**UNIVERSITY OF ZIMBABWE**

# THE ROLE OF INFRASTRUCTURE DEVELOPMENT IN ECONOMIC GROWTH IN ZIMBABWE (1981-2008)

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## DEDICATION

This dissertation is dedicated to my husband and my sons, who have been supportive throughout its compilation. Thank you for your patience and encouragement and being there for me.

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# ABSTRACT

The current study is aimed at examining the role infrastructure development plays in influencing economic growth in Zimbabwe using time series data from 1981 to 2008. The study also seeks to establish the direction of causality between infrastructure development and economic growth. The study makes use of three infrastructure indicators namely electricity production per capita, telephone mainlines density and energy consumption per capita to capture the effects of infrastructure development on economic growth. The study employed the VAR approach to examine the impact of infrastructure development on economic growth. The study findings revealed that infrastructure development as measured by all three indicators has positive effect on economic growth in the short run. In the long run, the study results were mixed with electricity production and energy consumption indicators having positive effects and telephone mainlines density exhibiting negative effect. The granger causality test revealed that past values of telephone mainlines density and energy consumption have an effect on future economic growth performance, while electricity production does not.

# Contents

**ACCRONYMS**

| | |
|---|---|
| AfDB | African Development Bank |
| AIC | Alkaike Information Criterion |
| AICD | Africa Infrastructure Country Diagnostic |
| CRS | Constant Returns to Scale |
| ESAP | Economic Structural Adjustment Programme |
| FDI | Foreign Direct Investment |
| FPE | Final Prediction Error |
| GCI | Global Competitiveness Index |
| GDP | Gross Domestic Product |
| GNP | Gross National Product |
| GNU | Government of National Unity |
| IFS | International Financial Statistics |
| IMF | International Monetary Fund |
| RBZ | Reserve Bank of Zimbabwe |
| SADC | Southern Africa Development Community |
| SIC | Schwartz information Criterion |
| VAR | Vector Autoregression |
| VEC | Vector Error Correction |
| WB | World Bank |
| WEF | World Economic Forum |
| ZEDTC | Zimbabwe Electricity Transmission and Distribution Company |
| ZESA | Zimbabwe Electricity Supply Authority |
| ZINARA | Zimbabwe National Road Agency |
| ZPC | Zimbabwe Power Company |

# CHAPTER 1
# OVERVIEW OF THE STUDY

## 1.1 INTRODUCTION

There has been arenewed concern with infrastructure by policy makers in both developed and developing countries which can be traced back tothe mid 1980s. From the mid 1980s to mid 1990s a number of countries had undertaken the structural adjustment reforms sponsored by the IMF and the World Bank. As a consequence this led to the reduced dominance of public sector provision of infrastructure as a result of the increasing pressures of fiscal adjustment and consolidation. In many developed countries there was an increased pace of opening up of infrastructure industries to private participation as reflected in widespread privatization of public utilities and multiplication of concession and other forms of public-private partnerships. However, in less developed countries this has been slow especially in many African countries, hence infrastructure development continues to lag behind.

Infrastructure can be defined as the capital stock that provides public goods and services, Yoshino &Nakahigashi (2000). It consists of both economic and social components. Economic infrastructure refers to public utilities and works that promote economic activity, such as roads, highways, railroads, airports, sea ports, electricity, telecommunications, water supply and sanitation. Social infrastructure is defined as the infrastructure that promotes the health, education and cultural standards of the population – activities that have both direct and indirect impact on the welfare. It consists of schools, libraries, universities, clinics, hospitals, courts, museums, theatres, playground and national parks.

Extensive and efficient infrastructure is critical for ensuring the effective functioning of an economy as it is an important factor determining the location of economic activity and the kinds of activities or sectors that can develop (World Economic Forum, GCI 2011). Studies carried out by Aschauer (1989), Canning, *et al* (1989), Easterly (2002) among others emphasize that well-developed infrastructure reduces the effect of distance between regions, integrating the national market and connecting it at low cost to markets in other countries and regions. In addition, the quality and extensiveness of infrastructure networks significantly impact economic growth and reduce income inequalities and poverty in a variety of ways.

According to the World Bank AICD Report (2005), infrastructure has been responsible for more than half of Africa's recent improved growth performance and has the potential to contribute even more in the future. The report,however, revealed that in Africainfrastructure networks are increasingly lagging behind those of other developing countries and are often characterized by missing regional links and stagnant household access.The infrastructure services are twice as expensive as in other parts of the world. Power is said to be the largest infrastructure challenge, with 30 countries facing regularpower shortages and many paying high premiums for emergency power. Another characteristic is that a large share of Africa's infrastructure is domestically financed, with the central government budget being the main driver of infrastructure investment.

The current study seeks to establish the role infrastructure development plays in influencing Zimbabwe economic growth performance for the period 1981-2008. Given the broad spectrum of infrastructure,and limitations in data availability the study will focus on three components of economic infrastructure, namely electricity, energy and telecommunication. Studies empirically examining the nexus between infrastructure development and economic growth have been done mostly in East Asian economies for example studies bySeethepalli*et al* (2008), Straub *et al* (2006) among others, but they are very few studies for African economies.

## 1.2 RESEARCH PROBLEM

The persistent decline in economic growth in Zimbabwe, experienced from the late 1990's to 2008 seems to be associated with a decline in the quality of infrastructure provision. Currentlythere is a prevailing sentiment from both the private and public stakeholders that the undersupply of infrastructure services is a binding constraint to the full recovery of the economy.The fact that the government requested the African Development Bank (AfDB)in January 2010 for assistance in assessing the state of Zimbabwe's infrastructure as well as establishing guidelines for the country's infrastructure investment projects, underscores the importance of infrastructure development in the country.The lack of sufficient and reliable infrastructure services is said to be holding back private investment in the economy. The current study therefore seeks to investigate the role of infrastructure development in influencing the growth of the Zimbabwean economy and to establish direction of causality if any.

Given the scarcity of financial resources in the country policy makers need to have a clear understanding of the extent to which infrastructure influences growth of the economy.The country needs an estimated $2 billion per year for the next decade, which translates to about 46% of GDP[1] annually in order to address the infrastructure challenges. It is therefore imperative to empirically examine the influence of infrastructure development on economic growth in Zimbabwe.

## 1.3 STUDY OBJECTIVE

The main objective of this research is to provide an empirical evaluation of the impact of infrastructure developmenton economic growth.The study also seeks to establish direction of causality between infrastructure indicators and economic growth.

## 1.4 HYPOTHESIS

Infrastructure developmentplays a positive role in economic growth in Zimbabwe.

## 1.5 JUSTIFICATION OF THE STUDY

The current study will add to existing literature on infrastructure and economic growth in Zimbabwe by providing an empirical evaluation of the relationship between the two.Much of the available literature in Zimbabwe on the subject is based more on the qualitative assessments and hardly any empirical investigation into the role infrastructure plays in economic growth.As an example,thecountry report on *Growth and Infrastructure in Zimbabwe*, sponsored by the AfDB in 2011, provide an assessment on the state of infrastructure development in Zimbabweand guidelines to the country’s infrastructure investment projects but does not carry out empirical

[1] The IMF GDP for 2009 was $4,397 billion (www.imf.org/external/np/sec/pn/2010/pn1062.htm)

tests to establish the role infrastructure plays in the country's economic growth.The study byPuskok&Briceno–Garmendia (2011) on *Zimbabwe's Infrastructure a Continental Perspective*only provides a comparative assessment of infrastructure development in the country.

The restoration of Zimbabwe's infrastructure baseis one of the greatest challengesthe country faces in having sustained economic growth. The economic cost of the recent neglect of maintenance, compounded by the legacy of past under-investment in infrastructure, places a considerable burden on the country.Costs of rehabilitation of infrastructure tend to be much higher than the costs of regular maintenance. The current study will assist policy makers in formulating growth stimulating policies by providing a clear understanding of the role infrastructure development plays in economic growth.

The country's competitiveness on the international platform has not been impressive, and infrastructure is one of the important factors said to be influencing the performance of the economy.Zimbabwe's global competitiveness ranking is currently at 132 out of a total of 149 countries in 2011, a slight improvement from the 136th rank 2010. The sub pillar index rank for infrastructure stands at 127 of the 149 countries[2].It is therefore important to examine the role infrastructure development in economic growth.

## 1.6 OUTLINE OF THE PAPER

The rest of the paper will be structured as follows: Chapter 2 looks at infrastructure development and economic growth in Zimbabwe, Chapter 3 review of literature on effects of infrastructure development on economic growth, Chapter 4 methodology, Chapter 5 estimation and analysis of results and Chapter 6conclusions and policy recommendations.

[2]Infrastructure is one of the 12 pillars of competitiveness and the infrastructure index rank for infrastructure is obtained from assigned scores on quality of overall infrastructure, quality of roads, quality of railroad infrastructure, quality of port infrastructure, quality of air transport, available airline seats km/week millions, quality of electricity supply, fixed telephone lines per 100 population and fixed mobile telephone subscriptions per 100 population

# CHAPTER 2

# INFRASTRUCTURE DEVELOPMENT AND ECONOMIC GROWTH IN ZIMBABWE

## 2.1 Introduction

The chapter provides a brief overview of infrastructure development in Zimbabwe, current state of some infrastructure sectorsand the trend in economic growth.

## 2.2 Infrastructure development in Zimbabwe

Zimbabwe made significant progress in infrastructure development following the attainment of independence in 1980, and also benefited substantively from the colonial infrastructure stocks. The country's infrastructurebackbone is very impressive compared to other countries in the Southern Africa region. Zimbabwe managed to put in place a national electricity network and establish regional interconnection in the power sector; to build an extensive network of roads for countrywide accessibility and integration into the regional transport corridors; to lay the water and sewerage system; and to make progress on building dams and tapping the significant irrigation potential, Puskok N &Briceno–Garmendia, (2011).The country is well integrated with all the neighbouring countries when it comes to road transport and power networks. It serves as a critical link for trade for its landlocked neighboursBotswana and Zambia.

As with many countries in Sub-Saharan Africa, Zimbabwe has a huge infrastructure gap, which stem from the lack ofnew investment and maintenance. Major cuts in public spending following the Economic Structural Adjustment Programme (ESAP) in 1990's have had a bearing on infrastructure development. Despite the major investments in infrastructure stocks the country has made, the assets are not generating the quantity and quality of services demanded.

The African Development Bank (AfDB) Zimbabwe Infrastructure report dubbed "*The Infrastructure and Growth in Zimbabwe (2010)*", spells out the extent of deterioration of Zimbabwe's infrastructure. The current study will provide just an overview of the current state of some of the major infrastructure sectors the country has developed.

### *2.2.1 Road*

Zimbabwe road network is managed by a number of authorities namely the State, Rural District Councils and Municipalities. The Ministry of Transport, Department of Roads is responsible for the primary and secondary roads, which links cities and towns as well centres of growth and development. District Councils are responsible for tertiary roads whichaccount for about 40% of the total road network. Municipalities are responsible for servicing about 9% of total road network in urban areas. The Zimbabwe National Road Agency (ZINARA) oversees the managing of road maintenance funds as well as setting user tariffs. Of the country's total road network of the 88,133 kilometres only about 15,000 kilometres are paved. The proportion of roads in fair to good condition has declined from 73 percent in 1995 to only 60 percent in 2009. In additional 12,800 kilometres was re-classified to 'poor condition', requiring complete rehabilitation at a cost of about US$1,1 billion at 2009 prices[3].

### *2.2.2 Rail*

The railway system in Zimbabwe is made up of 2,760 km of narrow gauge main track lines, of which 313 km are electrified, about 2,500 km of branch lines and sidings. The rail track is in poor condition and about 9% is under speed restriction.Railfalls under the responsibility of the National Railways of Zimbabwewhich is a statutory board of government with the exception of the Bulawayo-Beitbridge line.

The total rail traffic declined from nearly 14million tones per year in 1990 to an estimated 2,7 million tonnes in 2009, which is barely 15 percent of the original network capacity[4]. The available locomotive and rolling stock capacity is now well below what is required to meet

[3] AfDB (2010) , *The Infrastructure and Growth in Zimbabwe*

[4] Ibid

demand.Little expansion has taken place since the lines were constructed in mid twentieth century.

