although this study found this notion to be true for economic infrastructure, social infrastructure exhibited a significant negative association with economic growth. Although this result goes against economic theory and the conclusions drawn from most empirical studies, Devarajan *et al*., (1996), Munnell (1990b), Fedderke and Kaya (2013), Mastromarco and Weitek (2006), Garcia-Mila *et al*., (1996) and Nketiah-Amposah (2009) among others, find evidence of a negative or statistically insignificant role played by the social infrastructure component of government investment. It should be stressed that this result does not necessarily mean that social infrastructure is not an important factor in the growth process. There could be a number of reasons for this finding.

Firstly, social infrastructure investment may be an exogenous factor, hence only affecting growth and private investment indirectly through other macroeconomic factors, such as employment. The Granger causality tests reported in the previous chapter (see Table B13, Appendix B) strongly supports this justification by showing that social infrastructure is not caused by any of the variables in the system and, is exogenous in the estimated model. In an attempt to further understand how economic growth and social infrastructure interact, the researcher tested for a bi-variate cointegration relationship (not reported) and found that no long run relationship existed between the two variables. Hence, although conceptually and theoretically there is no doubt that social infrastructure is important, how it enters the system and therefore the economic growth process, must be further investigated, as it is of great relevance to economic policy.

Secondly, it can be argued that the negative result may not realistically reflect social infrastructure investment since its proxy, an index of health and education spending, incorporates the salaries of public health and education staff, for example, and not explicitly education and hospital facilities. Hence, the result could be a proxy problem. Even so, enhancing human capital should significantly contribute to economic growth. The negative impact on growth therefore raises concern over the quality of health and education in South Africa. According to the DBSA (2011), OECD (2013) and NPC (2012), South Africa suffers from poor quality of education and healthcare. Additionally, van Zyl and Bonga-Bonga (2008) find that the returns on education and training are not significant in South Africa and argue that this may be a result of misallocation of resources and skills shortage.

Thirdly, social infrastructure spending is most likely affecting growth with long lags for such spending possibly exhibiting intergenerational effects. This study's sample of 31 data points is too small to capture these effects. Lastly, it was argued in the previous chapter that although social infrastructure spending may have increased over time in nominal terms, its overall growth rate has declined. The growth rate of GDP on the other hand, albeit relatively flat, it has shown a weak upward trend.

Returning to the other aspects of the findings, a bi-directional causal effect was found between economic growth and employment and employment and economic infrastructure in the short run. Furthermore, economic growth was also found to lead to economic infrastructure investment and private investment. While the study found evidence of crowding-in of private investment by government investment in economic and social infrastructure in the short run, a crowding-out effect was observed over the long run. Although economically implausible, the results revealed that private sector responds to economic growth and thus, justifies the findings in this research.

6.2 Policy Implications and Recommendations

The findings of this study have important policy implications for the economic growth strategies and plans that the South African government implements. While the NGP and NDP stress the critical importance of infrastructure investment in order to stimulate economic growth and attract private sector investment, the single equation results of this study support these strategies but specifically for economic infrastructure in the long run. However, the IRFs of multiple equation models estimated in this study indicate that GDP attracts economic infrastructure investment in the short run. Hence the authorities should rather place more emphasis on identifying other factors that drive economic growth such as employment policies, domestic savings and business friendly policies, in conjunction with infrastructure investment, as opposed to laying such emphasis on infrastructure as the main growth driver. Additionally, the results suggest that the South African government should also give serious attention to the quality of education and health.

6.3 Strengths, Weaknesses and Policy Prescriptions

The overall long run results (especially from the single equation methods) confirm the policy prescription of the South African authorities that infrastructure investment is a key ingredient of economic growth, as are private sector investment and the reduction in the unemployment rate. Hence the emphasis on government, labour and the private sector working together to steer the economy on a high growth trajectory has merit.

The VAR/VECM analysis shows that in terms of short run adjustments a high growth path is critical for attracting private investment and government infrastructure spending. This is another important finding since the policy prescriptions of NGP and NDP place most of their emphasis on long run developments while ignoring the short run adjustment processes. Hence in the light of this study's findings, the authorities should focus on other policy aspects as well and not view infrastructure investment as being the panacea for all South Africa's economic development ailments. These other policy issues ought to factor in inflexible labour market policies, labour militancy in respect of strikes, fiscal and current account deficits, low savings rates, income inequalities, small to medium enterprise promotions and corruption. These policies have been singled out for they tend to be cited frequently as being the major stumbling blocks to attracting foreign investment.

The main weakness of this study is that it utilised a very small data set and this might be the main reason why contradictions were noted in the VECM analysis which performs best with long time series data sets. A second weakness of this study is that it did not attempt to assess the VECM model by using alternative proxies for social infrastructure spending or expanded definitions of social infrastructure spending such as proxies for school enrolment, infant mortality rate and the number of health and education facilities. Furthermore this study neglected to consider running a VECM where social infrastructure investment was included as an exogenous variable, especially since a strong case was made for the possibility that this type of spending might be exogenous (i.e., determined by political factors) to the variables included in the model (see section 6.1).

6.4 Recommendations for Future Research

Future studies ought to search archives for much larger data sets in order to carry out VAR/VECM type models which work best with large sample sizes. Together with larger sample size, future research ought to identify alternative proxies for social infrastructure spending. This study defined social infrastructure investment as an endogenous variable in the system however, the VAR granger causality tests suggested that it might be exogenous to the system, hence future research could attempt to estimate social infrastructure as an exogenous variable in the system. No clear consensus has been reached on the crowding-in and out of private investment by both components of infrastructure investment, hence more sophisticated estimation methods such as dynamic computable general equilibrium (CGE) could be used.

6.5 Conclusion

This chapter outlined the core thesis of the entire study, summarised the findings, gave policy recommendations and prescriptions, highlighted the strengths and weaknesses and proposed areas of future research. In light of the study's finding that economic infrastructure investment is important for economic growth in the long run, in order to accelerate growth in the shorter term, it is crucial for the South African government to also prioritise and harness other growth-driving processes and short run economic adjustment factors.

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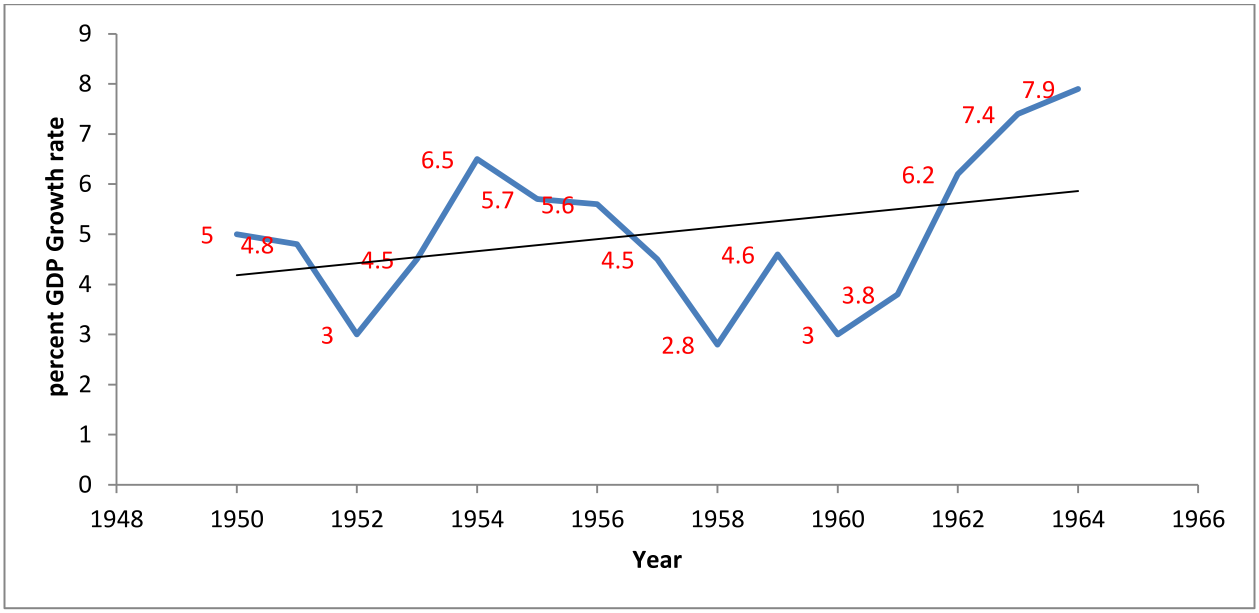
APPENDIX A

