ICT INFRASTRUCTURE INVESTMENT AND ECONOMIC GROWTH IN SOUTH AFRICA

By

LEBOGANG MATLOU (914577)

A DISSERTATION SUBMITTED IN FULFILLMENT OF THE REQUIRMENTS FOR THE DEGREE OF

MASTER OF MANAGEMENT IN THE FIELD OF

FINANCE AND INVESTMENTS

AT THE

WITS BUSINESS SCHOOL

SOUTH AFRICA

FEBRUARY 2019

Supervisor: Prof O. Kodongo

Abstract

The main goal of this study was to analyse the causal relationship between ICT infrastructure investment and economic growth in South Africa. It held the hypothesis that ICT infrastructure investment positively affected economic growth. Additionally, it also sought to test if economic growth, in turn had a positive impact on ICT infrastructure investment (bi-directionality of the relationship between ICT infrastructure investment and economic growth).

Several regression models have been used to test this relationship and the study used Perkins' model (2005 & 2010) to identify variables that affected economic growth alongside ICT infrastructure investment. These were Gross Fixed Capital Formation, real exchange rate, the Human Development Index and openness of trade.

The study relied on ICT investment data from WITSA from the period between 1992 and 2013. GDP, openness and real exchange rate data was obtained from the South African Reserve Bank. A time series analysis approached was applied in testing the hypothesis of the existence of the above relationship. Procedural tests that were applied were the Augmented Dickey Fuller test and the Philip Peron test to test for stationarity. Data was transformed into stationarity and the Johansen's co-integration test was conducted to test for co-integration.

It was noted that the variables co-integrated indicating a long term positive relationship between ICT investments and GDP. The Granger Causality tests conducted revealed that ICT was the Granger cause of GDP, GFCF, Openness of Trade and real exchange rate .GDP was not a Granger cause of ICT investment and therefore there was no bi-directionality in the relationship. The study recommended ICT investment incentivisation, the removal of ICT investment barriers and ICT research, education and training to bolster ICT infrastructure investment as this will translate to economic growth for South Africa.

Keywords: ICT infrastructure, Economic growth, South Africa, Gross Fixed Capital Formation, Real exchange rate, Trade openness, Human Development Index

Declarations on the authenticity and originality of research

I, the undersigned, **Lebogang Matlou** student number **914577**, declare that this dissertation for the Master of Management in the Field of Finance and Investments (MMFI) degree is both original and my own work. Furthermore this dissertation has not been submitted before and will not be submitted at any University.

Date: ____________________________

Signature: ____________________________

Declarations on Plagiarism

University of the Witwatersrand, Johannesburg

School of ……………………………..

SENATE PLAGIARISM POLICY

Declaration by Students.

I ___________________________ (Student number: _________________) am a student registered for ______________________ in the year __________. I hereby declare the following:

- **I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the original source) is wrong.**
- **I confirm that ALL the work submitted for assessment for the above course is my own unaided work except where I have explicitly indicated otherwise.**
- **I have followed the required conventions in referencing the thoughts and ideas of others.**
- **I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.**

Signature: _________________________ Date: ________________________

Acknowledgements

I would like to Acknowledge and thank the leadership and administrators of the Wits Business School ("WBS") for providing me with the opportunity to complete my thesis. I would like to thank Professor Kodongo, my supervisor, for his ever enduring support and patience throughout this dissertation; without which I would not have made it this far.

To my lectures and the administrators at the WBS, that facilitated the MMFI I wish to thank you for providing me with the most informative and life changing educational experience of my life. The entire course was structured, clear, challenging, professional and highly engaging; and I treasure every moment of it, as it has provided me with more opportunity and insight into the world finance than I ever imagined.

Dedications

To my parents, siblings and grandmother.

Table of Contents

List of Equations

List of Figures

List of Tables

Acronyms

ADF:	Augmented Dickey Fuller
AIC:	Akaike Information Criterion
ANC:	African National Congress
EG Model:	Engel and Granger Model
GDP:	Gross Domestic Product
GFCF:	Gross Fixed Capital Formation
HDI:	Human Development Index
ICASA:	Independent Communication Authority of South Africa
ICT:	Information and Communications Technology
IRF:	Impulse Response Function
JCT:	Johansen's co-integration Test
MFI:	Master of Management in the Field of Finance and Investments
OECD:	Organisation for Economic Co-operation and Development
PPT/PP:	Philip Peron Test
SA:	South Africa
SADC:	Southern Africa Development Community
SANRAL:	South African National Roads Agency SOC Ltd
SARB:	South African Reserve Bank
SATRA:	South African Telecommunications Regulatory Authority
SIC:	Schwarz Information Criterion
STATSSA:	Statistics South Africa
TSA:	Time Series Analysis
UNDP:	United Nations Development Programme
USD:	United States Dollar
VAR:	Vector Autoregression
VEC:	Vector Error Correction

VECM: Vector Error Correction Model

WBS: Wits Business School

WITSA: World Information Technology and Services Alliance

CHAPTER 1. INTRODUCTION

1.1. Introduction

Investment in an economy is a critical component of economic growth, as investment leads to increased productive capacity which in turn bolsters long run economic growth. Low investment or underinvestment may result in poor fixed capital formation, poor productivity and poor long-run employment. Therefore, the role and contribution of investment to economic development and growth cannot be overstated.