### *2.2.3 Electricity*

The power sector is crucial in that it plays a strategic in enabling and promoting economic activity is all sectors of the economy. There is state monopoly in the generation, transmission and distribution of electricity. ZESA Holdings a state owned company holds the government share of four of its subsidiaries namely the Zimbabwe Power Company (ZPC), Zimbabwe Electricity Transmission and Distribution Company (ZEDTC). The installed capacity is about 1960MW while the demand varies between 1600MW to 2100MW.Electricity consumption per capita inZimbabwe was 738 kWh in 1995, when theaverage for low income countries aroundthe world was 414 kWh per capita and theaverage for Sub-Saharan Africa was 437kWh. By 2009 per capita consumption inZimbabwe had declined to about 600kWh per capita, only marginally higher than theaverage for all of Sub-Saharan Africa[5]. The country now has less power generation capacity than it did at any time in the last 30 years. The demand for electricity in Zimbabwefar exceeds supply.

### *2.2.4 Telecommunication*

Zimbabwe has made some institutional reforms such as the creation of the Postal and Telecommunications Regulatory Authority of Zimbabwe (POTRAZ). The country has introduced competition in the mobile sector with three operators: Econet, Telecel, and Net-One. There is only one fixed-line operator and four Internet service providers (ISPs), and Econet dominates the mobile market. Fixed operator Tel-One and its mobile subsidiary Net-One are state owned.Zimbabwe has fallen behind its regional counterparts in terms of information communication technology service and broadband penetration. In 1995,Zimbabwe had 0.1 mobile phone subscribersper 100 people, similar to the rest of Sub-Saharan Africa. By 2005, the number stoodat 5.6 per 100 for Zimbabwe compared to12.5 per hundred for Sub-Saharan Africa,and 30.6 for lower middle income countriesaround the world[6].

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[5]AfDB (2011)

[6] Multi-Donor Trust Fund (2010), Zimbabwe Public Expenditure Notes, "*Financial and Regulatory Challenges in Infrastructure Parastatals and Sectors*"

## 2.3 Infrastructure and competiveness

Zimbabwe's competitiveness on the international platform has declined, and infrastructure is one of the important factors said to be influencing the performance of the economy. The country is classified as a factor driven economy[7], where competitiveness is maintained through well-functioning public andprivate institutions, well-developed infrastructure, a stable macroeconomic environment, and a healthy workforce that has received at least a basic education (WEF GCI Report 2011)[8]. Zimbabwe's global competitiveness ranking is currently at 132 out of a total of 149 countries in 2011, a slight improvement from the 136th rank 2010. The sub pillar index rank for infrastructure stands at 127 of the 149 countries[9]. Compared to other countries in the SADC region Zimbabwe's state of infrastructure has deteriorated and the efficiency with which infrastructure services are delivered has been a major glitch to the growth of the economy (See table 1).

The infrastructure index for Zimbabwe ranks behind countries like Zambia and Mozambique which currently rank at 112 and 123 respectively while Namibia and South Africa continues to lead the region with ranks of 58 and 62 respectively. Angola, Madagascar and Malawi are among the least ranked in infrastructure, with indices of 140, 133 and 131 respectively. The infrastructure indices reveal the need for improvement in quality and quantity of infrastructure in

[7]An economy is factor-driven and countries compete based on their factor endowments: primarily unskilled labor and natural resources. Companies tend to compete on the basis of price and sell basic commodities, with their low productivity reflected in low wages

[8] World Economic Forum, Global Competitiveness Report 2011, defines competitiveness as the set of institutions, policies, and factors that determine the level of productivity of a country.

[9]Infrastructure is one of the 12 pillars of competitiveness and the infrastructure index rank for infrastructure is obtained from assigned scores on quality of overall infrastructure, quality of roads, quality of railroad infrastructure, quality of port infrastructure, quality of air transport, available airline seats km/week millions, quality of electricity supply, fixed telephone lines per 100 population and fixed mobile telephone subscriptions per 100 population

order to improve the country's competitiveness and in the process economic growth and development.

**Table 1: Global Infrastructure Index rankings for SADC countries**

| Country | Global Competitiveness Rank 2011 | Infrastructure Index rank 2011 |
|---|---|---|
| Angola | 139 | 140 |
| Botswana | 80 | 92 |
| Lesotho | 135 | 124 |
| Madagascar | 130 | 133 |
| Malawi | 117 | 131 |
| Mozambique | 133 | 123 |
| Namibia | 83 | 58 |
| South Africa | 50 | 62 |
| Tanzania | 120 | 130 |
| Zambia | 113 | 112 |
| Zimbabwe | 132 | 127 |

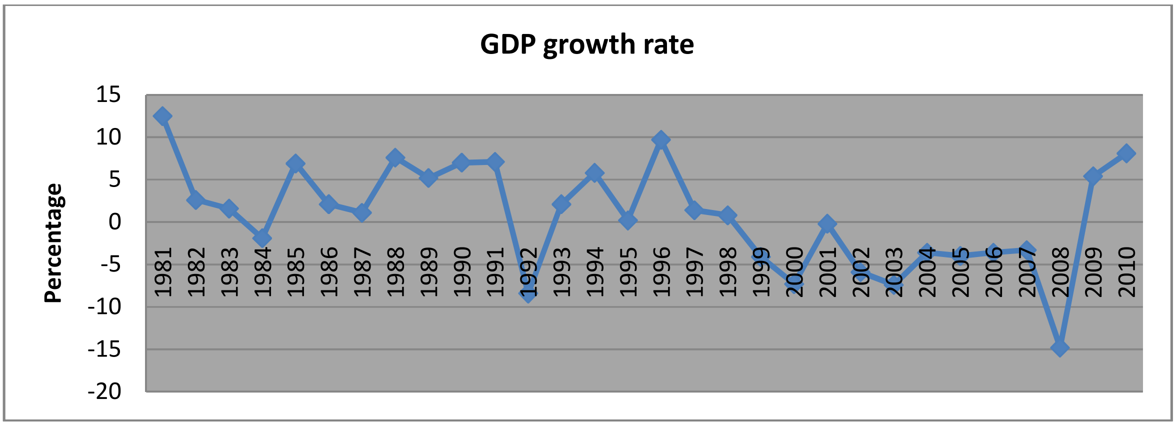
Source: World Economic Forum (WEF), Global Competitiveness Report, 2011

## 2.4 Economic Growth in Zimbabwe

Zimbabwe stands out as one of the few African countries that registered growth rates comparable to those of other developing countries regardless of the controlled macroeconomic environment which prevailed a decade following its independence. Much of the economic policies adopted for the period 1980 - 1990 had origins in the preceding Rhodesian government which had adopted inward looking, import substituting policies in response to international economic sanctions and isolation (Mbengegwi&Mabugu, 2002).

The removal of economic sanctions, following the attainment of independence in 1980 coincided with an improvement in world market prices which contributed to the county's impressive growth in GDP of 10.7% 1980 and 9.7% 1981 (see Figure 1).However, following the 1983- 1984 drought the GDP growth declined to -1.9% in 1984. Though growth in GDP improved for the period 1985-1989 it was not as high as the independence period since government retained the import substitution policies characterized by controls in all major economic activity. The government was targeting increasing of state participation in the economy and establishing new socio-economic institutions run and controlled by the people" (Government of Zimbabwe, 1982: 17).

**Figure 1: Gross Domestic Product GDP growth rate**




Source: CSO Quarterly Bulletin 2000, Various CSO monthly Bulletins., Reserve Bank of Zimbabwe indicators,

By mid 1980s the import substitution policies were not yielding any positive effects on growth and the government needed to come up with a new policy program. The country embarked on the World Bank sponsored Economic Structural Adjustment Programme (ESAP) in 1991, aimed at opening up the economy by pursuing export driven strategy. After a promising start with GDP growth rate of 7.1% in 1991, the economy declined in performance to -8.2% in 1992 as a result of the severe 1991/92 drought. The weak policy implementation, especially in the field of public sector and fiscal reforms also contributed to low growth. The failure of the ESAP contributed to dissatisfaction with liberalization policies from both the government and private sector, and helped strengthen the voice of those supporting increased state intervention in the economy in the form of land resettlement, management of the exchange rate and foreign currency earnings.

The economy registered impressive growth rate in 1996 of 9.7%, owing to improved export performance and alignment of the exchange rate. However, this was short-lived as the government embarked on huge unbudgeted expenditure towards supporting Zimbabwean troops involved in the Democratic Republic of Congo war as well as gratuity payouts made to war veterans. As a result economic growth declined from 1.4% in 1997 to 0.8% in 1998. The situation degenerated further by year 2000 owing to disruption of farming activities as a result of farm invasions and land reform exercise.

The period covering 2001-2008 was the most turbulent in terms of economic performance. The most notable events which affected the economic growth include the shortages of foreign currency, basic food stuffs, fuel and the Zimbabwean currency which were rampant from 2005-2008. These events not only fueled the parallel market activities but, also high levels of inflation. The decline in GDP for the period was at its worst in 2008 estimated at -14.8%[10]. Inflation was estimated around 1,216% in 2008. The political instability of 2008 only worsened the already fragile state of the economy.However, the formation of Government of National Unity (GNU) and adoption of the multicurrency system in 2009, instilled confidence back in the economy and this led a positive GDP growth rate of 5.4% and 8.1% for 2009 and 2010 respectively.

[10] There were no official inflation figures for the period , -14.8% is an IMF estimate

## CHAPTER 3:
## LITERATURE REVIEW

### 3.1 Introduction

This chapter looks at the theoretical and empirical literature concerning the relationship between economic growth and infrastructure development. The chapterwill explore how production functiongrowth theories factor in infrastructure as a component that influences output and ultimately overall economic growth. The study will focus on two most prominent theories of growth in literature namely the neoclassical growth theory also known as the Solow- Swan growth model and the endogenous growth theory.

### 3.2 The Production function

Growth theory in essence seeks to explain determinants of economic growth within a country and reasons for differences in growth rates and per capita incomes across countries.Central to growth theory is the use of the production function in establishing the determinants of growth of national output in an economy. The production function links the amount of output produced in an economy to the inputs of factors of production and state of technical knowledge (Dornbusch, R & Fischer, S 1994). The standard neoclassical model states that the level of output depends on just two inputs, labor and capital, and on the available technology. The relationship is commonly specified as a Cobb-Douglas function, named after Charles Cobb and Paul Douglas.

$$Q= f\,(AK,L) \qquad (1)$$

Where $Q$ is the aggregate output, $K$ is capital inputs, $L$ is labour inputs and $A$ denotes the state of technology or technological progress. The conventional neoclassical assumes technological progress is exogenously determined and the law diminishing returns holds. When tested empirically, the Cobb-Douglas function yields estimates of the responsiveness of output to a variation in inputs.The relationship can be expressed as follows

$$Y = Af(K,L) \quad (2)$$

### 3.3 Exogenous Growth Theory

**Neoclassical Growth Model**

The neoclassical growth model commonly known as the Solow growth model is an extension of the Harrod - Domar (1946) growth model which regard capital stock as the only factor of output production. Solow and Swan (1956) modified the Harrod -Domar Model to include labour as factor of production. The neoclassical model assumescapital is subject to diminishing returns to scale. Where output *Y(t)* is produced from capital stock *K(t)* and augmented labour*A(t)L(t)*, the neoclassical model can be summarized as follows.

$$Y(t) = f\,[K_t^{\alpha}\,(A_tL_t)]^{\beta} \quad (3)$$

Where $\alpha + \beta = 1$ depicting constant returns to scale.

According to the neoclassical growth model, in the short-run rate of economic growth is influenced by capital accumulation as determined by the saving and depreciation rates. In the long-runeconomic growth is exogenously determined by population growth rate and technological progress growth rate.

An important prediction of this model is international convergence in output levels: as poor countries are assumed to grow faster than rich countries. Another prediction is that when capital is mobile, advanced economies should invest in poor countries where capital is scarce and the marginal returns to investment are high.

Given the neoclassical growth model notion that long run growth is influenced by technological progress and labour force growth due to population change, shocks in infrastructure stock can only have temporary effects on income in the model. The possibility of infrastructure influencing output in the long run rests on endogenous growth theory which allows increasing or decreasing returns to scale can raise the steady state income per capita (Sahoo*et al*2010).

## 3.4 Endogenous growth theory

The endogenous growth theory also known as the new growth theory came about as a result of the dissatisfaction with how the exogenous growth theory explained long run economic growth. The endogenous growth model developed by Romer (1986) and Lucas (1988) focused on the role of human capital as a main source of increasing returns and divergence in growth rates between developed and underdeveloped countries.The endogenous growth theory states that investment in humancapital, innovation and knowledge are significant contributors to economic growth. In other words economic growth is mainly a result of endogenous and not external factors. The theory also emphasizes the importance of positive externalities and spillover effects as well as policy measures in determining economic growth in the long run.