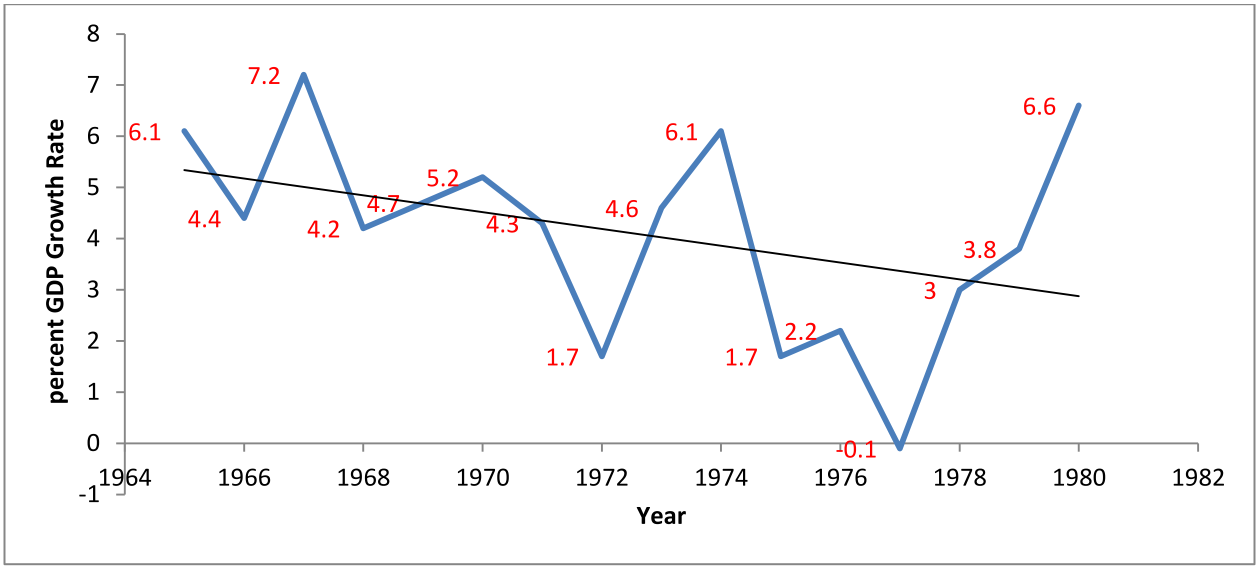
The following diagrams and calculations form the basis for the discussions in chapter two in subsection 2.3.1 of this study.

Figure A1: Short Run Real Economic Growth Trend, 1950 – 1964



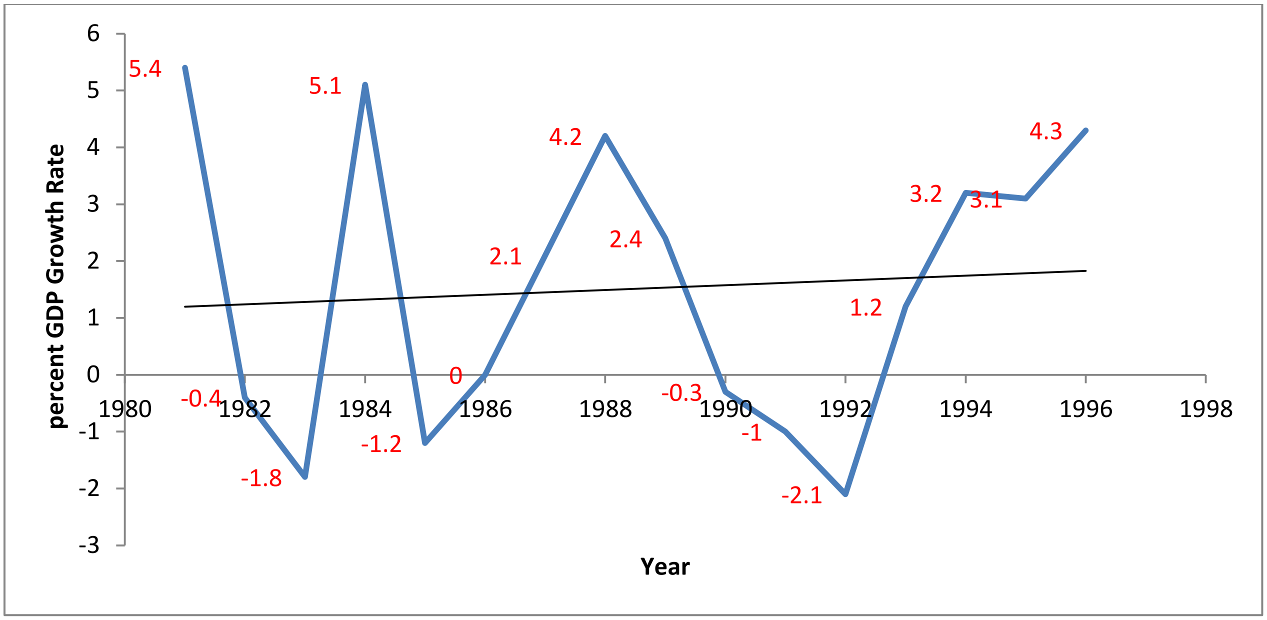
Source: Generated by the researcher, SARB data.

Figure A2: Short Run Real Economic Growth Trend, 1965 – 1980



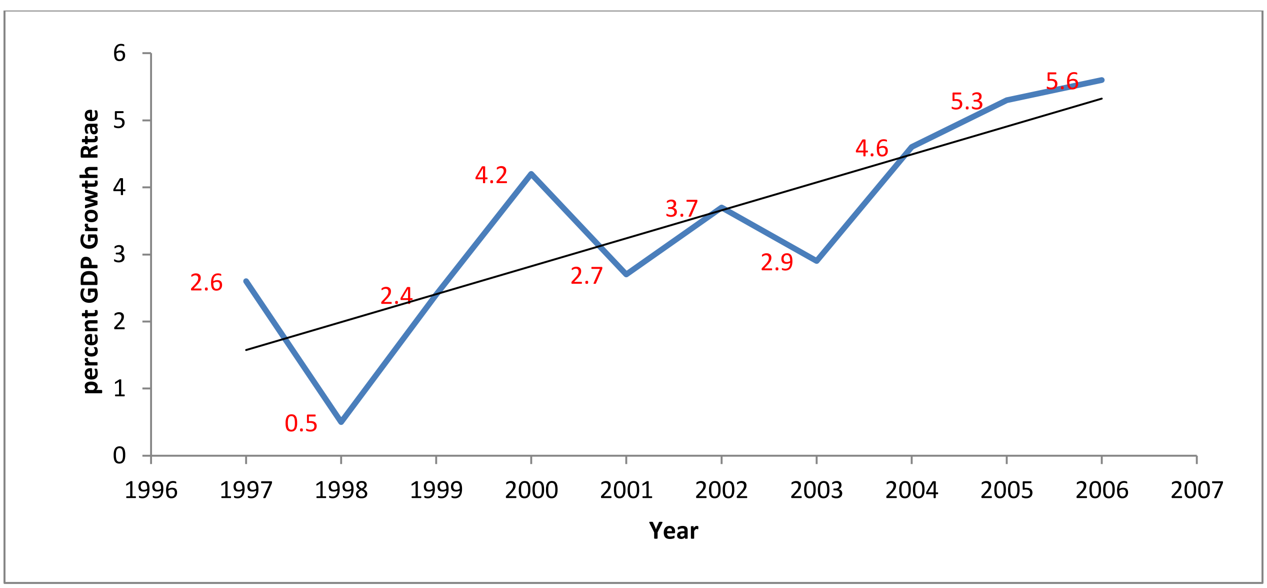
Source: Generated by the researcher, SARB data.