One form of investment that is quintessential to an economy, is infrastructure investment (Pettinger, 2016). Infrastructure is a dynamic concept, that can be constituted by either its physical or social manifestation, or a hybrid thereof. Infrastructure is one of the key elements for unlocking and sustaining the growth and development of an economy. It has the essential role of promoting long run economic development and, in turn, societal prosperity (Banister, 2012). Without infrastructure investment, a country cannot be efficient or competitive in a global context (Faulkner & Loewald, 2008).

Physical infrastructure can be understood as roads, railroads, airports, bridges, seaports and ICT resources (Bollou, 2006). Infrastructure thus is a dynamic grouping of physical and non-physical economic assets that constitute the build space, that both promote and defy the movement of economic value between producers and consumers, and within and between economies (Nasab & Aghaei, 2009). Generally, the makeup of an economies infrastructure has a significant bearing on its economic growth, trade and employment (Glamlich, 1994).

One type of infrastructure that is increasing as a driver of both economic and social development is Information Communication Technology (ICT) infrastructure (Nasab & Aghaei, 2009). ICT infrastructure describes the collective stock of all the devices, mediums, networks, information, data, protocols and procedures that are employed in the telecoms or information technology fields in countries and that foster interaction amongst different stakeholders (Mahyideen & Ismail, 2012). Essentially like all forms of infrastructure, ICT infrastructure is an input in the production process of various goods and services, that reduces cost and raises productivity (Beil, et al., 2005). It achieves this directly as an input of production and indirectly through promotion of the infrastructure network effect (Holmner & Britz, 2011).

ICT infrastructure is however distinguishable from the other forms of infrastructure, in that its primary function is to promote the free flow of intangibles such as information. Information and access to information, in the twenty first century has become a major imperative for developing countries (Samoilenko & Osei-Bryson, 2008). This is primarily driven by the global growth in the knowledge and digital economy, as well as the coming of the fourth industrial revolution (Visser, 2017).

Today South Africa is a modern and open economy, with well-developed and maintained infrastructure . Its network of infrastructure is vast, and includes rail, airports, telephone lines, ICT infrastructure, ports, and roads (Perkins, 2010). Its advanced network of infrastructure has provided it with comparative advantage on the continent and is a key driver of South Africa’s competitive advantage in global markets (Malefane & Odhiambo, 2018) . Despite this, South Africa's economic performance over the past decade, has fallen short of its economic growth potential (World Bank, 2018). Furthermore its economic outlook is poor (World Bank, 2018). With the fourth industrial revolution and a generally declining economic environment there is the need to appreciate whether South Africa should be placing greater emphasis on ICT Infrastructure as a driver of economic growth.

1.2. Background

This section presents the background behind South Africa’s current economic performance. It briefly aligns this background with S.A.’s political and social history. South Africa’s infrastructure development history is also presented in summary.

1.2.1. South Africa pre-democratic era

South Africa has a complicated history, marked by colonialism, violence, discrimination, segregation and social engineering; which have resulted in structural economic imbalances between sectors of society (Beinart & Dubow, 2013; Chipkin & Lipietz, 2012; Clifton, 2002). South Africa like many African countries was subject to colonial rule where the main objectives of the colonial endeavour by the British was the expansion of its empire, the extraction of resources and military occupation of the region (Nattrass, 2018; Swiegers, 2014). The result of this colonial project was the construction of infrastructure focused on promoting the interests of Britain. In Swiegers’ (2014) view, the consequence of South Africa's colonial rule, was the mass disposition of land and resources from the native population and the denial of access to, most importantly, social infrastructure in the form of education.

By 1948, colonial rule had diminished, and the Apartheid regime was ushered in by the National Party. The Apartheid regime was system of governance premised on institutionalised segregations and discrimination on the basis of race (Chipkin & Lipietz, 2012). The net effect of the 45-year Apartheid regime was mass economic and social segregation in South Africa, that resulted in deficits in every indicator of human development for the black population, with infrastructure development patterns being no different (Klasen, 2000).

However this regime was neither economically nor politically stable. By the 1980s, the GDP of South Africa was USD 82,984 billion and was steadily declining; while debt was steadily growing toward 40% of GDP (Faulkner & Loewald, 2008). This situation worsened over the years, as sanctions and international pressure began to mount economically (Faulkner & Loewald, 2008). Eventually the regime collapsed and by 1990, South Africa began its democratic transition.

1.2.2. Post-democratic era

The legacies of Apartheid planning and social engineering did not only hurt South Africa's social fabric, it also decimated South Africa's economy, leaving the state, for all intents and purposes, in a dire financial situation characterised by low economic growth in the late 1980s (Faulkner & Loewald, 2008). Furthermore, there were massive backlogs in basic infrastructure for black communities, that had to be addressed (Faulkner & Loewald, 2008). The ANC government managed to turn the situation around. It achieved an annual GDP growth above 5 % and a GDP of USD 136,362 billion, GDP per capita of USD 3037,23 and public debt of 27,84% of GDP in the year 2000. This trend continued till 2011 where GDP peaked at USD 416,4 billion (World Bank, 2018).