### The AK Model

The simplest endogenous growth model is a straightforward extension of the Solow model as is defined as follows.

$$Y = AK^{\alpha}L^{\beta} \qquad [4]$$

Where Y is national output, K is composite measure of capital stock and A is a constant on assumption of constant returns to scale (CRS). The CRS replaces the assumption of diminishing returns to scale in neoclassical growth theory so that investment matters for long run growth and growth is endogenous (KhaledHussien& A.P Thirwall, 2000).

The new growth theory, such as the first model in Lucas (1988), endogenizes the technology factor as follows:

$$At = BH^{c} \qquad 0 < c < 1 \qquad [5]$$

where H, is the level of human capital stock. If H increases by 1 percent, A, is assumed to increase by c percent.

Supposing that labor input is allocated between physical output production and human capital production by*xL*, and (1- x)L, respectively. Then the production function of equation (4) can be respecified as

$$Y = B[K^{a}H^{c}(xL)^{b}] \qquad (6)$$

In this model, endogenous growth is possible as long as there is continuous investment in human capital even if it keeps being accumulated. Model (6) introduces a critical assumption that there are no diminishing returns in the production of human capital.

Endogenous growth model purports that the growth rate of the economy depends positively on the savings/investment rate, therefore, any public policymeasure that increases the savings rate accelerates economic growth permanently.The model implies divergence in international income. If two economies start out with different initial stocks ofcapital, then the absolute gap gets larger as time proceeds. If two economies have different savings rates and hencedifferent growth rate, the ratio of international income level explodes (collapses).

Some of the early proponents of endogenous growth theory also include Kenneth Arrow (1962), HirohumiUzawa (1965), Miguel Sidrauki (1967), Paul M. Romer (1986), Robert Emerson Lucas (1988) and Rebelo (1991)[11].

**Conclusion**

Both endogenous and exogenous growth theories do not explicitly specify the role of infrastructure capital in the production process, whether it represent an additional input factor in the production function or influence the technology with which other inputs are combined. The role of infrastructure is implied on the premise of the underlying assumptions of the growth theories.Infrastructure investments feature temporary growth effects in the presence of

[11]En.Wikipedia.org/wiki/Endogenous_growth_theory

diminishing returns to capital under exogenous theory, while under the endogenoustheory they improve the efficiency of all other input factors and hence long-run productivity growth.

### 3.5 EMPIRICAL REVIEW

The impact of infrastructure on long-run economic growth has been studied extensively in literature. The basic theoretical framework of the impact of public capital on economic growth was developed first by Arrow and Kurz (1970). The empirical research on the role of infrastructure in economic growth started after the seminal work by Aschauer (1989).Various estimation methodologies linking infrastructure to economic performance using a variety of data (panel and time series data) and measures of infrastructure have been adopted over the years.

Majority of literature concerned with the growth effects of infrastructure, focuses on one single infrastructure sector. Some studies do this by design while others take a broad view of infrastructure but employ a single indicator for their empirical analysis of growth. The main reason for this simplification is the high correlation among measures of various kinds of infrastructure telecommunications, power capacity, road and railway networks, water and sanitation. In a linear regression framework, this close association among different infrastructure categories makes it difficult to obtain reliable estimates of the individual coefficients of variables representing different kinds of infrastructure assets.

Calderón and Servén (2004) carried out an empirical evaluation of the impact ofinfrastructure developmenton economic growth and the distribution of income using panel data of 121 countries over the 1960-2000 period.Unlike studies in literature, which focuses on one specific infrastructure sector, Calderon and Serven (2004) considered simultaneously transport, power and telecommunications, and also some experiments involving the water sector. The study took into account both quantity and quality of infrastructures and computed indices for stocks of infrastructure and improved quality of services as a measure of infrastructure development along with other economic growth control variables. Their results revealed that the volume ofinfrastructure stocks has a significant positive effect on long-run economic growth.

Theconclusion was robust to changes in the infrastructure measure used as well as the estimationtechnique applied. In contrast, the link between infrastructure quality and growth appearedempirically less robust, which they suggested reflect limitations of quality measures orstrong correlation in quantity and quality, such that quality effects ongrowth are already captured by the quantity measures.

With regard toincome inequality, infrastructure quantity and quality revealed a strong negative impact. A variety of specification testscarried out suggested that their results do capture the causal impact of the exogenous component of infrastructure quantity and quality on growth and inequality. Their two results combined suggest that infrastructure development can be highly effective in combating poverty. Simulations they carried out for Latin American countries suggested thatthese impacts are economically quite significant, and highlight the growth acceleration and inequalityreduction that would result from increased availability and quality of infrastructure.

The study by Canning and Pedroni (2004)used the production function approach based on the growth model developed byBarro (1990), to investigate the long run consequences of infrastructure provision on per capita income. Using panel data, theyregarded infrastructurestocksnamely paved roads, electricity generation and telephone lines as an input into aggregate production function. In their conclusions Canning and Pedroni(2004) were of the opinion that, there is an optimal level of infrastructure whichmaximizes the growth rate such that if infrastructure levels are set too high they divert investment awayfrom other capital to the point where income growth is reduced[12].Their study also revealed that in most cases infrastructure does induce long run growth effects, even though there may be variation in the results across individual countries. As a whole, their results demonstrate that telephones, electricity generating capacity and paved roads are provided at close to the growth maximizing level on average, but are under-supplied in some countries and over-supplied in others. These results help to explain

[12]Their model implied a simple “reduced form” relationship between income per capita and infrastructure stocks per capita. Below the growth maximizing infrastructure level positive shocks to infrastructure would tend to increase the level of output, while above the optimal level positive infrastructure shocks would tend to reduce the level of output. This therefore can help identify where each country’s infrastructure stock stands relative to the growth-maximizing level. From the simple panel based tests they developed which enabled them to isolate the sign and direction of the long run effect of infrastructure on income in a manner that is robust to the presence of unknown heterogeneous short run causal relationships.

why cross section and time series studies have in the past found contradictory results regarding a causal link between infrastructure provision and long run growth.

Stephane Straub, Charles Vellutini and Michael Warlters (2008) looked at the relationship between infrastructure and economic growth in East Asia. Using indicators from electricity, telecommunications and transport sectors they employed both growth accounting framework andcross-country regressionsto examine whether infrastructure investment has, indeed,contributed to East Asia's economic growth.Straub *et al* 2008, came up with two major conclusions firstly for most of the variables used, both the growthaccounting exercise and cross-country regressions fail to find a significant link betweeninfrastructure, productivity and growth. However when they do, they produce rather contradictoryconclusions, as growth accounting indicates no contribution of infrastructure to productivityin the richer countries (South Korea and Singapore), and some contribution in the relativelypoorest countries (of telecommunications in Indonesia and Philippines, and of roads inThailand), while cross-country growth regressions tend to indicate that the effects aregenerally negative for low-income countries and positive only for the high-income ones.Cross country growth regressions by Straub*et al* (2008), provide relatively fragile results on the impact of infrastructure in per capita GDP growth, a conclusion that contrasts with previous studies that found robust results (Easterly and Servén, 1993.

On the contrary to the study by Straub *et al* (2008), Seethepalli,Bramati, and Veredas (2008), found positive and significant effects for all infrastructure variables.Seethepalli*et al*(2008) examined how infrastructure sub-sectors – energy, telecommunications, water supply, sanitation, and transport – contributed to growth in East Asia during 1985-2004.They used a production function specification to examine theimpact of infrastructure on East Asia's growth. Their study provided additional insights on the relationship between infrastructure and growth by including the degree of private participation in infrastructure, the quality of governance, the extent of rural-urban inequality in access to infrastructure services, country income levels, as well as geography asadditional variables. Seethepalli*et al* 2008 results revealed that greater stocks of infrastructure were indeed associated with higher growth. However, infrastructure impact on the five additional variables yielded different results, with some sectors supporting conventional expectations and others yielding mixed or counterintuitive results. In particular, the telecom and sanitation sectors yield statistically significant results; electricity and water infrastructure provided mixed results; and road infrastructure consistently contradicts expectations.

D´emurger, Sylvie (2000)provided empirical evidence on the links between infrastructure investmentand economic growth in China.De'murger (2000), approach sought to explain disparities in economic growth in Chinese provinces. Using panel data from a sample of 24 Chinese provincesthroughout the 1985 to 1998 period, the estimation of a growthmodel shows that, besides differences in terms of reforms and openness, geographicallocation and infrastructure endowment did account significantly for observed differences ingrowth performance across provinces. The results indicate that transport facilities are a key differentiating factor in explaining the growth gap and point to the role of telecommunicationin reducing the burden of isolation.

A study Lumbila (2005) quoted in Estache (2006), revealed that African countries with larger infrastructure stocks experience significantly more foreign direct investment (FDI) and domestic investment than countries with low stock levels. Lumbila approximated infrastructure stock by telephone connections. The study revealed that countries with more developed infrastructure see a disproportionately greater impact of infrastructure on FDI and domestic investment on growth. However, countries with lower, underdeveloped infrastructure see no statistically significant impact of infrastructure of investment on growth. According to Estache (2006) this suggests that a lack of infrastructure can be an impediment to more investment, and it can also be one of the dimensions of the poverty trap argument since it seems that a critical mass of infrastructure is needed to convince investors to make the decisions leading to growth.

Aschauer (2000) finds that the stock of public infrastructure capital is a significant determinant of aggregate total factor of productivity and that investments in public sector not only improve quality of life but also increase economic growth and returns for private investments.

### 2.2.3 Conclusion

The majority of empirical literature results are consistent with the widely-accepted idea in policy research that infrastructure plays an important role in promoting growth.However there are studies which have found negatively results and the reasons for the contradiction has been a data constrains and time period considered in the analysis being insufficient to fully capture infrastructure impacts.

# CHAPTER 4
# METHODOLOGY

## 4.1 Introduction

This chapter serves to explain the methodology to be employed in the analysis of the role of infrastructure in economic growth. The chapter will look at: model specification, unit root tests, Granger Causality test and Vector Autoregression (VAR) estimation techniquesimpulse response functions and variance decomposition.

The study will make use of indicators from the power and telecommunications sectors to investigate the impact of infrastructure on economic growth. The study will also make use of time series data for the period 1981 to 2008.

## 4.2 Vector Autoregression (VAR)

The study is mainly looking at the role of infrastructure development in influencing economic growth as measured by the real GDP, by assessing infrastructure development impact on economic growth. The choice of VARmodel was influenced by the possibility of one or more endogenous variables arising from the arguable nature of the transmission mechanism between infrastructure and growth in the economy.In a linear regression framework, the close association among different infrastructure indicators makes it difficult to obtain reliable estimates of the individual coefficients of variables representing different kinds of infrastructure assets.There is a high degree of correlation among measures of various kinds of infrastructure that is: telecommunications, power capacity, road and railway networks, water and sanitation.

The VAR approach circumvent the need for structural modeling by treating all the variables as endogenous in the system as a function of the lagged values of all endogenous variables in the system.The compactness of structural VAR has two attractive features which are, the relative ease of estimation and interpretation, than large simultaneous models.

The concept of autoregressionarise in economic theory, when any economic cause produces its effect only after some lag in time, such that the effect is not felt all at once at a single point in time but is distributed over a period of time.

The mathematical representation of a VAR system is given by;

$[Y]_t = [A_0] + [A_1][Y]_{t-1} + \ldots\ldots\ldots\ldots + [A_p][Y]_{t-k} + [e]_t$

Where *p* is the number of variables in the system, *k* is the number of lags considered in the system, [Yt], [Yt-1], …, [Yt-k] are 1 x p vector of variables, [A],…[Ap] are p x p matrices of coefficients to be estimated, [e]t is 1 x p vector innovations.

The equations for the VAR model in the study will be as follows

$$GDPt = C1 + \sum_{k=1}^{n} \beta 1GDPt - k + \sum_{k=1}^{n} \beta 2PVTt - k + \sum_{k=1}^{n} \beta 3InfLt - k + e1t$$

$$PVTt = C2 + \sum_{k=1}^{n} \alpha 1PVTt - k + \sum_{k=1}^{n} \alpha 2GDPt - k + \sum_{k=1}^{n} \alpha 3Inft - k + e2t$$

$$Inft = C3 + \sum_{k=1}^{n} \lambda 1Inft - k + \sum_{k=1}^{n} \lambda 2GDPt - k + \sum_{k=1}^{n} \lambda 3PVTt - k + e3t$$

Where $GDP_t$ is the real gross domestic product,$PVT_t$ is the domestic private investment, $Inf_t$– infrastructure indicator. The infrastructure indicators are introduced separately into the system to capture their individual impact.$C_i$,$\beta i$, $\alpha_i$ and $\lambda_i$ are parameters to be estimated,$e_i$'s are the stochasticerror terms referred to as innovations or shocks.