Figure A3: Short Run Real Economic Growth Trend, 1981 – 1996



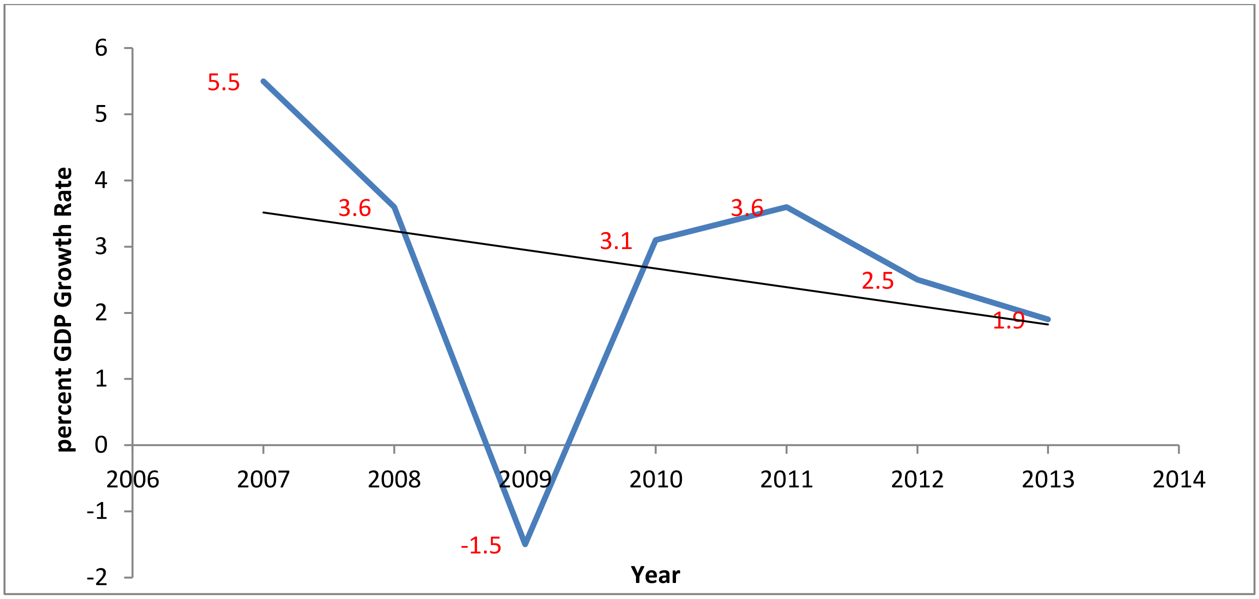
Source: Generated by the researcher, SARB data.

Figure A4: Short Run Real Economic Growth Trend, 1998 – 2006



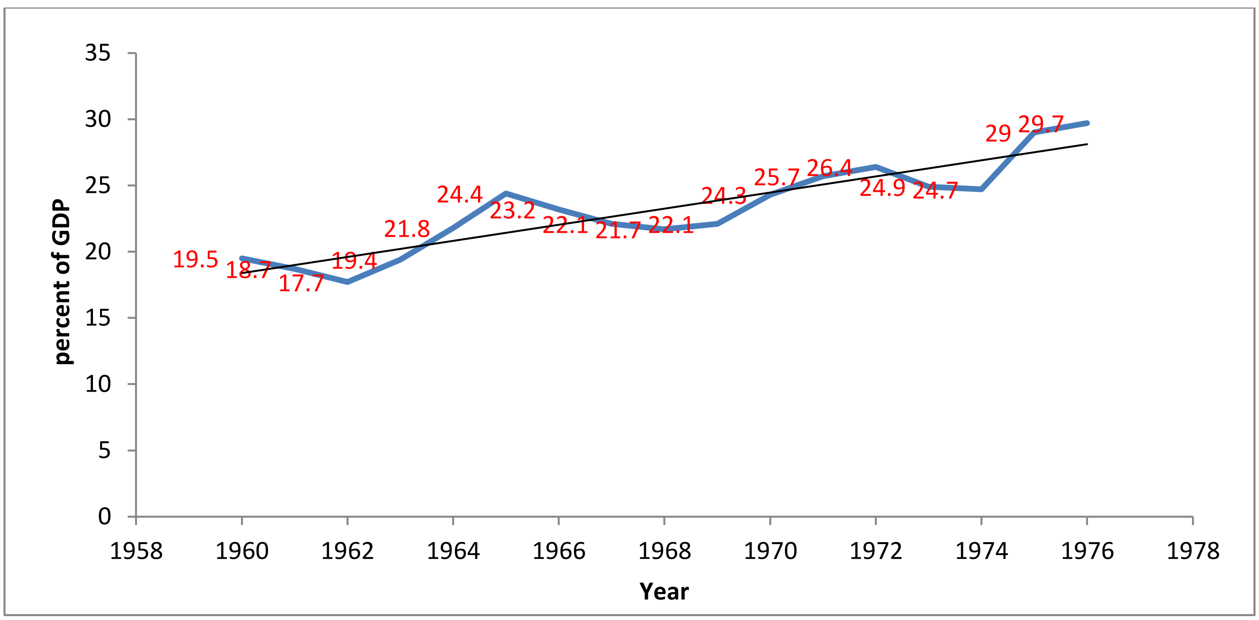
Source: Generated by the researcher, SARB data.

Figure A5: Short Run Real Economic Growth Trend, 2007 – 2013



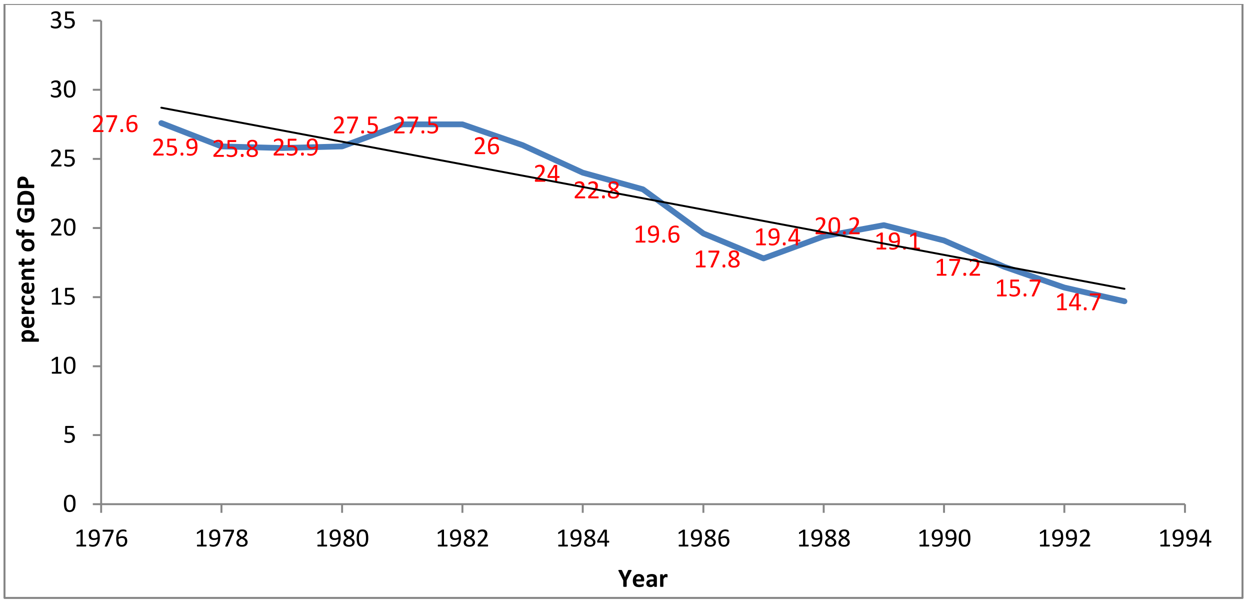
Source: Generated by the researcher, SARB data.