By 2011, South Africa's poor leadership, policy decisions and weak implementation of social and economic policies had begun to affect the economy (World Bank, 2018). Its failure to adequately address many of Apartheid structural inequalities; to grow its Black middle class; and to improve its productive capacity began to constrain South Africa's economic growth and employment (World Bank, 2018). The prevalence of low growth, corruption, and an incapacitated state began to create massive trust deficit among labour, business and the state (Bhorat, et al., 2014). This deepened South Africa's poor economic performance, and by 2016 GDP had fallen to USD 294,84 billion (World Bank, 2018).

More importantly, the populist policies embarked on by the state had led the country to high Debt-to-GDP ratio of close to 53%; as well as to staggering unemployment figures whereby youth employment in its narrow definition[1] stood at 50% and in the broad definition at 67% (World Bank, 2018). Most concerning of all is that South Africa today has the highest Gini coefficient in the world at 0,63 (Creamer, 2018).

South Africa's economic situation is clearly dire, and the South African economy requires economic growth to address the challenges stated above. More importantly, the type of economic growth required is one that is inclusive, labour absorbing and supply side driven.

1.2.3. History of Infrastructure Investment

The development patterns of infrastructure in South Africa mirrors, to a large extent, its colonial and Apartheid legacy (Perkins, 2010). The focus and distribution of infrastructure was geared towards not only serving South Africa's white population; but also towards excluding the black population from the mainstream economy and designating them to being nothing more than a source of cheap labour (Negota, 2001).

In the colonial era, most infrastructure investment had the objective of meeting the needs of British colonial rule (Reddy, 2016) . Thus railway lines were built to allow for the ease of movement of mineral resources and road networks were built to meet the needs of military forces (Negota, 2001). During the Apartheid era, massive infrastructure projects were undertaken including investment in rail, telephone and power lines, road infrastructure and ports; all of which were centrally controlled through South Africa's parastatal network (Eskom, Transnet, SANRAL and Telkom). The objective of these parastatals was to economically capacitate 'white South Africa' as well as to foster the creation of employment for the white minority.

Townships and the infrastructure within them, were designed to have cheap, accessible and controllable labour close to metropolitan and industrial areas; where the means of exit and entry were few (Nattrass, 2018). This combined with Group Areas Act of 1950 and the Natives (Abolition of Passes and Co-ordination of Documents) Act of 1952, which required non-white South Africans to carry in effect passports (with limited time in the city); meant that in effect black native population were kept in designated areas with poor infrastructure (Swiegers, 2014). These patterns of infrastructure development are still visible in today's South Africa

[1] Since 1998, Statistics South Africa (StatsSA) has adopted a ‘strict’ measure of unemployment as the official measure for South Africa: to be counted, an unemployed person must have "taken active steps to look for work or to start some form of self-employment". The official rate of unemployment therefore excludes all individuals who report that they do want to work but have not taken active steps (as specifically defined) to search for work in the previous month.

Figure 1.1:Internet Access - South Africa

(Kuralatne, 2006). Although much has been done to address this, in the post-democratic era, there remains massive infrastructure backlogs in South Africa (Ramdhani, 2017) . This is still particularly the case in historically black areas.

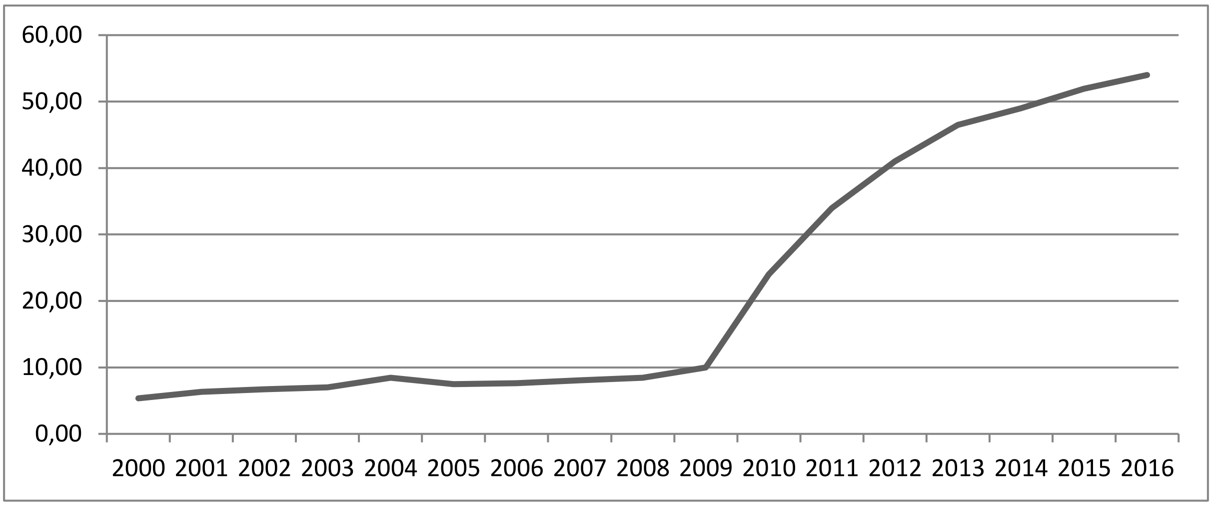
However the infrastructure that was built during the Apartheid era was, by any measure, world class, and assisted greatly in the post democratic era's economic growth (Perkins, 2010). This was because it allowed South Africa to attract investment capital from around the world, as well as provide the country with a framework upon which to build (Perkins, 2010).