## 4.3 ESTIMATION PROCEDURE

Preliminary tests on the time series data such as unit root tests will be carried out prior to carrying the VAR estimations.

#### *4.3.1 Unit root tests*

The existence of unit roots indicates the non-stationarity in a data series. The Augmented Dickey Fuller (ADF) test is to be used to test the existence of unit roots and determine the order of integration of the variables. According to Engle and Granger 1987 a non-stationary series *X* is said to be integrated of *d* if it can be made stationery by differencing it *d* times.

#### *4.3.2 Granger Causality tests*

Causality as defined by Granger (1969) exists when lagged values of a variable, have explanatory power on another variable. The idea of causality is that the cause precedes the effect, that is, if economic growth is the cause of infrastructure development, then economic growth should precede infrastructure development. Therefore, if economic growthgranger causes infrastructure developmentindicators, the prediction error of current infrastructure indicator declines when lagged values of real GDPare used.If both variables that is real GDP and infrastructure indicator X cause one another, then there is feedback mechanism in the system.

However, Granger Causality tests require the series to be stationarysince using non-stationary data can yield spurious causality results (Simset al. (1990).If series are non-stationary they may also be cointegrated, that is, theremay be a stationary relationship between them even though they are individually non-stationary. In that case, Vector Error Correction Model (VECM) a multivariate model containing errorcorrection mechanism terms will have to be used. Cointegration guarantees the existence of Granger causality between the series in at least one direction. Bycontrast, if series are integrated but not cointegrated, causality tests may beimplemented by estimating a VAR for the differenced series to achieve stationarity.

#### *4.3.3VAR Diagnostic Tests (Lag length, Stability and Residual Tests)*

Before estimation, there is need to check the appropriateness of VAR so that we do not end up with a spurious VAR. The optimal lag length will be determined using the lag length selection criteria using theAlkaike Information Criterion (AIC). There is also need to carry out the stability condition test. The VAR residual serial correlation test will be done using the autocorrelation

LM Test. Residual normality test is to be carried out using the JarqueBera statistic. The residual heteroskedasticity test will also be carried out.

#### *4.3.4 Impulse Response Functions and Variance Decomposition*

The impulse response functions as well as the forecast error variance decomposition will be part of the analysis of this study. Both computations are useful in assessing how shocks to economic variables reverberate through a system.

Impulse Response functionis used to produce a time path of dependent variables in the VAR, to shocks from all explanatory variables. If the system equation is stable, any shock should decline to zero and an unstable system would produce an explosive path. Impulse response functions enable one of the variables in the system to shocked and define its path on the system all else being constant.

Variance Decomposition serves as an alternative method for examining the effects of shocks on the dependent variable. Wald decomposition theorem purports that it is possible to uniquely decompose the variance of each variable into components accounted for by each innovation, in the absence of contemporaneous correlation among innovation. The variance decomposition technique determines how much of the forecast error variance of variable in the system is explained by innovation to each explanatory variable over a series of time shocks. Own series tend to explain much of the shocks of the error variance, although the shock will also affect other variables.

## 4.4 Definition of Variables

**Real Gross Domestic Product:**

Real gross domestic product GDP refers to GDP that has been adjusted to base year using the GDP deflator. GDP measures the total value of final goods and services produced by the residents of a country, unlike the gross national product (GNP) which includes net transfer payments abroad. Changes in real GDP reveal how an economy is performing over a given period of time, implying the growth rate of the economy.

**Domestic Private Investment:**

This refers to the aggregate private sector investment in the Zimbabwean economy.Private investment is a form of capital and is regarded as the engine for economic growth in the country. Private investment stimulates increased productivity in crucial economic sectors like mining, agriculture and manufacturing.

**Infrastructure Indicators:**

- **Telecommunications sector:** Telephone mainlines density as measured by telephone mainlines per 1000 people. A telephone mainline is a single fixed telephone line going to a house or structure irrespective of a number of the number of telephones connected to that particular line. The telecommunications sector was chosen because it has been the most dynamic infrastructure sector in the Zimbabwean economy.
- **Power sector: Electricity production (in kilowatts per capita) -** refers to the aggregate electricity generated in the economy divided by the population size. This measures the production of power plants and combined heat and power plants less transmission, distribution and transformation losses and own use heat and power plants.The power sector was chosen because of the crucial role it plays in enabling and promoting economic activity is all sectors of the economy.
- **Energy Consumption: Energy Use (Kilogram (Kg) of oil equivalent per capita).** Energy refers to the use of primary energy before transformation to other end use fuels which is equal to indigenous production plus imports and stock changes minus exports and fuels supplied to aircraft engaged in international transport.

### 4.5 Data Sources

Data on real GDP was obtained from Zimstats National Income Accounts, Quarterly Digests of Statistics and Reserve Bank of Zimbabwe (RBZ). Private investment data were obtained from the IMF's International Financial Statistics. Data on infrastructure indicator electricity production was obtained from African Development Indicators. The energy consumption per capita and telephone lines series were obtained from the World Bank database of Economic Indicators.

# CHAPTER 5
# ESTIMATION AND ANALYSIS OF RESULTS

## 5.1 Introduction

The results of tests carried out in the study as well as their interpretation are presented in this chapter. The relationship between economic growth and infrastructure is then established. Econometric procedures were done using Econometric Views (E-View, Version 5.0).

## 5.2 Unit Root Tests

The presence of unit root indicates that the variables are not stationary. Unit root tests were carried out. Electricity production per capita (ELECPC) series were stationary at levels. The other variables were not stationary at levels i.e. we failed to reject null hypothesis that there is presence of unit roots at levels. After first differencing the domestic private investment (LPVT) and energy use per capita (ENERG) variables became stationary therefore they are I(1) as shown in Table 2. Real GDP (LLRGDP) and Telephone mainlines per 1000 people (LLTELLNE) became stationary at second differencing therefore they are I(2).

**Table 2: Unit Root test results**

| VARIABLE | Augmented Dickey Fuller Test statistic | Critical Values at 1% level of significance | Critical Values at 5% level of significance | CONCLUSION |
|---|---|---|---|---|
| **Unit Root tests at levels** | | | | |
| ELECPC | -3.852640 | -4.394309 | -3.612199 | Stationary |
| **Unit Root tests at first difference** | | | | |
| LPVT | -2.434639 | -2.669359 | -1.956406 | Stationary |
| LENERG | -2.107214 | -2.669359 | -1.956406 | Stationary |
| **Unit Root tests at second difference** | | | | |
| LLRGDP | -4.028854 | -3.769567 | -3.004861 | Stationary |
| LLTELLNE | -3.965842 | -3.769567 | -3.004861 | Stationary |
| | | | | |

Since the variables are not integrated of the same order, it implies that they are not cointegrated therefore there is no need for carrying out cointegration test. The VECM cannot be employed and this warrants the use of VAR approach.

**5.3 VAR Lag Structure and Residual DiagnosticTests**

The generated estimatesare only reliable if the model being estimated represents the true relationship generating the data. The VAR lag length test was carried out using the lag length selection criterion and was found to be one (see Appendix II). The stability check of the model was done and was found to be stable as all the roots of the polynomial were within the unit circle.The VAR residual diagnostic tests were done so as to avoid running a spurious VAR. Residual tests on serial correlation using lag order 1 were also carried out and there was no presence of serial correlation found. The VAR residual tests for normality and heteroskedasticity revealed that were also carried out.For the detailed diagnostic tests results of the system of equations involving the different infrastructure indicators see the Appendix II.

**5.4 GRANGER CAUSALITY**

The Granger causality tests are used to determine whether one variable can help improve the forecast of another. The concept involves the effect of past values of one variable on current values of another. Pairwise Granger causality Tests were carried out using E-Views 5 and results were as shown in Table 3.

Basing on the probability outcome of the Granger Causality test of 0.03237, we fail to accept the null hypothesis that domestic private investment does not granger cause real GDP and conclude that domestic private investment does granger cause real GDP. Real GDP however does not granger cause domestic private investment. This implies that domestic private investment can help improve forecast of economic growth, as past values of domestic private investment have an effect on current values of real GDP.

The granger causality test results in table 3 also reveal that electricity production does not granger causes real GDP, neither do real GDP granger cause electricity production given the probabilities of 0.86385 and 0.36602 respectively. Therefore electricity generation capacity does not granger cause economic growth. The results also reveal that electricity production does not granger cause domestic private investment. Domestic private investment, however, granger causes electricity production given the probability 0.01235. This may imply that domestic private investment play a role in influencing the future electricity generation capacity.

The granger causality test results show that the infrastructure indicator of energy consumption granger causes real GDP, as we fail to accept the null hypothesis basing on the probability of 0.02245. This result may imply that current energy consumption may have a causal effect on future economic growth performance. The causality is unidirectional as real GDP does not granger cause energy consumption.

There is a bidirectional granger causality between telephone mainlines density and real GDP. Given the probability outcomes of 0.00155 and 0.00459, at 5% p-value we conclude that telephone mainlines density granger causes real GDP and real GDP granger causes telephone mainlines density. This implies a feedback mechanism between the provision of telephone mainlines and economic growth. This also implies that past values of telephone mainlines help predict current economic growth performance. The telecommunication technology play an important role in reducing transaction costs through providing improved connectivity and reduction in the burden of isolation for households and businesses alike.

With regards to telephone mainlines density and domestic private investment there is a bidirectional causality. At 10% p-value, we can conclude telephone mainlines density granger causes domestic private investment. At 5% p-value we can conclude that domestic private investment granger causes telephone mainlines density. The relationship could possibly arise as a result of the facilitative role telecommunication infrastructure plays in business transactions thereby reducing costs.

**Table 3: Pairwise Granger Causality Tests – Summary**

Sample: 1981 2008

Lags: 1

| Null Hypothesis: | Obs | F-Statistic | Probability |
|---|---|---|---|
| LPVT does not Granger Cause LLRGDP | 25 | 5.21763 | 0.03237 |
| LLRGDP does not Granger Cause LPVT | | 0.09683 | 0.75859 |
| LELECPC does not Granger Cause LLRGDP | 25 | 0.03010 | 0.86385 |
| LLRGDP does not Granger Cause LELECPC | | 0.85194 | 0.36602 |
| LELECPC does not Granger Cause LPVT | 25 | 0.87522 | 0.35923 |
| LPVT does not Granger Cause LELECPC | | 7.37078 | 0.01235 |
| LENERG does not Granger Cause LLRGDP | 25 | 6.02783 | 0.02245 |
| LLRGDP does not Granger Cause LENERG | | 2.39688 | 0.13584 |
| LENERG does not Granger Cause LPVT | 25 | 1.16605 | 0.29141 |
| LPVT does not Granger Cause LENERG | | 0.00294 | 0.95719 |
| LLTELLNE does not Granger Cause LLRGDP | 25 | 13.0472 | 0.00155 |
| LLRGDP does not Granger Cause LLTELLNE | | 9.95807 | 0.00459 |
| LLTELLNE does not Granger Cause LPVT | 25 | 3.49544 | 0.07491 |
| LPVT does not Granger Cause LLTELLNE | | 4.74552 | 0.04037 |

The Granger causality tests results show that telephone mainlines density and energy consumption can help improve the forecast of economic growth. Economic growth likewise can help improve the forecast of telephone mainline density, but not energy consumption. Domestic private investment granger causes economic growth and electricity production. This implies that the causality effect of infrastructure on economic growth is stronger than that of economic growth on infrastructure.