Figure A6: Ratio of Infrastructure to GDP Trend, 1960 – 1976



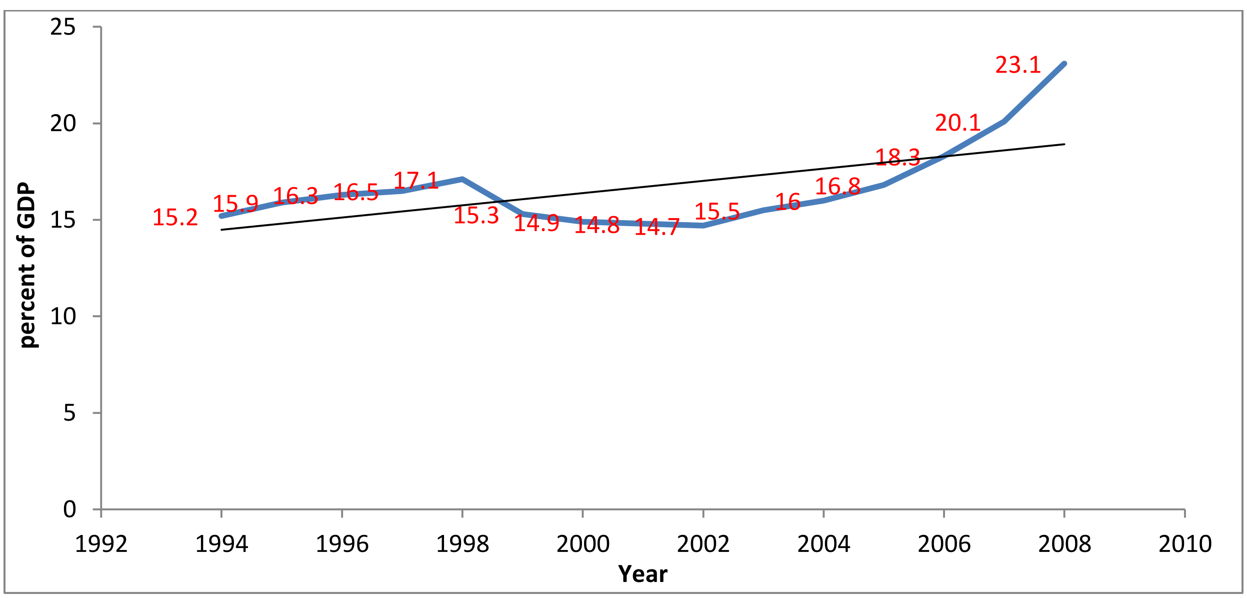
Source: Generated by the researcher, SARB data.

Figure A7: Ratio of Infrastructure to GDP Trend, 1977 – 1993



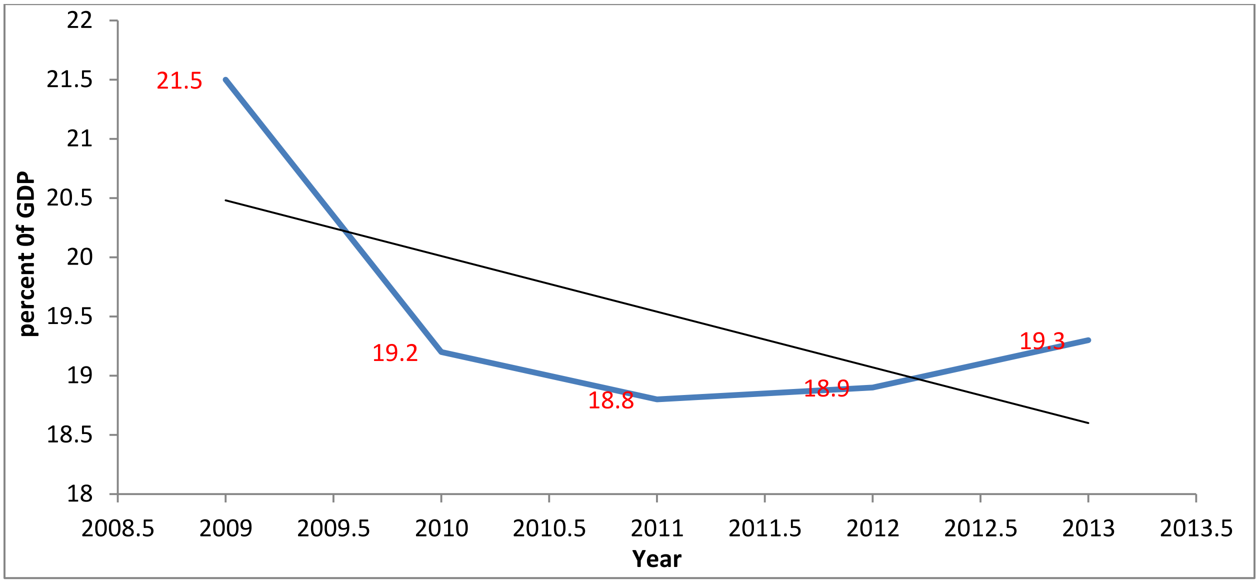
Source: Generated by the researcher, SARB data.

Figure A8: Ratio of Infrastructure to GDP Trend, 1994 – 2008



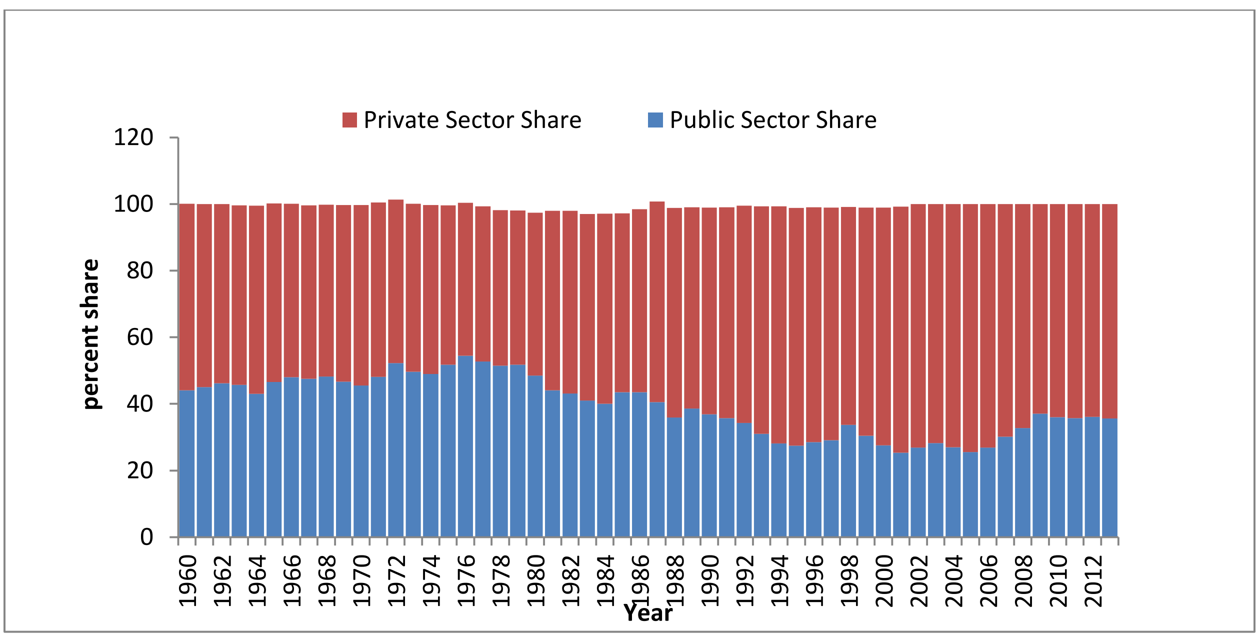
Source: Generated by the researcher, SARB data.

Figure A9: Ratio of Infrastructure to GDP Trend 2009 – 2013



Source: Generated by the researcher, SARB data.

Figure A10: Share of Public and Private Sector Investment to Gross Infrastructure Investment, 1960 – 2013



Source: Generated by the researcher, own calculations - SARB data.

Calculations

(1) Ratio of Infrastructure Investment to GDP

$$= \frac{\text{Gross Fixed Capital Formation}}{\text{GDP}}$$

(2) Public Sector Infrastructure Investment as Share of GDP

$$= \frac{\text{Gross Fixed Capital Formation: General government} + \text{Public Corporations}}{\text{GDP}} \times 100$$

(3) Private Sector Infrastructure Investment as Share of GDP

$$= \frac{\text{Gross Fixed Capital Formation: Private Business Enterprises}}{\text{GDP}} \times 100$$

(4) Contribution to Investment Growth:

(a) **Private Business Enterprises**

$$= \frac{\%\ \Delta\ \text{Gross Fixed Capital Formation: Private Business Enterprises}}{\%\ \Delta \text{Gross Fixed Capital Formation}}$$

(b) **Government**

$$= \frac{\%\ \Delta \text{Gross Fixed Capital Formation: General government}}{\%\ \Delta \text{Gross Fixed Capital Formation}}$$

(c) Public Corporations

$$= \frac{\%\ \Delta \text{Gross Fixed Capital Formation: Public Corporations}}{\%\ \Delta \text{Gross Fixed Capital Formation}}$$

(5) Percentage Change/Growth rate

$$= \left[\left(\frac{\text{Value of Current Year} - \text{Value of Previous Year}}{\text{Value of Previous Year}}\right) \times 100\right]$$