1.2.4. ICT Infrastructure in South Africa

South Africa's ICT history kindled in 1988, at Rhodes University in the Eastern Cape. At this university Francois Jacot Guilarmod, Dave Wilson and Mike Lawrie established the first email link to the Internet (Esselaar & Miller, 2001). Access to the internet, at this time, was controlled by Telkom the fixed telephone line parastatal of South Africa which operated as a monopoly on all telephone lines. From the year 1990, Telkom continue to expand its fix line penetration into South Africa’s economy, while constantly improving internet speed and capability. During this period mobile operators were expanding their cellular network infrastructure across the country (Esselaar & Miller, 2001).

By the year 2000, wireless network capability had advanced to the stage where internet access could be achieved through the wireless networks of the two major telecommunications companies namely MTN and Vodacom (Esselaar & Miller, 2001). From 2001, South Africa's ICT infrastructure growth began to take off as subscriber adoption, service providers, the ICT skills and national expenditure on ICT began to increase (Esselaar & Miller, 2001).

From the period 2002 to 2010 according to the World Bank (2018), fixed broadband connection grew from 0,006 per 100 people to 1,44 per 100 people. Mobile penetration in the same period grew from 29,135 mobile cell phone subscriptions per 100 people to 97,649 per 100 people. The increasing connectivity through cell phone internet capability and the introduction of faster and more affordable internet, allowed internet usage to increase across the South African population as illustrated below by the International Telecommunications Union (2018).



Source: International Communications Union (2018)

As shown above, from 2000 internet access increased from around 5% of the South African population to around 10% in 2009 (ITU, 2018). A sharp growth trend is observable from 2009 until 2016 where a usage of 54% was reported. This highlights an improvement in the rate of internet adoption by South Africans from 2009 onwards.

South Africa, from the early 1990s, had adopted a liberalised and privatized approach to managing its ICT industry and framework. The regulator in South Africa is Independent Communication Authority of South Africa (ICASA) formulated under the Independent Communication Authority of South Africa Amendment Act of 2000, amended in 2005. ICASA is a result of the merger of the telecommunications regulator, the South African Telecommunications Regulatory Authority (SATRA) and the Independent Broadcasting Authority (IBA). ICASA is mandated to regulate the telecommunications, broadcasting and postal industries in the public interest and ensure affordable services of a high quality for all South Africans (ICASA, 2018).

Despite the significant advancements made in terms of internet access, regulation, ICT infrastructure and quality improvements, the digital divide exists in the South African economy (Blignaut, 2009). This digital divide runs in parallel with Apartheid infrastructure legacy of South Africa where poor, black and rural people have less access to the digital economy than previously advantaged South Africans. The Digital Divide, as described by Castells (2002: 248), is an "inequality of access to the internet." The digital divide is thus a form of structural inequality that has the consequence of reinforcing poverty.

1.3. Problem Statement

The South African economy is struggling to achieve economic growth, and has performed disappointingly for the past five years, achieving an average growth rate of 1,7 % per year (World Bank, 2018). At the same period, its debt to GDP ratio has accelerated to 53% and it is well on its way to 60%, (meaning that the state's debt capacity is constrained). Unemployment is also extremely high at 26,7% and youth unemployment stands at 53% in the narrow definition and in the extended definition 67% (Marleny, 2018). Furthermore, income inequality is stifling economic growth and political stability in South Africa (Barro, 2000).

Infrastructure investment promotes *economic growth* through positively affecting both the demand side and supply side of the economy (Bhorat & Hodge, 1999; Perkins, 2010, Echui & Keho 2012; Demurger, 2001). Infrastructure investment has historically been used as stimulus to kick start economic growth (Bhorat & Hodge, 1999).

There are three main theoretical channels through which ICT Investment promotes economic growth. Firstly, through the effect of output growth of ICT-producing firms (van Ark, 2002); Secondly the adoption of ICT and its productive use in the other sectors of the economy (Dolton and Makepeace, 2004); and thirdly the spin-offs from ICT in terms of the innovations that emerge in the wake of ICT diffusion (Plepys, 2002).

Within the literature, ICT investment has been found in the majority to have positive and causal effect on economic growth (Roller & Waverman, 2001; Thompson & Garbcz, 2007). Gruber and Koutrumpis (2010), using data from 192 countries found that telecommunications diffusion has a positive effect on both GDP and productivity growth. Roller and Waverman (2001) using data for 22 OECD countries found that broadband penetration, has had a significant positive causal link with economic growth, especially when a critical mass of infrastructure was present, a finding that is supported by Jacobsen (2003). However, early studies often relied on a narrow measurements of ICT infrastructure like Broadband connection and telephone lines and gave little weighting to the skill capacity of individual to utilise ICT infrastructure.