## 5.5 IMPULSE RESPONSE FUNCTIONS

The impulse response function is used to produce a time path of dependent variables in the VAR to shocks from all explanatory variables

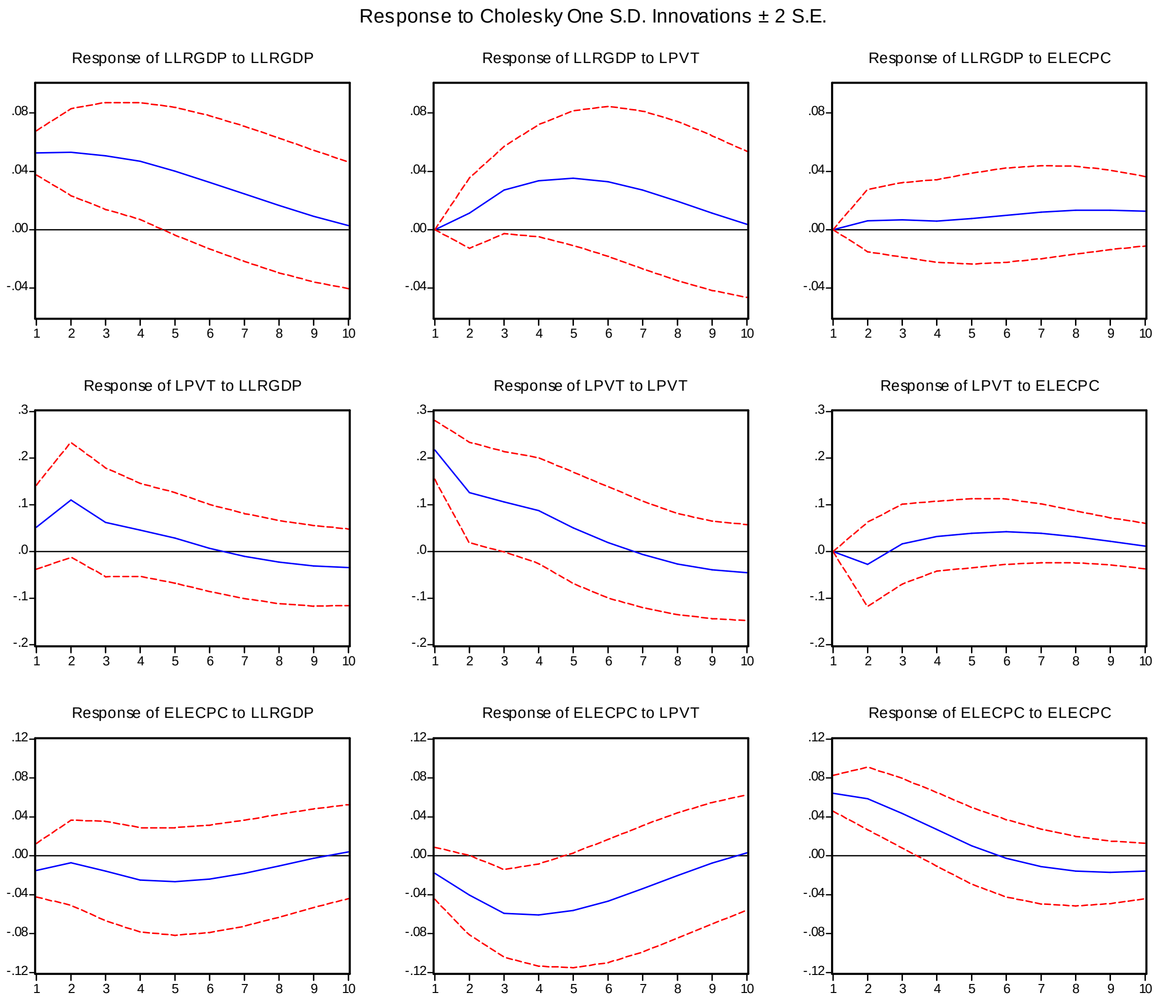
### *5.5.1 Impulse response – Real GDP, Domestic Private Investment and Electricity Production*

The results from the study reveal that real GDP responds positively to own shocks for the 10 year period (see Figure 2).The greatest response is felt in the first 4 years and then begins to decline from the 5$^{th}$ year onwards. This implies that economic growth responds positively to own shocks.The response of real GDP to shocks in domestic private investment is positive throughout the ten year period, meaning that economic growth responds positively to shocks in domestic private investment. Response of real GDP to shocks in electricity production is positive throughout the 10 year period, though at very low levels. This shows that economic growth responds positively to shocks in electricity generation.As shown in figure 2, the response of real GDP to shocks in electricity production starts out at 0 but rises as we get to period 2. From period to period 4 it remains constant and rises further from period 5 to period 8.

Domestic private investment responds positively to real GDP shocks in the short run but negatively in the long run. With regards to own shocks domestic private investment also respond positively in the short run and negatively in the long run. Response of domestic private investment to shocks in electricity generation is negative in the first two years, but becomes positive in the long run.

Response of electricity production to shocks in economic growth as represented by real GDP, is negative in both the short and long run. The response of electricity production to shocks in domestic private investment is also negative in both the short and long run. The response of electricity production to own shocks is positive in the short run and negative in the long run as shown in figure 2.

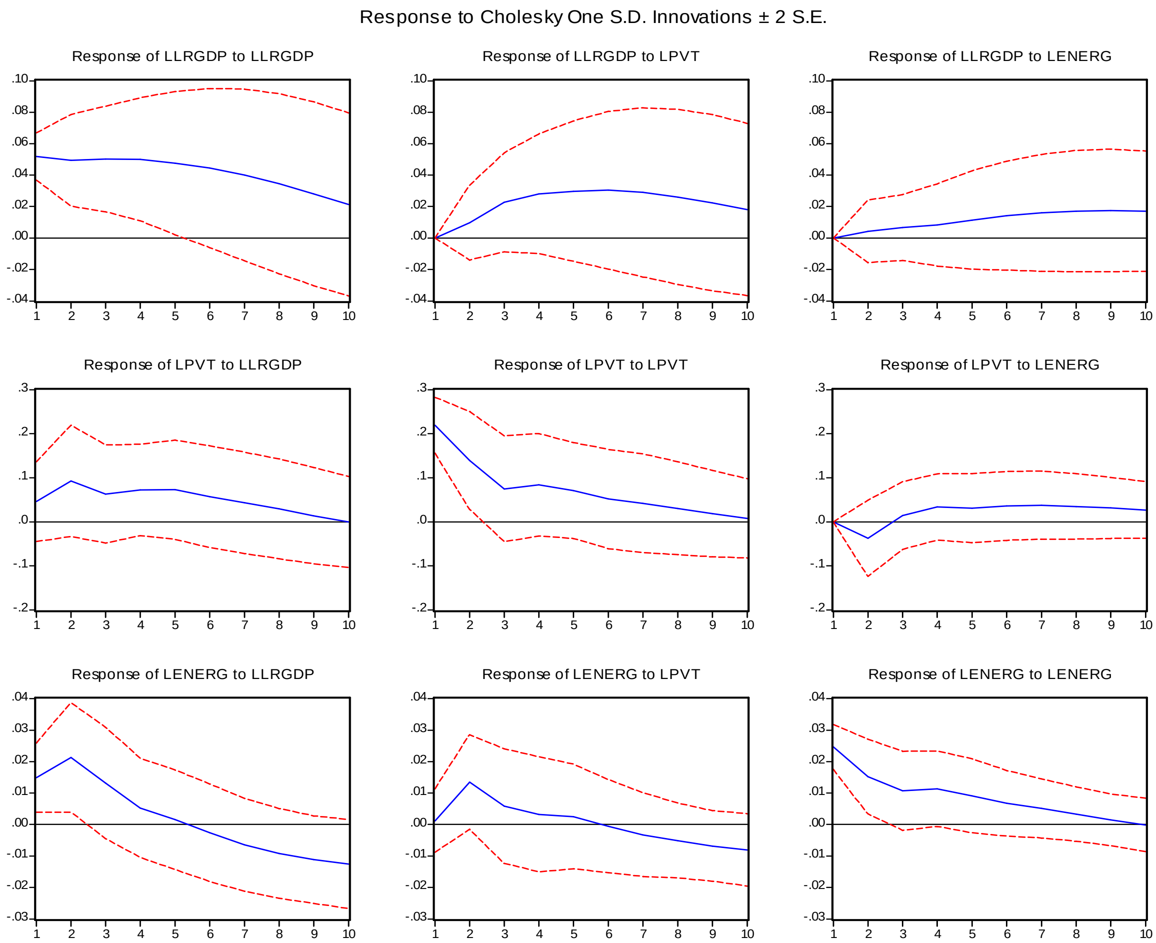
**Figure 2: Impulse response functions Real GDP, Domestic Private Investment and Electricity Production**




***5.5.2 Impulse response - Real GDP, Domestic Private Investment and Energy consumption***

When energy consumption is considered in the system, real GDP responds positively and quite significantly to own shocks in both the short and long run. However the greatest effect is felt from period 1 to period 5 as shown in figure 3. From period 4 it starts declining but remaining in the positive range. The response of real GDP to shocks in domestic private investment is also positive throughout the 10 year period, though it initially starts at zero in period 1.The response of real GDP to shocks in energy consumption is positive throughout the 10 year period though it initially begins at zero. Real GDP responds more positively to energy consumption  in the long run from period 6 onwards. This shows that economic growth responds positively to shocks in energy use.

**Figure: 3 Impulse response functions Real GDP, Domestic Private Investment and Energy**




The response of domestic private investment to shocks in real GDP is positive from period 1 to period 9. Domestic private investment responds positively own shocks and the response is more pronounced in the short run. The response of domestic private investment to shocks in energy consumption is negative in the short run that is from period I to period 3. In the long run domestic private investment responds positively to shocks in energy consumption.

Energy consumption on the other hand responds positively to shocks in real GDP in the short run but negatively in the long run. A similar pattern also emerge with regards to shocks in domestic private investment, in the short run energy consumption responds positively and in the long run negatively. Response of energy consumption to own shocks is positive in both the short and long run periods. Positive effect of own shocks are more pronounced in the initial period than any other period.

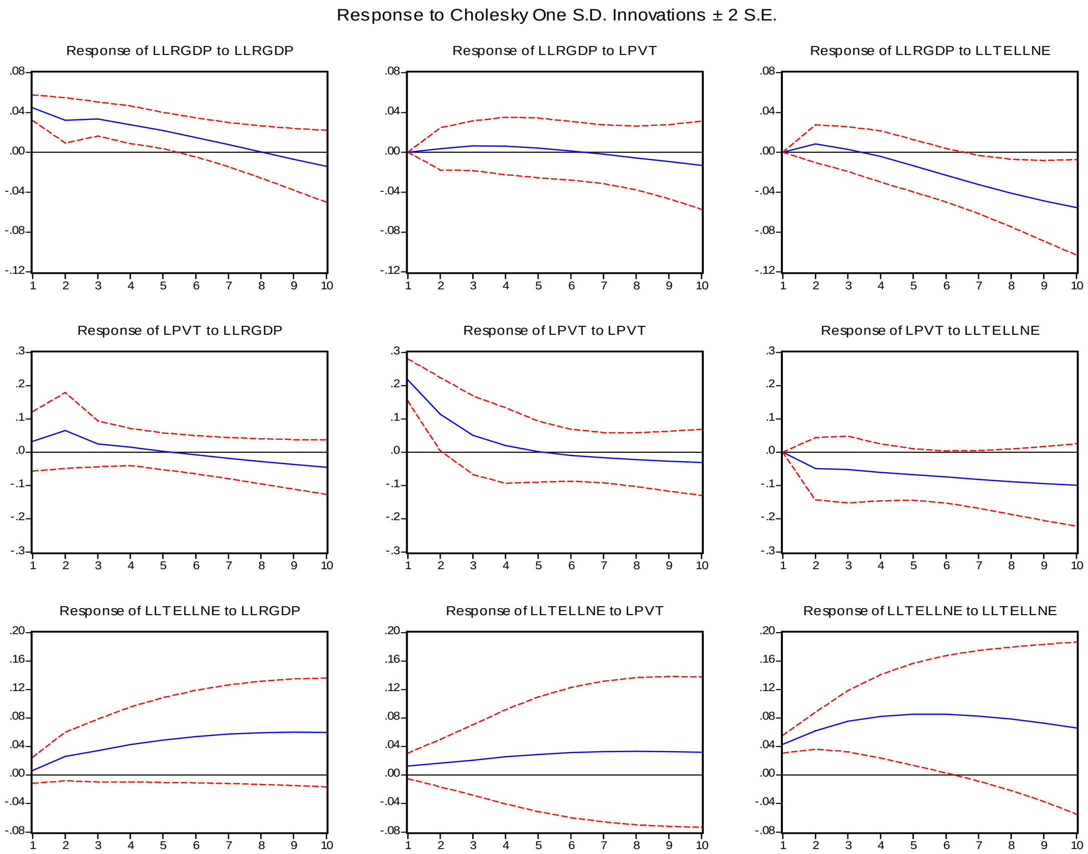
### *5.5.3Impulse response - Real GDP, DomesticPrivate Investment and Telephone mainlines Density*

The response of real GDP to own shocks when telephone mainlines density is added in the system is positive in the short run and tends to negative in period 8. The response of real GDP to shocks in domestic private investment holding other things constant is positive in the short run at low levels and becomes negative in the long run. The response of real GDP to telephone mainlines density is positive in the first 3 years, and becomes negative for the rest of the 10 year period.