APPENDIX B

Figure B1: Graphic Plots of Variables in First Differences

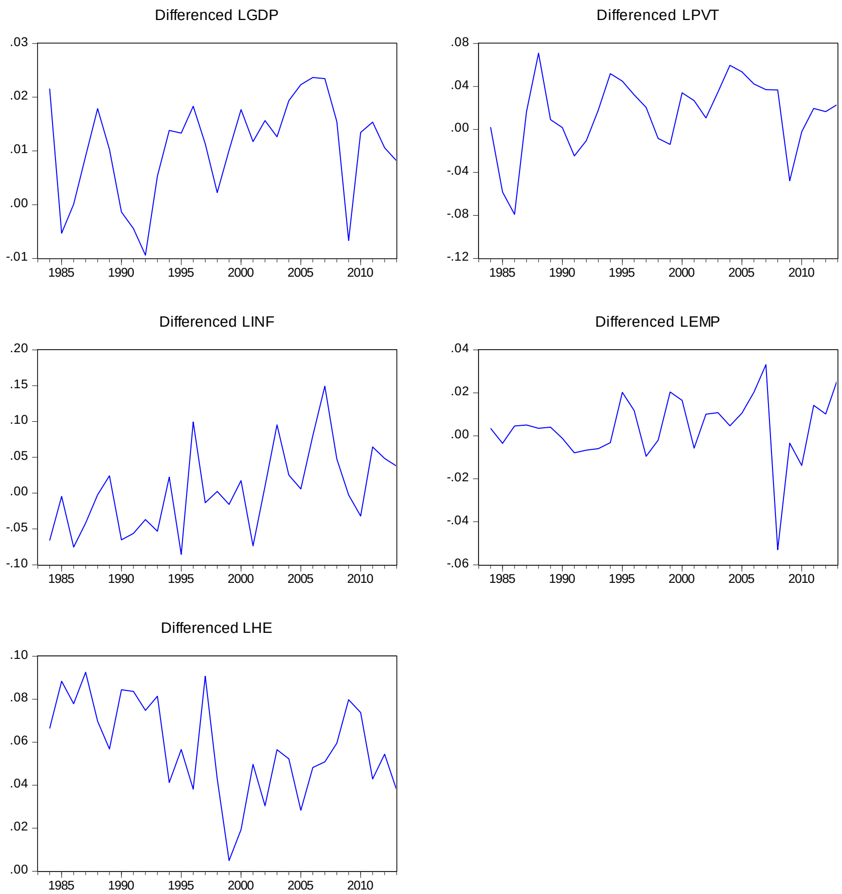


Table B1: Optimal Lag Length Results

Lag	LogL	LR	FPE	AIC	SC	HQ
0	229.6813	NA	1.28e-13	-15.49526	-15.25952	-15.42143
1	414.6888	293.4603*	2.13e-18	-26.53026	-25.11582*	-26.08728*
2	444.5152	37.02586	1.81e-18*	-26.86312*	-24.26997	-26.05098

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Table B2: Autoregressive Roots Results

Roots of Characteristic Polynomial
Endogenous variables: LGDP LPVT LINF LEMP LHE
Exogenous variables: C
Lag specification: 1 2
Date: 10/31/14 Time: 17:32

Root	Modulus
0.987174	0.987174
0.785629	0.785629
0.706049 - 0.141720i	0.720131
0.706049 + 0.141720i	0.720131
0.381804 - 0.528799i	0.652229
0.381804 + 0.528799i	0.652229
-0.154091 - 0.425385i	0.452434
-0.154091 + 0.425385i	0.452434
-0.418389	0.418389
0.222841	0.222841

No root lies outside the unit circle.
VAR satisfies the stability condition.

Figure B2: Autoregressive Roots Results

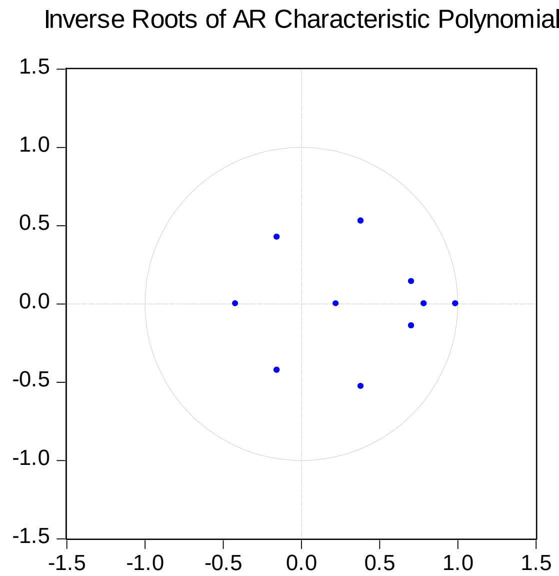


Table B3: VAR Estimation Results

Vector Autoregression Estimates
Date: 12/02/14 Time: 10:38
Sample (adjusted): 1985 2013
Included observations: 29 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	LGDP	LPVT	LINF	LEMP	LHE
LGDP(-1)	1.368034	2.415643	4.441496	0.733942	0.043662
	(0.37241)	(1.04931)	(2.08716)	(0.68135)	(0.96227)
	[3.67346]	[2.30212]	[2.12801]	[1.07719]	[0.04537]
LGDP(-2)	-0.125848	-1.804245	-2.460607	0.647544	0.185725
	(0.38141)	(1.07467)	(2.13759)	(0.69781)	(0.98552)
	[-0.32995]	[-1.67889]	[-1.15111]	[0.92796]	[0.18845]
LPVT(-1)	-0.026877	0.452270	-0.098640	0.060291	-0.133208
	(0.09927)	(0.27972)	(0.55638)	(0.18163)	(0.25651)
	[-0.27073]	[1.61688]	[-0.17729]	[0.33195]	[-0.51930]
LPVT(-2)	-0.012222	-0.104267	0.115037	-0.120713	0.077804
	(0.07851)	(0.22121)	(0.44000)	(0.14364)	(0.20286)
	[-0.15567]	[-0.47135]	[0.26145]	[-0.84039]	[0.38354]
LINF(-1)	-0.048670	-0.023182	0.461593	-0.135263	0.149020

	(0.03567)	(0.10051)	(0.19992)	(0.06526)	(0.09217)
	[-1.36442]	[-0.23065]	[2.30894]	[-2.07261]	[1.61680]
LINF(-2)	0.000189	-0.001900	0.141641	-0.036472	-0.142500
	(0.04162)	(0.11727)	(0.23325)	(0.07615)	(0.10754)
	[0.00453]	[-0.01620]	[0.60724]	[-0.47898]	[-1.32510]
LEMP(-1)	0.216557	0.990489	0.629774	0.146750	-0.226993
	(0.15746)	(0.44366)	(0.88248)	(0.28808)	(0.40686)
	[1.37531]	[2.23253]	[0.71364]	[0.50940]	[-0.55791]
LEMP(-2)	-0.323368	-0.598910	-1.717770	-0.411479	0.361696
	(0.13651)	(0.38463)	(0.76506)	(0.24975)	(0.35272)
	[-2.36884]	[-1.55711]	[-2.24528]	[-1.64755]	[1.02544]
LHE(-1)	0.066522	0.510542	0.959514	-0.312025	1.016132
	(0.10099)	(0.28456)	(0.56602)	(0.18477)	(0.26096)
	[0.65867]	[1.79413]	[1.69521]	[-1.68868]	[3.89387]
LHE(-2)	-0.082223	-0.410207	-1.181813	0.153450	-0.079446
	(0.09792)	(0.27590)	(0.54879)	(0.17915)	(0.25301)
	[-0.83970]	[-1.48679]	[-2.15349]	[0.85654]	[-0.31400]
C	-0.253688	-3.520205	-1.975742	2.144268	-1.721822
	(0.69526)	(1.95898)	(3.89656)	(1.27202)	(1.79648)
	[-0.36488]	[-1.79696]	[-0.50705]	[1.68572]	[-0.95844]
R-squared	0.996745	0.992173	0.959345	0.927580	0.998923
Adj. R-squared	0.994936	0.987825	0.936758	0.887346	0.998325
Sum sq. resids	0.000927	0.007358	0.029110	0.003102	0.006188
S.E. equation	0.007176	0.020218	0.040215	0.013128	0.018541
F-statistic	551.1213	228.1794	42.47462	23.05496	1670.192
Log likelihood	108.9415	78.90061	58.95813	91.42324	81.41190
Akaike AIC	-6.754585	-4.682801	-3.307457	-5.546431	-4.855993
Schwarz SC	-6.235956	-4.164171	-2.788828	-5.027801	-4.337364
Mean dependent	6.125842	5.133790	4.311608	6.937426	4.840293
S.D. dependent	0.100834	0.183232	0.159914	0.039114	0.453070