To conclude this sub-section, the research problem can therefore be summarized as the need to appreciate the extent to which ICT investment can or has impacted South Africa’s economic growth. This is important considering the economic challenges South Africa is going through as highlighted above. Limited research on the relationship between ICT investment and economic performance has resulted in a situation where this relationship cannot be reliably ascertained.

1.4. Research objectives.

The main objectives of the study was to investigate the impact of ICT infrastructure investment on the growth rate of South Africa's economy.

The Specific objectives of the study are:

- To determine the impact of ICT infrastructure investment on GDP growth rate of South Africa;
- To assess if GDP growth in turn positively affects growth in ICT Investment (bi-directionality);
- To assess the growth/decline patterns in ICT Investment and GDP between 1992 and 2013;
- To make policy recommendations based on the findings relating to the above.

The first research objective of the study was further reduced to hypotheses that were tested using Time Series Analysis.

1.4.1. Research hypothesis

The following hypotheses were developed in order to meet the above objectives:

- Ha1: ICT infrastructure investment has a positive impact on South Africa's economic growth rates.
- Ho1: ICT infrastructure growth does not have a positive impact on economic growth rates in South Africa.
- Ha2: GDP growth in turn positively affects growth in ICT Investment (bi-directionality).
- Ho2: GDP growth in turn does not positively affect growth in ICT Investment (bi-directionality).

1.5. Significance of the study

The South African government has over the years introduced various policies to address inequality, unemployment and lack of economic growth. These include GEAR, RDP and ASGISA all of which have failed to meet their intended goals (Mosala et al.,2017). South Africa has the problems of low growth, high unemployment, income inequality and limited debt capacity to finance infrastructure projects to spark economic growth (Moyo & Mamobolo, 2014).

Many views from the literature suggest that ICT infrastructure investment can positively impact economic growth (Nasab & Aghaei, 2009; Holmner & Britz, 2011). Such views call for increased government and private sector expenditure on ICT as a way to bolster the economy. However, without empirically testing the truthfulness of these views, it is a challenge to implement any policy changes that involve the use of ICT infrastructure investment as a tool for economic growth. Furthermore, there is a need to appreciate the extent to which the hypothesized relationship between ICT infrastructure and economic growth is effective. This information is important for use in the consideration to use ICT as a vehicle for economic growth or not. Therefore the significance of this study is that it will be able to deduce whether the hypothesized relationship exists or not.

The study will not only test the hypothesized relationships between ICT investment and economic growth but will also provide models that can be further applied in making forecasts and projections between the two variables. It therefore plays a pivotal role in being part of the solution to the socio-economic problems that have been broadly discussed in this chapter. It does this by providing a model that proves or disapproves as well as quantifies the relationships between the two variables for application within the professional and academic circles.

ICT infrastructure, as discussed by several scholars, can potentially help address many of the above stated problems. ICT infrastructure has the ability to improve national output, as well as to improve financial and economic inclusion which can mitigate South Africa's unemployment and income inequality problems (Cronin, et al., 1991). Perhaps the most valuable attribution of ICT infrastructure, is that compared to other forms of infrastructure that require a high weighting of state funding, ICT has significant private participation, and the bottleneck to growth is often more a function of regulation meaning the high levels of ICT-led economic growth can be achieved with very little capital expenditure on the states part (Ngwenyama & Morawczynski, 2009).

Further to the point above, South Africa cannot afford to fall behind on its ICT Infrastructure needs. This is because South Africa will not be able to compete in the digital economy, and most importantly the coming fourth industrial revolution (Visser, 2017). This fourth industrial revolution will display many business, industries and jobs; which will only deepen further many of the structural issues of South Africa that undermine its economic growth (Visser, 2017).

1.6. Delimitations of the study

The study uses data from the period from 1992 to 2013 to access the causal relationships between ICT investment and Gross Domestic Product (GDP). It emphasizes on ICT infrastructure as opposed to all the other types of infrastructure such as transportation infrastructure and residential infrastructure and so on. It focuses on South Africa as a case for study.

1.7. Outline of the study

The study is presented in this report in five chapters. These are briefly outlined below.

1.7.1. Chapter 1

This chapter introduced this study, and the problem that the study sought to address. It also outlined the study objectives, the hypotheses to be tested and importance of this study.

1.7.2. Chapter 2

In Chapter 2, literature relating to South Africa's economic situations, infrastructure development history, ICT investment situations and other related material is presented. The theoretical framework that guided this study is also presented in the same chapter.

1.7.3. Chapter 3

This chapter introduces the methods and processes that were carried out in data collection, data analysis, and data presentation. It defines the time series analysis approach, outlining the various processes and stages that were carried out to test the given hypotheses and to meet research objectives.

1.7.4. Chapter 4

In Chapter 4, the results of the study are presented. The hypotheses that were given in Chapter 1 are also tested.

1.7.5. Chapter 5

In Chapter 5, findings to the study are summarized and relevant conclusions given. Recommendations for policy purposes and for further studies are also made in the same chapter.