Domestic private investment responds positively to shocks in real GDP in the short run and negatively in the long run as depicted in figure 4. The response of domestic private investment to own shocks is positive in the short run and turns negative in 5$^{th}$ period going forward. The response of domestic private investment to shocks telephone mainlines density in negative in both the short and the long run.

Telephone mainlines density responds positively to in shocks real GDP, domestic private investment and own shocks in both the short and long run periods as shown in figure 4.

**Figure 4: Impulse response functionsReal GDP, Domestic Private Investment and Telephone mainlines density**




In summary, t the impulse response functions reveal that economic growth as represented by changes in real GDP, responds positively to shocks in electricity production and energy consumption in both short and long run time frames. The response of economic growth to telephone mainlines density is positive in the short run and becomes negative in the long run.

The response of infrastructure indicators to shocks in economic growth varies. Electricity production responds negatively, while energy responds positively in the short run and then negatively in the long run. Telephone mainlines density responds positively to shocks in economic growth.

## 5.6VARIANCE DECOMPOSITION

The Wald decomposition theorem purports that it is possible to uniquely decompose the variance of each variable into components accounted for by each innovation, in the absence of contemporaneous correlation among innovation. The variance decomposition technique determines how much of the forecast error variance of a variable in the system is explained by innovations to each explanatory variable over a series of time horizons. It is an alternative method to the impulse response functions for examining the effects of shocks to the dependent variables.Own series tend to explain much of the shocks of the error variance in the short run, but as the lagged variables' effect starts kicking in, the percentage of the effect of other shocks increases over time.

### *5.6.1 Variance Decomposition of LRGDP*

As shown in Table 4real GDPexplains 100% of the variance in itself in the initial period for three scenarios with all three infrastructure indicators.When the electricity production indicator is used, the forecast error variance for real GDP is largely accounted for by its own shocks throughout the 10 year period. In period 4 domestic private investment contributes about 16% of real GDP forecast error variance, while electricity production contributes an insignificant 0.9%. In period 10 real GDP accounts 68% of its own variance while domestic private investment account for 27% and electricity production 4.6%.

When telephone mainlines density is introduced into the system, contribution of domestic private investment to real GDP variance loses significance. In period 10 real GDP accounts for 38.7% of its own error variance, while domestic private investment accounts for a mere 2.7% and telephone mainlines density a significant 58.7%. This implies real GDP responds more to innovations in the telephone mainlines density.

When considering energy consumption, real GDP accounts for much of its own error variance throughout the 10 year period.  Domestic private investment contributes 21.7% in period 10, while energy consumption contributes 6.28%.

Contribution of infrastructure indicators to real GDP forecast error variance are very low in the first 5 years. In the 10 year period contributions to real GDP variance from innovations in electricity production ranges from 0 to 4.58%. In the same period telephone mainlines density contribution to real GDP error variance ranges from 0 to 58.66%, while energy consumption contribution ranges from 0 to 6.28%.

### *5.6.2 Variance Decomposition of Domestic Private Investment - LPVT*

Domestic private investment error variance is explained more by its own innovations throughout the ten year period than other variables.

When considering the electricity production indicator in the system of equations, real GDP contribution to domestic private investment error variance range from 5.44% in period 1 to 20% in period 10 as shown in table 5. Electricity production contribution to domestic private investment for the 10 year period ranges from 0 to 6.9%. Therefore outside of own shocks in domestic private investment real GDP has a significant contribution in explaining the forecast error variance.

When telephone mainlines density is introduced to the system as an infrastructure indicator, it explains a significant part of domestic private investment error variance. From period 5 to period 10, telephone mainline density contribution range from 16.1% to 40.47%.

When considering energy consumption in the system, apart from own innovations in domestic private investment real GDP contributes more to the forecast error variance. Energy consumption contributions are less than 10% during the 10 year period. The lowest contribution was in period 2 of 1.76% and the highest in period 10 of 7.1%.

## Table 4: Variance Decomposition of LRGDP

| | Electricity Production Indicator | | | | Telephone mainline density Indicator | | | | Energy Consumption Indicator | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period | S.E. | LLRGDP | LPVT | ELECPC | S.E. | LLRGDP | LPVT | LLTELLNE | S.E. | LLRGDP | LPVT | LENERG |
| 1 | 0.052669 | 100.0000 | 0.000000 | 0.000000 | 0.044672 | 100.0000 | 0.000000 | 0.000000 | 0.051817 | 100.0000 | 0.000000 | 0.000000 |
| 2 | 0.075878 | 97.10949 | 2.237612 | 0.652896 | 0.055707 | 97.25866 | 0.380878 | 2.360463 | 0.072319 | 97.83507 | 1.821069 | 0.343866 |
| 3 | 0.095386 | 89.56131 | 9.531570 | 0.907121 | 0.065321 | 96.77911 | 1.273127 | 1.947762 | 0.091129 | 91.93681 | 7.315919 | 0.747273 |
| 4 | 0.111698 | 83.02756 | 16.02305 | 0.949388 | 0.071314 | 96.20027 | 1.827320 | 1.972409 | 0.108024 | 86.92716 | 11.95862 | 1.114223 |
| 5 | 0.124057 | 77.74700 | 21.10209 | 1.150915 | 0.075919 | 93.17175 | 1.947806 | 4.880444 | 0.122274 | 82.98915 | 15.26431 | 1.746546 |
| 6 | 0.132787 | 73.83621 | 24.59866 | 1.565126 | 0.080736 | 85.81159 | 1.755338 | 12.43307 | 0.134327 | 79.69394 | 17.74209 | 2.563979 |
| 7 | 0.138283 | 71.23968 | 26.56548 | 2.194834 | 0.087326 | 74.13202 | 1.553353 | 24.31463 | 0.144027 | 77.06879 | 19.47126 | 3.459952 |
| 8 | 0.141287 | 69.63011 | 27.37836 | 2.991528 | 0.096612 | 60.56761 | 1.619194 | 37.81320 | 0.151351 | 74.98426 | 20.60395 | 4.411793 |
| 9 | 0.142698 | 68.68293 | 27.48162 | 3.835450 | 0.108794 | 48.17126 | 2.026557 | 49.80219 | 0.156545 | 73.31949 | 21.30878 | 5.371729 |
| 10 | 0.143335 | 68.11463 | 27.30375 | 4.581613 | 0.123498 | 38.66698 | 2.674315 | 58.65871 | 0.159935 | 72.02010 | 21.69609 | 6.283814 |

## Table 5: Variance Decomposition of LPVT

| | Electricity Production Indicator | | | | Telephone mainline density Indicator | | | | Energy Consumption Indicator | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Period** | **S.E.** | **LLRGDP** | **LPVT** | **ELECPC** | **S.E.** | **LLRGDP** | **LPVT** | **LLTELLNE** | **S.E.** | **LLRGDP** | **LPVT** | **LENERG** |
| 1 | 0.223808 | 5.449890 | 94.55011 | 0.000000 | 0.219730 | 2.197255 | 97.80275 | 0.000000 | 0.224222 | 4.190726 | 95.80927 | 0.000000 |
| 2 | 0.281080 | 18.97073 | 80.07431 | 0.954964 | 0.261017 | 7.841419 | 88.56969 | 3.588887 | 0.282294 | 13.48101 | 84.76054 | 1.758452 |
| 3 | 0.307333 | 19.98351 | 78.94885 | 1.067649 | 0.272205 | 8.054085 | 84.96547 | 6.980448 | 0.299103 | 16.42166 | 81.77901 | 1.799330 |
| 4 | 0.324415 | 19.94208 | 78.09159 | 1.966324 | 0.280055 | 7.924811 | 80.77125 | 11.30394 | 0.320774 | 19.38295 | 77.95476 | 2.662289 |
| 5 | 0.331915 | 19.81163 | 76.91643 | 3.271938 | 0.287974 | 7.503093 | 76.39377 | 16.10314 | 0.337946 | 22.12912 | 74.62797 | 3.242907 |
| 6 | 0.335252 | 19.46517 | 75.72638 | 4.808451 | 0.297681 | 7.088183 | 71.58821 | 21.32360 | 0.348468 | 23.48317 | 72.39533 | 4.121499 |
| 7 | 0.337718 | 19.26935 | 74.66251 | 6.068143 | 0.309682 | 6.883169 | 66.43781 | 26.67902 | 0.355621 | 24.01090 | 70.89589 | 5.093205 |
| 8 | 0.340988 | 19.34706 | 73.85546 | 6.797486 | 0.324060 | 7.005591 | 61.14933 | 31.84508 | 0.359834 | 24.11176 | 69.97552 | 5.912715 |
| 9 | 0.345349 | 19.66085 | 73.31360 | 7.025551 | 0.340557 | 7.493389 | 55.99633 | 36.51028 | 0.361925 | 23.98057 | 69.42872 | 6.590709 |
| 10 | 0.350148 | 20.07056 | 72.98357 | 6.945875 | 0.358678 | 8.312599 | 51.22057 | 40.46683 | 0.363000 | 23.83892 | 69.06326 | 7.097822 |

### *5.6.3 Variance Decomposition of Infrastructure Indicators*

Table 6 shows the variance decomposition of all the infrastructure indicators used in the study. The electricity production error variance is largely due to own innovations in the first 4 years, but from the $5^{th}$ year going forward domestic private investment contributes more than own shocks. In period 10 domestic private investment contributes 53.4%, while real GDP 9.45% to electricity production innovations.

With regards to telephone mainlines density, own shocks explain more of its error variance throughout the ten year period. Real GDP contributions range from 2.03% in period to 26.6% in period 10. Domestic private investment contributions do not change much, ranging from 7.94% in period to 8.87% in period 10.

Energy consumption error variance is largely due to own shocks as well as shocks in the real GDP. Real GDP contributions to energy consumption range from 26.6% to 44.26% in the 10 year period, while domestic private investment contributions range from 0.18% in period to 13.11% in period 10.

The variance decomposition technique reveals that the contributions of electricity production and energy consumption to forecast error variance of economic growth are not very significant. They are below 10% in both cases. However telephone mainlines density has significant contributions to forecast error variance of economic growth.

**Table 6: Variance Decomposition of Infrastructure Indicators**

| | Electricity Production Indicator | | | | Telephone mainline density Indicator | | | | Energy Consumption Indicator | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period | S.E. | LLRGDP | LPVT | ELECPC | S.E. | LLRGDP | LPVT | LLTELLNE | S.E. | LLRGDP | LPVT | LENERG |
| 1 | 0.068305 | 4.807082 | 6.957241 | 88.23568 | 0.045274 | 2.031494 | 7.935678 | 90.03283 | 0.028838 | 26.63292 | 0.180513 | 73.18657 |
| 2 | 0.099126 | 2.805326 | 20.06876 | 77.12592 | 0.082691 | 10.36129 | 6.394576 | 83.24413 | 0.041225 | 39.79999 | 10.78987 | 49.41015 |
| 3 | 0.124458 | 3.394030 | 35.39214 | 61.21383 | 0.118873 | 13.25266 | 6.182993 | 80.56434 | 0.044966 | 42.03068 | 10.77924 | 47.19008 |
| 4 | 0.143387 | 5.561864 | 44.76234 | 49.67580 | 0.152819 | 15.83570 | 6.504626 | 77.65968 | 0.046780 | 40.09466 | 10.42501 | 49.48033 |
| 5 | 0.156567 | 7.512789 | 50.39311 | 42.09410 | 0.183928 | 18.00932 | 6.956386 | 75.03429 | 0.047745 | 38.58866 | 10.28529 | 51.12604 |
| 6 | 0.165102 | 8.827861 | 53.29206 | 37.88008 | 0.212003 | 19.98722 | 7.419105 | 72.59368 | 0.048290 | 38.02225 | 10.06829 | 51.90946 |
| 7 | 0.169873 | 9.455977 | 54.32743 | 36.21659 | 0.236945 | 21.81663 | 7.848887 | 70.33448 | 0.049101 | 38.53172 | 10.17772 | 51.29056 |
| 8 | 0.172135 | 9.570968 | 54.31365 | 36.11538 | 0.258729 | 23.53269 | 8.234130 | 68.23318 | 0.050326 | 40.02254 | 10.72889 | 49.24857 |
| 9 | 0.173167 | 9.479654 | 53.86486 | 36.65549 | 0.277371 | 25.15035 | 8.574156 | 66.27550 | 0.052032 | 42.08460 | 11.76375 | 46.15165 |
| 10 | 0.173958 | 9.452290 | 53.40763 | 37.14008 | 0.292942 | 26.67501 | 8.871550 | 64.45344 | 0.054140 | 44.26121 | 13.11153 | 42.62725 |

## 5.7 CONCLUSION

Basing on the empirical results obtained we accept the null hypothesis that infrastructure plays a positive role in the growth of the Zimbabwean economy,especially in the short run as all the infrastructure indicators exhibit this positive relationship.The long run impact of infrastructure is mixed according to the results. In the long run electricity production and energy consumption cause positive impulses to economic growth while telephone mainline density impulses are negative. The short run positive growth effect of infrastructure is in line with neoclassical view which regards infrastructure investments to cause temporary growth effects in the presence of diminishing returns to capital.