Determinant resid covariance (dof adj.)	3.63E-19
Determinant resid covariance	3.34E-20
Log likelihood	444.5152
Akaike information criterion	-26.86312
Schwarz criterion	-24.26997

Table B4: Variance Decomposition of LGDP

Period	S.E.	LGDP	LPVT	LINF	LEMP	LHE
1	0.007176	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.012487	95.73830	0.016086	0.902846	2.760712	0.582056
3	0.016932	89.94982	0.453922	7.516689	1.572381	0.507191
4	0.020834	81.80578	1.060640	14.97629	1.597270	0.560015
5	0.023276	77.46805	1.586961	18.78658	1.433033	0.725376
6	0.024977	74.90846	1.865446	21.09807	1.257200	0.870822
7	0.026272	73.34244	1.990439	22.57731	1.137947	0.951866
8	0.027326	72.23919	2.045027	23.68069	1.060001	0.975098
9	0.028208	71.30738	2.075161	24.64943	0.998633	0.969392
10	0.028947	70.47137	2.093031	25.53837	0.948860	0.948369

Table B5: Variance Decomposition of LPVT

Period	S.E.	LGDP	LPVT	LINF	LEMP	LHE
1	0.020218	60.79602	39.20398	0.000000	0.000000	0.000000
2	0.036401	71.25335	19.33323	0.348796	5.030048	4.034575
3	0.044308	77.30226	13.18226	2.514893	3.979484	3.021108
4	0.051951	69.54207	10.20837	13.61147	4.259049	2.379047
5	0.056062	63.58714	9.638291	19.96693	4.482106	2.325530
6	0.057435	61.60310	9.586894	22.11801	4.279882	2.412115
7	0.058085	60.93479	9.472745	22.87848	4.274060	2.439923
8	0.058628	60.68284	9.322269	23.27976	4.305782	2.409346
9	0.059168	60.51716	9.169563	23.68474	4.262582	2.365959
10	0.059685	60.28244	9.031914	24.16978	4.189870	2.325990

Table B6: Variance Decomposition of LINF

Period	S.E.	LGDP	LPVT	LINF	LEMP	LHE
1	0.040215	0.759669	0.015432	99.22490	0.000000	0.000000
2	0.055835	29.14999	1.479834	63.27357	0.039553	6.057051
3	0.067260	48.23607	1.020394	44.05914	2.142913	4.541488
4	0.079992	58.92419	0.863301	32.88695	4.047066	3.278495
5	0.089054	63.50900	1.076239	28.51381	4.197747	2.703204
6	0.096554	65.84951	1.297770	26.51921	3.816799	2.516714
7	0.102847	67.00119	1.508833	25.52810	3.401920	2.559954
8	0.108181	67.38924	1.704533	25.14703	3.076045	2.683152
9	0.112567	67.26128	1.894629	25.16481	2.841439	2.837841
10	0.116043	66.87413	2.064897	25.40443	2.675694	2.980847

Table B7: Variance Decomposition of LEMP

Period	S.E.	LGDP	LPVT	LINF	LEMP	LHE
1	0.013128	12.58905	0.005792	9.932791	77.47237	0.000000
2	0.017074	29.55110	1.207292	11.88944	50.50204	6.850132
3	0.021244	34.13137	2.558321	23.15276	32.67064	7.486903
4	0.022874	33.09650	3.858932	26.51267	28.22294	8.308952
5	0.023634	31.90615	4.515495	27.96292	26.55826	9.057168
6	0.023984	31.33843	4.750240	28.52868	25.94892	9.433727
7	0.024145	31.13688	4.815668	28.69861	25.80113	9.547719
8	0.024234	31.07770	4.833084	28.81096	25.71505	9.563208
9	0.024294	31.06292	4.837589	28.94118	25.61606	9.542246
10	0.024334	31.05244	4.837234	29.05859	25.53623	9.515505

Table B8: Variance Decomposition of LHE

Period	S.E.	LGDP	LPVT	LINF	LEMP	LHE
1	0.018541	7.664505	19.49481	1.160381	12.01555	59.66475
2	0.027394	11.08182	14.96458	1.731623	16.66942	55.55256
3	0.033353	8.877306	14.75741	1.715155	14.79321	59.85692
4	0.036807	7.291563	15.07996	1.521060	14.20190	61.90551
5	0.039561	7.711756	14.92864	1.603634	13.72072	62.03526
6	0.042024	10.15164	14.14115	2.573836	13.05885	60.07453
7	0.044566	13.71318	12.93821	4.714803	12.26033	56.37348
8	0.047164	17.36771	11.66482	7.563501	11.39678	52.00719
9	0.049731	20.64215	10.51787	10.56023	10.52093	47.75882
10	0.052209	23.43596	9.546263	13.38105	9.697892	43.93884

Table B9: VAR Diagnostic Tests

VAR Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Date: 11/24/14 Time: 15:01
Sample: 1983 2013
Included observations: 29

Lags	LM-Stat	Prob
1	27.84924	0.3148
2	40.22077	0.0277
3	28.08374	0.3040
4	39.45338	0.0332
5	29.67162	0.2368

Probs from chi-square with 25 df.

VAR Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)
Null Hypothesis: residuals are multivariate normal
Date: 11/24/14 Time: 15:13
Sample: 1983 2013
Included observations: 29

Component	Jarque-Bera	df	Prob.
1	1.828004	2	0.4009
2	1.929970	2	0.3810
3	1.026057	2	0.5987
4	3.489344	2	0.1747
5	0.698043	2	0.7054
Joint	8.971418	10	0.5348

VAR Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)
Date: 11/24/14 Time: 15:15
Sample: 1983 2013
Included observations: 29

Joint test:

Chi-sq	df	Prob.
304.9458	300	0.4098

Table B10: Cointegration Test Results

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.833533	113.8248	88.80380	0.0003
At most 1	0.619419	61.82906	63.87610	0.0735
At most 2	0.462776	33.81342	42.91525	0.2971
At most 3	0.309679	15.79455	25.87211	0.5091
At most 4	0.159738	5.047192	12.51798	0.5896

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.833533	51.99573	38.33101	0.0008
At most 1	0.619419	28.01565	32.11832	0.1462
At most 2	0.462776	18.01886	25.82321	0.3758
At most 3	0.309679	10.74736	19.38704	0.5395
At most 4	0.159738	5.047192	12.51798	0.5896

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table B11: VECM Results

Vector Error Correction Estimates
Date: 12/02/14 Time: 19:27
Sample (adjusted): 1985 2013
Included observations: 29 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1				
LGDP(-1)	1.000000				
LPVT(-1)	0.392355 (0.05351) [7.33267]				
LINF(-1)	-0.155299 (0.02031) [-7.64602]				
LEMP(-1)	-0.813914 (0.17171) [-4.74006]				
LHE(-1)	-0.065415 (0.05943) [-1.10072]				
@TREND(83)	-0.012055 (0.00386) [-3.12514]				
C	-1.306552				
Error Correction:	**D(LGDP)**	**D(LPVT)**	**D(LINF)**	**D(LEMP)**	**D(LHE)**
CointEq1	-0.177409 (0.09100)	-1.402090 (0.22346)	-0.338075 (0.63625)	0.085259 (0.19622)	0.357498 (0.25306)