1.8. Conclusion

This chapter introduced the study topic as *The relationship between ICT infrastructure investment and economic growth in South Africa*. It focused on the need to ascertain whether ICT investments had a positive short and long term relationship with economic growth. Understanding this relationship was deemed to be important for ICT investment policy and general economic growth policy considerations. There was a strong view from the study's background that ICT investment and indeed general infrastructure was a strong impetus for economic growth. However, there was no study to verify this assertion within the South African ICT and economic performance contexts. The next chapter reviews literature that sheds more light on past and current debates on this relationship.

CHAPTER 2. LITERATURE REVIEW

2.1. Introduction

This chapter reviews the literature on the relationship between broad infrastructure investment and economic growth. It starts by briefly discussing the theoretical framework that guided the study. It then takes a narrower approach where it centres the discussion on ICT infrastructure investment versus economic growth. Lastly, it presents results from several empirical studies that were conducted on the relationship between ICT and economic growth in both the developing and developed economies.

2.2. Theoretical framework

A theoretical framework is a set of views, concepts and models that are used to support or develop the main suppositions of a study (Labaree, 2009). This study used various works that related infrastructural investment to economic growth as part of its theoretical framework. The common denominator of these works is that they applied Cob Douglas functions and linear regression models to outline the relationship between infrastructure investment and economic growth.

These include the model by Nasab and Aghaei (2009) and by Perkins (2005) below. Perkins model forms the basis of the theoretical framework of the study. This model is presented below:

Equation 1: Perkins Model on ICT Investment and Economic Growth

$$G_t = a_t + \beta X_1 + \beta X_2 + \beta X_3 + \beta X_4 + \mu_t$$

$\boldsymbol{G_t}$= Real GDP growth rate

$\boldsymbol{X_1}$= ICT infrastructure Investment *(positive relationship with G*)

$\boldsymbol{X_1}$= (GFCF minus ICT Investment) *(positive relationship with G*)

$\boldsymbol{X_3}$= Real exchange rate *(positive relationship with G*)

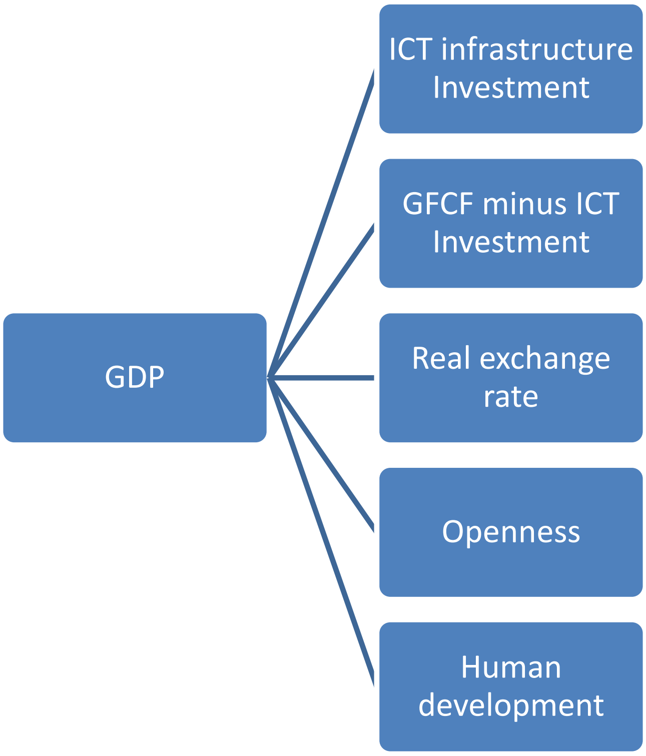
$\boldsymbol{X_4}$= Openness *(positive relationship with G)*

$\boldsymbol{X_4}$= Human development *(positive relationship with G)*

The model basically asserts that economic growth is a function of ICT investment, GFCF, real exchange rate, openness of trade and human development (as assessed through the Human

Development Index). In the model, there is a positive relationship between economic growth as measured using GDP and the function variables which are thus classified as dependent variables.

Figure 2.1: Perkins GDP - ICT Investment Model



Source: Perkins (2005)

Nasab and Aghaei (2009) like Perkins above, also assert that GDP growth related to ICT investment can be explained by ICT Investment changes over time, physical capital and human capital. This relationship is captured in the model below:

Equation 2: ICT- Economic Growth Model

$$Y = A + \alpha_c C + \alpha_k \dot{K} + \alpha_h \dot{H} + \alpha_n N$$

Y represents economic growth or economic value added by ICT, C stands for ICT investments inputs while K and H stand for physical and human capital and N stands for labour stock. In the model, ICT contributes towards economic growth through the products and services that are needed in ICT executions, infrastructure from the economy at large and human and labour effects. ICT thus contribute to economic growth alongside other supporting factors identified in the model. In a different model, Kadongo and Ojah (2016) tested whether ICT investment really had the envisaged effect on economic growth. Their model, like Nasab and Aghaei (2009) above was also in the form of a linear regression model.

The study was therefore based on the view that there is a linear relationship between GDP and economic growth and that this can be tested through Time Series Analysis. While GDP and economic growth as variables of the model, are broadly defined in the study, the other variables are briefly explained below.