The Granger Causality tests revealed that there is one-way causality effect between energy consumption and economic growth, with energy consumption granger causing economic growth (real GDP). Causality between telephone mainlines density and economic growth is bidirectional, implying a feedback mechanism in the system. We can therefore conclude that the direction of causality is more inclined towards infrastructure development causing economic growth than economic growth causing infrastructure development.

Although the use of telephone lines, electricity production and energy use per capita as infrastructure indicators does not fully capture economic infrastructure, it provides some basis for empirical analysis on the subject. The omission of other infrastructure indicators for sectors like transport, water and air was due to the unavailability of complete time series data in Zimbabwe. There are several studies in other countries that have used telephone lines, electricity production and energy consumption as infrastructure indicators for example; Lopez (2003), quoted in Calderon and Serven (2004) used telephone density as an infrastructure indicator to assess the effect of infrastructure on growth and income distribution, and found it to have positive effect on growth and reduces income inequality. Loayza, Fajnzylber and Calderon (2003) found that telecommunication density as an infrastructure indicator is robustly related to growth in a large panel dataset consisting of both developed and developing countries.Sahoo*et al* (2010) used all three indicators among other infrastructure indicators.

# CHAPTER 6
# POLICY IMPLICATIONS AND CONCLUSIONS

## 6.1 SUMMARY

The study was aimed at examining the role that infrastructure plays in the economic growth process of Zimbabwe. The study objectives were to examine empirically the impact of infrastructure on economic growth and establish the direction of causality between the two.The findings of the study provide evidence that infrastructure plays a positive role in influencing economic growth in the short run, and has mixed effects in the long run. The study results show that infrastructure development does have a bearing on the growth of the Zimbabwean economy, and therefore lack of infrastructure development has really been a binding constraint to economic growth performance in the country.

The variables used in the study were real GDP to capture the economic growth effect, private investment and telephone mainlines density, electricity production per capita and energy consumption per capita as infrastructure indicators. The study examined the stochastic characteristics of the time series data by testing for stationarity using the Augmented Dickey Fuller (ADF) test. The effects of stochastic shocks of each of the endogenous variables were examined using the unrestricted Vector Autoregressive (VAR) model. The Granger Causality tests were also carried out.

The results from the VAR impulse response functions revealed that real GDP responds positively to infrastructure shocks in the short run. The short run positive effect is in line with the neoclassical view of short run economic growth. The variance decomposition results revealed that greater sources of variance in variables are due to own shocks. The forecast error variance decomposition also shows that innovation of the three infrastructure indicators, telephone mainlines density is a strong predictor of economic growth in the country.This emphasizes the importance of telecommunication technologies in influencing economic growth.

The Granger Causality test revealed that there is one-way causality effect between energy consumption and economic growth, with energy consumption granger causing economic growth (real GDP). Causality between telephone mainlines density and economic growth is bidirectional, implying a feedback mechanism in the system.The causality effect of infrastructure in influencing economic growth is stronger, than that of economic growth influencing infrastructure development.Domestic private investment granger causes economic growth and electricity production.

The overall conclusion of the study is that we accept the hypothesis that infrastructure development plays a positive role in Zimbabwe’s economic growth in the short run, but the hypothesis does not hold strongly for the long run growth as there are mixed effects.The study findings are consistent with some finding in empirical literature on infrastructure and economic growth which revealed mixed results. The majority of studies however revealed that infrastructure has a positive effect on economic growth, while a few studies found it to have a negative role due to data constraints and methodological issues.

## 6.2 POLICY IMPLICATIONS AND RECOMMENDATIONS

Economic infrastructure provision in the country has been largely the responsibility of the Zimbabwean government with the private sector playing a minor role.Policy makers may therefore target public spending on infrastructure projects as a way of improving economic growth in the short run. Public investment on infrastructure projects may positively influence economic growth through both direct and indirect transmission mechanisms.

Since the study empirical results show that energy consumption and telephone mainline density help in improving the forecast error variance of economic growth (real GDP), it implies that economic growth can be stimulated through provision of essential infrastructure services which form businesses and household’s needs. Policy makers therefore need focus on not just improving the quantity of infrastructure stocks but also the quality of infrastructure service delivery. There is therefore need to improve efficiency in the operations of regulatory bodies to ensure service delivery of the various infrastructure sectors.

In order to improve the quantity of infrastructure stocks  or development given the stringent lack of financial resources the country has been experiencing, policy makers need promote private sector involvement though the public -private partnerships.

The positive impact of infrastructure development on economic growth more strongly in the short run as exhibited by the infrastructure indicators, could imply anincrease in aggregate demand in the economy through large-scale public works expenditure. The public expenditure on infrastructure can help stimulate aggregate demand as a result of increased job opportunities through public works. It is therefore important for authorities in Ministry of Transport and Communication, Ministry of Energy and Power Development, State Procurement Board and other responsible agencies to consider local contractors when awarding tenders for infrastructure projects. The economy would benefit more if tenders are awarded to local businesses as opposed to foreign contractors, as this would reduce the possibility of capital flight.

The study results revealed that  private investment has a causal effect on economic growth, policy makers therefore need to ensure improved quality of infrastructure to businesssince it can help serve as an input into private sector production thereby augmenting output and productivity. A prominent argument for increase in public spending on infrastructure has been that infrastructure services have strong growth promoting effect through their impact on productivity of private inputs and rate of return on capital.

## 6.3 SUGGESTIONS FOR FUTURE RESEARCH

The results of the study are not by all means exhaustive, there is need to look at the role of infrastructure development in economic at sectoral level. The aggregate approach could be best tackled by computing an  infrastructure index, instead of using sectoral indicators, however lack of data in some key sectorsis a challenge to the index computation.

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# APPENDICES

## APPENDIX I: UNIT ROOT TESTS

Null Hypothesis: D(RGDP,2) has a unit root
Exogenous: Constant
Lag Length: 3 (Fixed)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -4.028854 | 0.0056 |
| Test critical values: | 1% level | -3.769597 | |
| | 5% level | -3.004861 | |
| | 10% level | -2.642242 | |

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(TELLNE,2) has a unit root
Exogenous: Constant
Lag Length: 3 (Fixed)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -3.965842 | 0.0065 |
| Test critical values: | 1% level | -3.769597 | |
| | 5% level | -3.004861 | |
| | 10% level | -2.642242 | |

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(PVT) has a unit root
Exogenous: None
Lag Length: 3 (Fixed)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -2.434369 | 0.0174 |
| Test critical values: | 1% level | -2.669359 | |
| | 5% level | -1.956406 | |
| | 10% level | -1.608495 | |

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: ELECPC has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 3 (Fixed)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -3.852640 | 0.0310 |
| Test critical values: | 1% level | -4.394309 | |
| | 5% level | -3.612199 | |
| | 10% level | -3.243079 | |

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(ENERG) has a unit root
Exogenous: None
Lag Length: 3 (Fixed)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -2.107214 | 0.0363 |
| Test critical values: | 1% level | -2.669359 | |
| | 5% level | -1.956406 | |
| | 10% level | -1.608495 | |

*MacKinnon (1996) one-sided p-values.

## APPENDIX II: VAR Diagnostic tests

## A: Endogenous variables: LLRGDP LPVT LELECPDN

VAR Lag Order Selection Criteria
Endogenous variables: LLRGDP LPVT ELECPC
Exogenous variables: C
Date: 05/23/12 Time: 06:31
Sample: 1981 2008
Included observations: 23

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 26.34627 | NA | 2.64e-05 | -2.030110 | -1.882002 | -1.992861 |
| 1 | 74.38206 | 79.36348* | 8.94e-07* | -5.424527* | -4.832095* | -5.275532* |
| 2 | 79.79687 | 7.533657 | 1.28e-06 | -5.112772 | -4.076016 | -4.852030 |
| 3 | 86.23316 | 7.275807 | 1.82e-06 | -4.889840 | -3.408761 | -4.517353 |

* 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

Roots of Characteristic Polynomial
Endogenous variables: LLRGDP LPVT ELECPC
Exogenous variables: C
Lag specification: 1 2
Date: 05/23/12 Time: 06:32

| Root | Modulus |
|---|---|
| 0.838037 - 0.287337i | 0.885928 |
| 0.838037 + 0.287337i | 0.885928 |
| 0.558983 - 0.111333i | 0.569962 |
| 0.558983 + 0.111333i | 0.569962 |
| -0.178846 - 0.324779i | 0.370766 |
| -0.178846 + 0.324779i | 0.370766 |

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

VAR Residual Serial Correlation LM Tests
H0: no serial correlation at lag order h

Date: 05/23/12 Time: 06:33
Sample: 1981 2008
Included observations: 24

| Lags | LM-Stat | Prob |
|---|---|---|
| 1 | 7.884525 | 0.5458 |

Probs from chi-square with 9 df.

VAR Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)
H0: residuals are multivariate normal
Sample: 1981 2008
Included observations: 24

| Component | Jarque-Bera | Df | Prob. |
|---|---|---|---|
| 1 | 2.775325 | 2 | 0.2497 |
| 2 | 2.426088 | 2 | 0.2973 |
| 3 | 3.881307 | 2 | 0.1436 |
| Joint | 9.082719 | 6 | 0.1690 |

VAR Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)
Date: 05/23/12 Time: 06:34
Sample: 1981 2008
Included observations: 24

Joint test:

| Chi-sq | df | Prob. |
|---|---|---|
| 69.01628 | 72 | 0.5778 |

## B: ENDOGENOUS VARIBALES LLRGP LPVT LENERG

VAR Lag Order Selection Criteria

Included observations: 24

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 45.74544 | NA | 5.70e-06 | -3.562120 | -3.414863 | -3.523052 |
| 1 | 99.08352 | 88.89681* | 1.43e-07* | -7.256960* | -6.667933* | -7.100691* |
| 2 | 106.5393 | 10.56231 | 1.70e-07 | -7.128273 | -6.097476 | -6.854802 |

* indicates lag order selected by the criterion

Roots of Characteristic Polynomial

| Root | Modulus |
|---|---|
| 0.923936 - 0.194358i | 0.944157 |
| 0.923936 + 0.194358i | 0.944157 |
| 0.541922 | 0.541922 |
| -0.180088 - 0.460169i | 0.494153 |
| -0.180088 + 0.460169i | 0.494153 |
| 0.093051 | 0.093051 |

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

VAR Residual Serial Correlation LM Tests
H0: no serial correlation at lag order h

| Lags | LM-Stat | Prob |
|---|---|---|
| 1 | 8.669479 | 0.4683 |

Probs from chi-square with 9 df.