	[-1.94962]	[-6.27442]	[-0.53135]	[0.43450]	[1.41272]
D(LGDP(-1))	0.454952	2.647747	4.605117	-0.188033	-0.325577
	(0.36062)	(0.88558)	(2.52149)	(0.77763)	(1.00287)
	[1.26158]	[2.98983]	[1.82635]	[-0.24180]	[-0.32464]
D(LPVT(-1))	0.016893	0.107272	-0.125575	0.073670	-0.163582
	(0.07015)	(0.17226)	(0.49048)	(0.15127)	(0.19508)
	[0.24081]	[0.62272]	[-0.25602]	[0.48703]	[-0.83854]
D(LINF(-1))	-0.019432	-0.113027	-0.109202	-0.095409	0.113680
	(0.02856)	(0.07013)	(0.19969)	(0.06158)	(0.07942)
	[-0.68040]	[-1.61159]	[-0.54685]	[-1.54923]	[1.43133]
D(LEMP(-1))	0.167061	0.306782	0.603625	-0.088335	0.058362
	(0.11582)	(0.28441)	(0.80980)	(0.24974)	(0.32208)
	[1.44247]	[1.07865]	[0.74540]	[-0.35371]	[0.18120]
D(LHE(-1))	0.002136	0.423112	0.435733	-0.340371	0.330052
	(0.08656)	(0.21257)	(0.60524)	(0.18666)	(0.24072)
	[0.02468]	[1.99046]	[0.71993]	[-1.82351]	[1.37109]
C	0.004501	-0.040591	-0.068276	0.025182	0.043435
	(0.00729)	(0.01790)	(0.05096)	(0.01572)	(0.02027)
	[0.61764]	[-2.26796]	[-1.33984]	[1.60236]	[2.14306]
R-squared	0.491272	0.789161	0.367121	0.213368	0.357381
Adj. R-squared	0.352528	0.731659	0.194518	-0.001168	0.182121
Sum sq. resids	0.001194	0.007202	0.058383	0.005553	0.009236
S.E. equation	0.007368	0.018093	0.051515	0.015887	0.020489
F-statistic	3.540849	13.72413	2.126967	0.994557	2.039152
Log likelihood	105.2656	79.21159	48.86714	82.98148	75.60470
Akaike AIC	-6.776940	-4.980110	-2.887389	-5.240102	-4.731359
Schwarz SC	-6.446903	-4.650073	-2.557352	-4.910065	-4.401322
Mean dependent	0.010138	0.014348	0.005883	0.003802	0.057494
S.D. dependent	0.009156	0.034927	0.057399	0.015878	0.022656

Determinant resid covariance (dof adj.)	6.85E-19
Determinant resid covariance	1.72E-19
Log likelihood	420.7383
Akaike information criterion	-26.18885
Schwarz criterion	-24.25578

Table B12: VECM Diagnostic Tests

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Date: 11/24/14 Time: 16:07
Sample: 1983 2013
Included observations: 29

Lags	LM-Stat	Prob
1	25.21921	0.4501
2	18.23386	0.8323
3	24.90067	0.4680
4	29.98946	0.2247
5	28.64186	0.2792

Probs from chi-square with 25 df.

VEC Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)
Date: 11/05/14 Time: 12:15
Sample: 1983 2013
Included observations: 29

Joint test:

Chi-sq	df	Prob.
164.6550	180	0.7874

VEC Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)
Null Hypothesis: residuals are multivariate normal
Date: 11/24/14 Time: 16:08
Sample: 1983 2013
Included observations: 29

Component	Jarque-Bera	df	Prob.
1	0.659283	2	0.7192
2	0.414258	2	0.8129
3	0.187334	2	0.9106
4	2.631841	2	0.2682
5	0.398786	2	0.8192
Joint	4.291502	10	0.9332

Table B13: VAR Granger Causality Results

VAR Granger Causality/Block Exogeneity Wald Tests
Date: 11/02/14 Time: 21:24
Sample: 1983 2013
Included observations: 29

Dependent variable: LGDP

Excluded	Chi-sq	df	Prob.
LPVT	0.611758	2	0.7365
LINF	2.705488	2	0.2585
LEMP	6.674770	2	0.0355
LHE	0.897407	2	0.6385
All	18.07505	8	0.0207

Dependent variable: LPVT

Excluded	Chi-sq	df	Prob.
LGDP	5.359240	2	0.0686
LINF	0.084099	2	0.9588
LEMP	6.511354	2	0.0386
LHE	3.688076	2	0.1582
All	48.80664	8	0.0000

Dependent variable: LINF

Excluded	Chi-sq	df	Prob.
LGDP	5.310437	2	0.0703
LPVT	0.075700	2	0.9629
LEMP	5.186207	2	0.0748
LHE	5.860106	2	0.0534
All	36.06360	8	0.0000

Dependent variable: LEMP

Excluded	Chi-sq	df	Prob.
LGDP	9.751608	2	0.0076
LPVT	1.236075	2	0.5390
LINF	8.224924	2	0.0164
LHE	8.454405	2	0.0146
All	22.57889	8	0.0039

Dependent variable: LHE

Excluded	Chi-sq	df	Prob.
LGDP	0.138231	2	0.9332
LPVT	0.281894	2	0.8685
LINF	2.869453	2	0.2382
LEMP	1.218413	2	0.5438
All	11.04934	8	0.1989

APPENDIX C

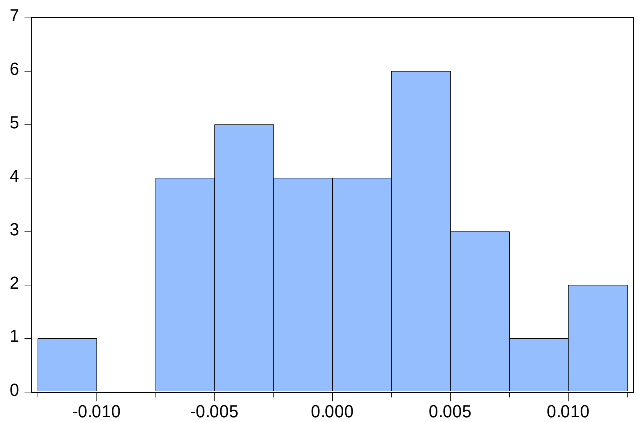
Table C1: FMOLS Results

Dependent Variable: LGDP
Method: Fully Modified Least Squares (FMOLS)
Date: 11/27/14 Time: 20:48
Sample (adjusted): 1984 2013
Included observations: 30 after adjustments
Cointegrating equation deterministics: C @TREND
Long-run covariance estimate (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LPVT	0.065413	0.029953	2.183847	0.0390
LINF	0.088600	0.009866	8.980206	0.0000
LEMP	0.200850	0.083318	2.410635	0.0239
LHE	-0.081402	0.033189	-2.452715	0.0218
C	4.199590	0.667727	6.289381	0.0000
@TREND	0.013041	0.002228	5.851909	0.0000

R-squared	0.996977	Mean dependent var	6.121834
Adjusted R-squared	0.996348	S.D. dependent var	0.101482
S.E. of regression	0.006133	Sum squared resid	0.000903
Long-run variance	3.08E-05		

Figure C1: FMOLS Normality Test Results



Series: Residuals
Sample 1984 2013
Observations 30

Mean	0.000445
Median	0.000952
Maximum	0.010161
Minimum	-0.011369
Std. Dev.	0.005561
Skewness	-0.039188
Kurtosis	2.207874
Jarque-Bera	0.792007
Probability	0.673004

Table C2: CCR Results

Dependent Variable: LGDP
Method: Canonical Cointegrating Regression (CCR)
Date: 11/27/14 Time: 20:51
Sample (adjusted): 1984 2013
Included observations: 30 after adjustments
Cointegrating equation deterministics: C @TREND
Long-run covariance estimate (Bartlett kernel, Newey-West fixed bandwidth
= 4.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LPVT	0.062210	0.029838	2.084893	0.0479
LINF	0.089032	0.011312	7.870792	0.0000
LEMP	0.209997	0.105911	1.982761	0.0590
LHE	-0.077443	0.035497	-2.181674	0.0392
C	4.134523	0.839262	4.926381	0.0001
@TREND	0.012856	0.002394	5.369486	0.0000

R-squared	0.996894	Mean dependent var	6.121834
Adjusted R-squared	0.996247	S.D. dependent var	0.101482
S.E. of regression	0.006217	Sum squared resid	0.000928
Long-run variance	3.08E-05		