2.2.1. Gross Fixed Capital Formation (GFCF)

This includes land, transportation infrastructure, telecommunications infrastructure among others (Pettinger, 2016). Several econometric models acknowledge the significance of GFCF in economic growth. GFCF refers to the total value physical factors of production within an economic entity. These include Nasab and Aghaei (2009) who present the below equation where GFCF is shown by changes in physical capital (K).

Equation 3: GFCF and Economic Growth

$$Y = A + \alpha_c C + \alpha_k \dot{K} + \alpha_h \dot{H} + \alpha_n N$$

The other elements of the above equations are similar to those in Equation 1 above. In agreement, Mankiw et al. (1992) also present the function below:

Equation 4: GFCG and Economic Growth

$$Y = K^{a} H^{B} (AL)^{1-a-b}$$

Capital formation is represented by capital stock changes (K). Other variables of this functions are labour , technology state and human capital.

As argued in the above two models, for economic growth to occur, capital is required as an input of the production processes. Secondly, capital, as it increases in stock, it represents increasing production output. Thus GFCF affects economic growth mainly through enabling production and resulting in demand for capital equipment that also has to be produced.

2.2.2. Human Development Index (HDI)

Human Development Index (HDI) is “a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and having a decent standard of living.” (UNDP, 2019:1). It is an important measure that also assesses the economic and social progression of a country, which ordinarily have been measured using GDP (UNDP, 2019). A high HDI implies that an economy has got a population whose health, knowledge and living can positively enable it to contribute more positively to economic growth. Kodongo and Ojah (2016) assert that human capital is a critical factor in economic development as it endows the population with skills needed for economic development. Because of these assertions, HDI was included in the model that this study tested to assess the relationship between GDP and economic growth.

2.2.3. Openness

Openness in this study relates to trade openness particularly the value of exports made less imports in the period of interest. This variable has been argues as directly impacting economic growth with an increase in exports having a more positive relationship with GDP. Mafelane and Odhiambo (2017) found a positive relationship between trade openness and GDP growth in South Africa. Similarly, Keho (2017) argues that trade openness positively influenced economic growth in the following equation:

Equation 5: Economic Growth and Trade Openness

$$Q_t = \phi \mathrm{OP}_t^{\delta_1} K_t^{\alpha} L_t^{1-\alpha} Z_t^{\rho}$$

In the above function, trade openness (OP), alongside capital stock, labour and technological change exerted a positive impact on economic output. Kodongo and Ojah (2016:6-7) also support the effect of trade openness on economic growth. They state that, "infrastructure access, and quality, also relate to economic growth indirectly via export diversification (trade competitiveness), and cross-border capital flows and export diversification, respectively". The above arguments points towards both the direct and the indirect impact of trade openness to economic growth.

2.3. Understanding Infrastructure

Infrastructure spending was historically defined as consumption expenditure by either the state or private sector, but now it is near universally defined as capital expenditure, as infrastructure has been recognised as a capital good (Gramlich, 1994). Furthermore, infrastructure can be a private or public good (Pettinger, 2016). Lastly, in the economic literature, infrastructure can be understood and examined as both a stock and a flow variable, and it imperative that measurements or any analysis or approach uses the appropriate measure (Perkins, 2005) . With the above context in mind, there are essentially within the literature two categories of infrastructure recognised within an economy: Economic and social infrastructure respectively.

Social infrastructure relates to physical investment in schools, hospitals, universities, cultural and recreational facilities (Kuralatne, 2006). Social infrastructure, although not the focus of this paper, plays a critical role in the development of a nation, and has strong long-term influence on economic development; and most importantly its use as an economic tool to address social imbalances and inequality (Fourie, 2006).

Economic infrastructure on the other hand refers, in the main, to roads, telephone and electric lines, powers stations, ICT infrastructure, rail, ports and airports (Kuralatne, 2006). There are several approaches to measuring infrastructure. Physical and financial measures are however commonly applied (Torissi, 2009). Economic infrastructure measures vary across the multitude of infrastructure types, some of the most common being paved road length, power capacity and container processed a port; this approach is suitable when measuring specific type of infrastructure (Torissi, 2009). Financial measures are more commonly used when measuring aggregate infrastructure stocks or flows.

Both the approaches above have their own shortcomings, whether it be in data in general, data at different levels, or accounting for improvement, maintenance, quality; as well as inappropriate aggregation or geography aggregation (Fedderke & Garlick, 2008).

2.4. The theoretical linkages between infrastructure and GDP

Several views on how infrastructure and GDP are linked are discussed in the literature. Some of these focus on the supply and demand sides of this linkage.

2.4.1. Supply side channel

Infrastructure can be viewed as a factor of production, whereby an increase in the stock levels of infrastructure promotes economic growth directly (Collier & Gunning, 1999). Secondly, infrastructure can be accounted for as complement to other factors, in that it could lower the cost of production or increase the productivity of other inputs (Barro, 1998). Thirdly, infrastructure can be viewed as stimulus to factor accumulation (Fedderke & Garlick, 2008).