VAR Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)
H0: residuals are multivariate normal

| Component | Jarque-Bera | Df | Prob. |
|---|---|---|---|
| 1 | 1.705029 | 2 | 0.4263 |
| 2 | 1.380672 | 2 | 0.5014 |
| 3 | 2.602902 | 2 | 0.2721 |
| Joint | 5.688603 | 6 | 0.4590 |

VAR Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)

Joint test:

| Chi-sq | df | Prob. |
|---|---|---|
| 69.54979 | 72 | 0.5599 |

## C: ENDOGENOUS VARIABLES LLRGDP LPVT LLTELLNE

VAR Lag Order Selection Criteria

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 8.416895 | NA | 0.000125 | -0.471034 | -0.322926 | -0.433786 |
| 1 | 86.88093 | 129.6362* | 3.02e-07* | -6.511385* | -5.918953* | -6.362390* |
| 2 | 92.38723 | 7.660949 | 4.29e-07 | -6.207586 | -5.170830 | -5.946844 |
| 3 | 104.4957 | 13.68784 | 3.72e-07 | -6.477888 | -4.996808 | -6.105401 |

* indicates lag order selected by the criterion

Roots of Characteristic Polynomial
Endogenous variables: LLRGDP LPVT LLTELLNE

| Root | Modulus |
|---|---|
| 0.980687 - 0.138761i | 0.990455 |
| 0.980687 + 0.138761i | 0.990455 |
| 0.517345 - 0.099230i | 0.526776 |
| 0.517345 + 0.099230i | 0.526776 |
| -0.271751 | 0.271751 |
| -0.001820 | 0.001820 |

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

VAR Residual Serial Correlation LM Tests
H0: no serial correlation at lag order h

| Lags | LM-Stat | Prob |
|---|---|---|
| 1 | 6.526766 | 0.6863 |

Probs from chi-square with 9 df.

VAR Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)
H0: residuals are multivariate normal

| Component | Jarque-Bera | Df | Prob. |
|---|---|---|---|
| 1 | 2.750253 | 2 | 0.2528 |
| 2 | 1.683733 | 2 | 0.4309 |
| 3 | 1.744061 | 2 | 0.4181 |
| Joint | 6.178047 | 6 | 0.4035 |

VAR Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)
Date: 05/22/12 Time: 12:50
Sample: 1981 2008
Included observations: 24

Joint test:

| Chi-sq | df | Prob. |
|---|---|---|
| 62.04981 | 72 | 0.7923 |

## APPENDIX III: GRANGER CAUSALITY TESTS

Pairwise Granger Causality Tests
Date: 05/23/12 Time: 06:38
Sample: 1981 2008
Lags: 1

| Null Hypothesis: | Obs | F-Statistic | Probability |
|---|---|---|---|
| LPVT does not Granger Cause LLRGDP | 25 | 5.21763 | 0.03237 |
| LLRGDP does not Granger Cause LPVT | | 0.09683 | 0.75859 |
| ELECPC does not Granger Cause LLRGDP | 25 | 0.03010 | 0.86385 |
| LLRGDP does not Granger Cause ELECPC | | 0.85194 | 0.36602 |
| ELECPC does not Granger Cause LPVT | 26 | 0.87522 | 0.35923 |
| LPVT does not Granger Cause ELECPC | | 7.37078 | 0.01235 |

Lags: 1

| Null Hypothesis: | Obs | F-Statistic | Probability |
|---|---|---|---|
| LPVT does not Granger Cause LLRGDP | 25 | 5.21763 | 0.03237 |
| LLRGDP does not Granger Cause LPVT | | 0.09683 | 0.75859 |
| LENERG does not Granger Cause LLRGDP | 25 | 6.02783 | 0.02245 |
| LLRGDP does not Granger Cause LENERG | | 2.39688 | 0.13584 |
| LENERG does not Granger Cause LPVT | 26 | 1.16605 | 0.29141 |
| LPVT does not Granger Cause LENERG | | 0.00294 | 0.95719 |

Date: 05/22/12 Time: 12:53
Sample: 1981 2008
Lags: 1

| Null Hypothesis: | Obs | F-Statistic | Probability |
|---|---|---|---|
| LPVT does not Granger Cause LLRGDP | 25 | 5.21763 | 0.03237 |
| LLRGDP does not Granger Cause LPVT | | 0.09683 | 0.75859 |
| LLTELLNE does not Granger Cause LLRGDP | 25 | 13.0472 | 0.00155 |
| LLRGDP does not Granger Cause LLTELLNE | | 9.95807 | 0.00459 |

| | | | |
|---|---|---|---|
| LLTELLNE does not Granger Cause LPVT | 25 | 3.49544 | 0.07491 |
| LPVT does not Granger Cause LLTELLNE | | 4.74552 | 0.04037 |

## APPENDIX IV: VECTOR AUTOREGRESSION ESTIMATES

Vector Autoregression Estimates
Date: 05/22/12 Time: 12:40
Sample (adjusted): 1985 2008
Included observations: 24 after adjustments
Standard errors in ( ) & t-statistics in [ ]

| | LLRGDP | LPVT | LENERG |
|---|---|---|---|
| LLRGDP(-1) | 0.863768 | 1.659887 | 0.183259 |
| | (0.26567) | (1.14961) | (0.14786) |
| | [ 3.25124] | [ 1.44387] | [ 1.23944] |
| LLRGDP(-2) | -0.04871 | -1.477559 | -0.25947 |
| | (0.25393) | (1.09881) | (0.14132) |
| | [-0.19182] | [-1.34468] | [-1.83600] |
| LPVT(-1) | 0.043507 | 0.642726 | 0.058008 |
| | (0.05407) | (0.23398) | (0.03009) |
| | [ 0.80460] | [ 2.74690] | [ 1.92758] |
| LPVT(-2) | 0.026113 | -0.059112 | -0.056629 |
| | (0.05681) | (0.24583) | (0.03162) |
| | [ 0.45965] | [-0.24046] | [-1.79103] |
| LENERG(-1) | 0.171895 | -1.517341 | 0.616175 |
| | (0.40142) | (1.73699) | (0.22340) |
| | [ 0.42822] | [-0.87354] | [ 2.75814] |
| LENERG(-2) | 0.080714 | 2.210024 | 0.110417 |
| | (0.35891) | (1.55307) | (0.19975) |
| | [ 0.22488] | [ 1.42300] | [ 0.55278] |
| C | 0.865091 | -4.434082 | 3.103224 |
| | (2.41797) | (10.4629) | (1.34569) |
| | [ 0.35778] | [-0.42379] | [ 2.30605] |

| | | | |
|---|---|---|---|
| R-squared | 0.908096 | 0.646116 | 0.853629 |
| Adj. R-squared | 0.875659 | 0.521216 | 0.801969 |
| Sum sq. resids | 0.045646 | 0.854681 | 0.014138 |
| S.E. equation | 0.051817 | 0.224222 | 0.028838 |
| F-statistic | 27.99590 | 5.173066 | 16.52389 |
| Log likelihood | 41.12432 | 5.966449 | 55.18888 |
| Akaike AIC | -2.843693 | 0.086129 | -4.01574 |
| Schwarz SC | -2.500094 | 0.429728 | -3.672141 |
| Mean dependent | 16.83554 | 7.953967 | 6.716043 |
| S.D. dependent | 0.146949 | 0.324047 | 0.064804 |

| | |
|---|---|
| Determinant resid covariance (dof adj.) | 7.87E-08 |
| Determinant resid covariance | 2.80E-08 |
| Log likelihood | 106.5393 |
| Akaike information criterion | -7.128273 |
| Schwarz criterion | -6.097476 |

Vector Autoregression Estimates
Date: 05/23/12 Time: 06:31
Sample (adjusted): 1985 2008
Included observations: 24 after adjustments
Standard errors in ( ) & t-statistics in [ ]

| | LLRGDP | LPVT | ELECPC |
|---|---|---|---|
| LLRGDP(-1) | 0.975319 | 1.440716 | 0.234359 |
| | -0.24555 | -1.04344 | -0.31845 |
| | [ 3.97196] | [ 1.38074] | [ 0.73594] |
| LLRGDP(-2) | -0.202694 | -1.339352 | -0.176832 |
| | -0.21189 | -0.90041 | -0.2748 |
| | [-0.95659] | [-1.48749] | [-0.64349] |
| LPVT(-1) | 0.060067 | 0.544034 | -0.110587 |
| | -0.05656 | -0.24036 | -0.07336 |
| | [ 1.06193] | [ 2.26342] | [-1.50754] |
| LPVT(-2) | 0.05282 | 0.079306 | -0.068456 |
| | -0.06144 | -0.26109 | -0.07968 |

| | | | |
|---|---|---|---|
| | [ 0.85968] | [ 0.30376] | [-0.85911] |
| ELECPC(-1) | 0.095557 | -0.428104 | 0.916995 |
| | -0.16481 | -0.70034 | -0.21374 |
| | [ 0.57980] | [-0.61128] | [ 4.29027] |
| ELECPC(-2) | -0.050622 | 0.736173 | -0.230623 |
| | -0.14998 | -0.6373 | -0.1945 |
| | [-0.33754] | [ 1.15514] | [-1.18572] |
| C | 2.635395 | -0.734687 | 2.530004 |
| | -1.43565 | -6.10059 | -1.86186 |
| | [ 1.83568] | [-0.12043] | [ 1.35886] |
| R-squared | 0.905051 | 0.64742 | 0.865945 |
| Adj. R-squared | 0.87154 | 0.52298 | 0.818631 |
| Sum sq. resids | 0.047158 | 0.851533 | 0.079315 |
| S.E. equation | 0.052669 | 0.223808 | 0.068305 |
| F-statistic | 27.00727 | 5.202665 | 18.30226 |
| Log likelihood | 40.7332 | 6.010731 | 34.49413 |
| Akaike AIC | -2.8111 | 0.082439 | -2.291177 |
| Schwarz SC | -2.467501 | 0.426038 | -1.947578 |
| Mean dependent | 16.83554 | 7.953967 | 6.586598 |
| S.D. dependent | 0.146949 | 0.324047 | 0.160388 |

| | |
|---|---|
| Determinant resid covariance (dof adj.) | 5.41E-07 |
| Determinant resid covariance | 1.92E-07 |
| Log likelihood | 83.41244 |
| Akaike information criterion | -5.201037 |
| Schwarz criterion | -4.17024 |

Vector Autoregression Estimates
Date: 05/22/12 Time: 12:47
Sample (adjusted): 1985 2008
Included observations: 24 after adjustments
Standard errors in ( ) & t-statistics in [ ]

| | LLRGDP | LPVT | LLTELLNE |
|---|---|---|---|
| LLRGDP(-1) | 0.684044 | 1.197398 | 0.375693 |

| | | | |
|---|---|---|---|
| | (0.23083) | (1.13536) | (0.23393) |
| | [ 2.96346] | [ 1.05464] | [ 1.60597] |
| LLRGDP(-2) | 0.169181 | -0.586873 | -0.27408 |
| | (0.22236) | (1.09374) | (0.22536) |
| | [ 0.76083] | [-0.53658] | [-1.21620] |
| LPVT(-1) | 0.004128 | 0.594707 | -0.008479 |
| | (0.04929) | (0.24243) | (0.04995) |
| | [ 0.08375] | [ 2.45309] | [-0.16975] |
| LPVT(-2) | 0.022123 | -0.061785 | 0.008795 |
| | (0.04861) | (0.23909) | (0.04926) |
| | [ 0.45512] | [-0.25841] | [ 0.17854] |
| LLTELLNE(-1) | 0.199232 | -1.151063 | 1.443743 |
| | (0.21876) | (1.07600) | (0.22170) |
| | [ 0.91075] | [-1.06976] | [ 6.51208] |
| LLTELLNE(-2) | -0.346094 | 0.892195 | -0.412724 |
| | (0.24115) | (1.18617) | (0.24440) |
| | [-1.43515] | [ 0.75217] | [-1.68871] |
| C | 2.655020 | -5.839793 | -1.779414 |
| | (1.39237) | (6.84868) | (1.41113) |
| | [ 1.90683] | [-0.85269] | [-1.26099] |

| | | | |
|---|---|---|---|
| R-squared | 0.931693 | 0.660151 | 0.985033 |
| Adj. R-squared | 0.907585 | 0.540205 | 0.979750 |
| Sum sq. resids | 0.033926 | 0.820784 | 0.034846 |
| S.E. equation | 0.044672 | 0.219730 | 0.045274 |
| F-statistic | 38.64611 | 5.503715 | 186.4678 |
| Log likelihood | 44.68514 | 6.452065 | 44.36407 |
| Akaike AIC | -3.140428 | 0.045661 | -3.113673 |
| Schwarz SC | -2.796829 | 0.389260 | -2.770074 |
| Mean dependent | 16.83554 | 7.953967 | 2.743008 |
| S.D. dependent | 0.146949 | 0.324047 | 0.318154 |

| | |
|---|---|
| Determinant resid covariance (dof adj.) | 1.74E-07 |
| Determinant resid covariance | 6.18E-08 |

| | |
|---|---|
| Log likelihood | 97.02783 |
| Akaike information criterion | -6.335653 |
| Schwarz criterion | -5.304856 |