Figure C2: CCR Normality Test Results

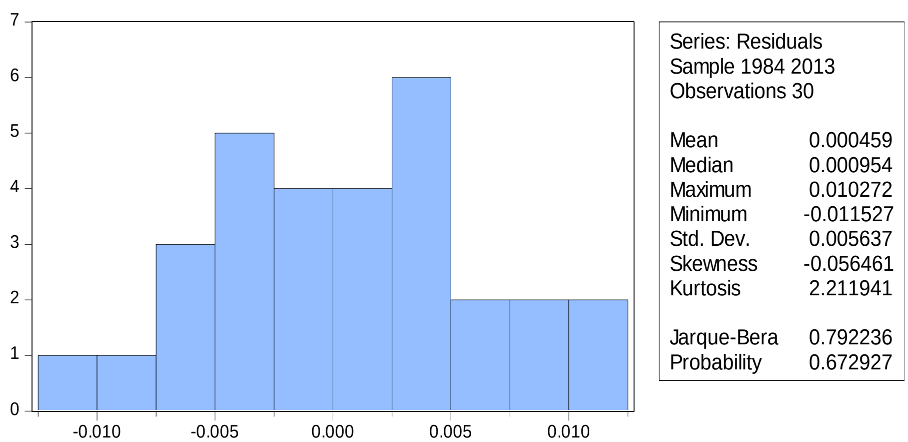


Table C3: DOLS Results

Dependent Variable: LGDP
Method: Dynamic Least Squares (DOLS)
Date: 11/27/14 Time: 20:50
Sample (adjusted): 1985 2012
Included observations: 28 after adjustments
Cointegrating equation deterministics: C @TREND
Fixed leads and lags specification (lead=1, lag=1)
Long-run variance estimate (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LPVT	0.028874	0.070501	0.409557	0.6908
LINF	0.111227	0.020809	5.345238	0.0003
LEMP	0.284666	0.196975	1.445187	0.1790
LHE	-0.067497	0.058199	-1.159776	0.2731
C	3.640237	1.576343	2.309292	0.0436
@TREND	0.012668	0.004212	3.007872	0.0132

R-squared	0.999107	Mean dependent var	6.119636
Adjusted R-squared	0.997590	S.D. dependent var	0.096881
S.E. of regression	0.004757	Sum squared resid	0.000226
Long-run variance	2.65E-05		

Figure C3: DOLS Normality Test Results

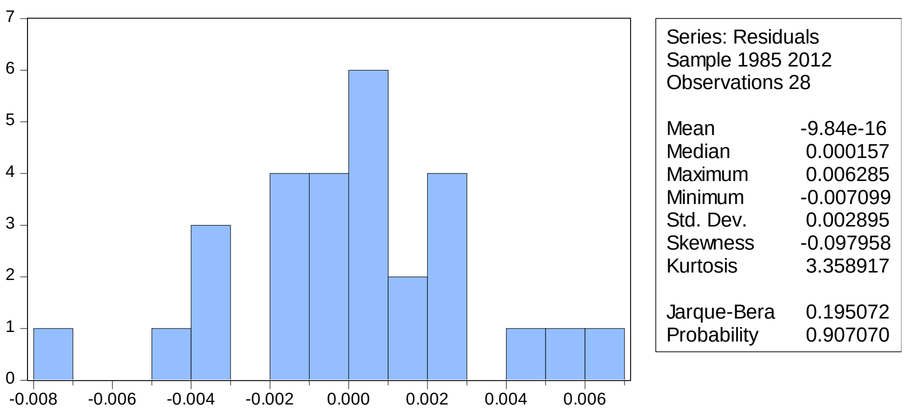


Table C4: ARDL Model Estimates

```
                  Autoregressive Distributed Lag Estimates
       ARDL(1,1,0,0,0) selected based on Akaike Information Criterion
*******************************************************************************
 Dependent variable is LGDP
 30 observations used for estimation from 1984 to 2013
*******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 LGDP(-1)                   .56005             .11677             4.7961[.000]
 LPVT                       .18993            .030505             6.2261[.000]
 LPVT(-1)                  -.12012            .031784            -3.7792[.001]
 LHE                      -.075104            .025399            -2.9570[.007]
 LINF                      .029564            .015573             1.8983[.071]
 LEMP                      .031684            .063809             .49654[.624]
 TREND                    .0073404           .0021367             3.4354[.002]
 INPT                       2.2321             .74763             2.9856[.007]
*******************************************************************************
 R-Squared                     .99881   R-Bar-Squared                   .99844
 S.E. of Regression          .0040135   F-Stat.    F(7,22)      2645.6[.000]
 Mean of Dependent Variable    6.1218   S.D. of Dependent Variable      .10148
 Residual Sum of Squares     .3544E-3   Equation Log-likelihood       127.6271
 Akaike Info. Criterion      119.6271   Schwarz Bayesian Criterion    114.0223
 DW-statistic                  1.9869   Durbin's h-statistic     .046558[.963]
*******************************************************************************

Testing for existence of a level relationship among the variables in the ARDL model
*******************************************************************************
 F-statistic  95% Lower Bound  95% Upper Bound  90% Lower Bound  90% Upper Bound
    5.0588         4.1977          5.5082           3.4682          4.6455

 W-statistic  95% Lower Bound  95% Upper Bound  90% Lower Bound  90% Upper Bound
   25.2939        20.9886         27.5409          17.3408         23.2276
*******************************************************************************
```

Table C5: ARDL Long Run Coefficient Estimates

```
Estimated Long Run Coefficients using the ARDL Approach
       ARDL(1,1,0,0,0) selected based on Akaike Information Criterion
*******************************************************************************
 Dependent variable is LGDP
 30 observations used for estimation from 1984 to 2013
*******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 LPVT                       .15868            .060895             2.6058[.016]
 LHE                       -.17071            .067077            -2.5450[.018]
 LINF                      .067197            .021936             3.0634[.006]
 LEMP                      .072016             .14268             .50473[.619]
 TREND                     .016685           .0041704             4.0007[.001]
 INPT                       5.0735             1.1698             4.3372[.000]
*******************************************************************************
```

Table C6: ARDL Short Run Coefficient Estimates

```
        Error Correction Representation for the Selected ARDL Model
       ARDL(1,1,0,0,0) selected based on Akaike Information Criterion
*******************************************************************************
 Dependent variable is dLGDP
 30 observations used for estimation from 1984 to 2013
*******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 dLPVT                      .18993            .030505              6.2261[.000]
 dLHE                     -.075104            .025399             -2.9570[.007]
 dLINF                     .029564            .015573              1.8983[.070]
 dLEMP                     .031684            .063809               .49654[.624]
 dTREND                   .0073404           .0021367              3.4354[.002]
 ecm(-1)                   -.43995             .11677             -3.7676[.001]
*******************************************************************************
 List of additional temporary variables created:
 dLGDP = LGDP-LGDP(-1)
 dLPVT = LPVT-LPVT(-1)
 dLHE = LHE-LHE(-1)
 dLINF = LINF-LINF(-1)
 dLEMP = LEMP-LEMP(-1)
 dTREND = TREND-TREND(-1)
 ecm = LGDP   -.15868*LPVT +   .17071*LHE  -.067197*LINF  -.072016*LEMP  -.0166
 85*TREND   -5.0735*INPT
*******************************************************************************
 R-Squared                    .85678   R-Bar-Squared                      .81122
 S.E. of Regression         .0040135   F-Stat.    F(6,23)     21.9357[.000]
 Mean of Dependent Variable  .010520   S.D. of Dependent Variable    .0092371
 Residual Sum of Squares    .3544E-3   Equation Log-likelihood       127.6271
 Akaike Info. Criterion     119.6271   Schwarz Bayesian Criterion    114.0223
 DW-statistic                 1.9869
*******************************************************************************
 R-Squared and R-Bar-Squared measures refer to the dependent variable
 dLGDP and in cases where the error correction model is highly
 restricted, these measures could become negative.
```

Table C7: ARDL Diagnostic Tests

```
                               Diagnostic Tests
*******************************************************************************
*    Test Statistics  *        LM Version       *         F Version          *
*******************************************************************************
*                     *                         *                            *
* A:Serial Correlation*CHSQ(1)  =  .085497[.770]*F(1,21)      =  .060019[.809]*
*                     *                         *                            *
* B:Functional Form   *CHSQ(1)  =   .47147[.492]*F(1,21)      =   .33530[.569]*
*                     *                         *                            *
* C:Normality         *CHSQ(2)  =   .47733[.788]*       Not applicable       *
*                     *                         *                            *
* D:Heteroscedasticity*CHSQ(1)  =   .35994[.549]*F(1,28)      =   .34002[.564]*
*******************************************************************************
   A:Lagrange multiplier test of residual serial correlation
   B:Ramsey's RESET test using the square of the fitted values
   C:Based on a test of skewness and kurtosis of residuals
   D:Based on the regression of squared residuals on squared fitted values
```