2.4.2. Demand side Channel

Infrastructure can be viewed as stimulus to aggregate demand, in that large infrastructure projects promote the demand for various inputs and goods, either through construction or maintenance (Marrioti, 2002). Secondly, infrastructure can be viewed as a tool of industrial policy that cultivates private sector investment in a specific direction (Canning & Padromi, 2004).Thirdly infrastructure can stimulate economic growth thorough second round effects associated with consumption (Fedderke & Garlick, 2008). Amongst economists, there exists a relative consensus that demand-side considerations are important in determining short run fluctuation in economic performance but play a less significant role in determining medium and long run patterns of economic growth (Romer, 2004).

2.4.3. Pushing GDP or Pulled by GDP

A common and pervasive theme throughout the development of the literature, as highlighted by Fedderke and Bogetic (2006), is that the relationship between infrastructure investment and economic growth is not linear; more importantly, that in many cases it can be multi directional; and many authors have alluded to the fact that the causality relationship has proven to run in the opposite direction (Calderon &Server, 2004). This means that GDP growth at times drives and explains infrastructure growth and investment, and not the other way around as economic theory would dictate.

Demurger (2001) recognised the positive economic effects of infrastructure investment but note that the effect decreased with accumulation; in addition, Arslanalp, et al. (2010), 1suggests that the degree of efficiency and investment in public infrastructure maybe subject to a threshold effect. This implies that infrastructure investments effect on economic growth is subject to diminishing returns and even negative returns. Thus, to maintain the integrity of the gains of infrastructure investment, it requires optimisation of the network effect though optimal infrastructure allocation, infrastructure mix and quality, timing and the eradication of bottlenecks in infrastructure (Banister, 2012).

2.4.4. The Spill over effect

Recent studies have noted the need to account for spatial dimension of growth-enhancing effects of infrastructure (Cantos *et al*, 2005; Chandra & Thompson, 2000). This is because a portion of the benefits derived would spread across regions and would not just have an effect on the investment region. More importantly as Deng (2013) notes, the spatial spill over effect is agnostic, and thus may either bring a benefit or suffering to a neighbouring regions or states where infrastructure investment is made. Thus investment in infrastructure can have self-cannibalising effect on GDP growth. This therefore means that the expected positive benefits of infrastructure investment may not be realised.

Wang, Deng and Wu (2014) investigated the impact of infrastructure on economic growth in China for the period 1990 to 2010. Their conceptual point of departure was the use of the Feder model: making use of provincial data and applying a time-lag model in a spatial model. They found that investment in infrastructure has two effects, namely, a direct effect (Aschauer, 1989; Munnell ,1990) and an indirect effect on economic growth or spill overs.

More specifically Wang, Deng and Wu (2014) found that infrastructure had a positive spill over effect on economic growth although the effect varied in different regions, due to economic disparities between these regions. This finding points to the fact that the extent of the spill over effect was stronger the more industrialised the region was. Lastly, the impact of the spill over effect is that it carries a significant time lag, and its effect becomes weaker as time passes.

The above findings take away the simplicity of the relationship between ICT infrastructure and GDP growth. As noted, other effects including spill overs and cannibalism effects could also affect the linear relationships suggested by Kodongo and Ojah (2016) and Nasab and Aghaei, (2009).

2.5. Infrastructure in South Africa

South Africa as an economy and nation has complex history, whereby its development infrastructure is marred with complexities, that are best summarised by Perkins (2010:27)

> *"The building of South Africa economic infrastructure during the 19th and 20th centuries was dominated by the state. Nonexclusively, but certainly for the most part, it was the state that owned and operated railway lines, roads, harbours, airports, water systems, power station and communication networks. As social infrastructure, access to economic infrastructural services was in most cases determined along racial lines, heavily skewed in favour of the minority white population and away from the majority black population. The damage so done is incalculable, except to say the it must have been enormous; no assessment of it will be attempted here."*

The infrastructural history of South Africa has left a legacy of inequality, and disparities in social and physical infrastructure amongst South Africa's population that have culminated over the years into its dual economy (Perkins, 2010; Odeyemi, 2009). This dual economy consist of a sector that resembles a developed state and another a third world nation, where low levels of literacy, low access to resources and high unemployment are pervasive (Perkins, 2010; Odeyemi, 2009). This structural split in the economy has become a mine field for policy makers to navigate. This is because resource allocation to infrastructure itself is not only complicated by the need for GDP optimisation; but also by the value judgments consideration related to historical justice (Negota, 2001).

> *"The development of economic and social infrastructure in South Africa has a long and troubled history. Excellent in parts yet hopelessly inadequate in other and riddled with discriminatory practices and inequalities that were the hallmarks of the country's Apartheid past, the South African infrastructure experience does not lend itself to generalisation or easy assessment"(Perkins, 2010:24)*

Despite South Africa's chequered past, the country remains the most infrastructural capacitated countries within Sub-Saharan Africa and SADC, which explains, to a large degree, why it remains the most attractive investment destination in the region (Perkins, 2010).

Negota (2001), argues that in order for South Africa to truly harness the full potential of infrastructure-led economic growth, a more regional approach is required. In this approach, SADC economies could collaborate on infrastructure investment to eradicate irrational and un-coordinated infrastructure investment. Negota (2001),finds that the lack of co-ordination has locked up economic potential in the region and created friction to trade and economic growth.

Fedderke (2006), investigated the relationship between GDP growth and infrastructure investment in South Africa for the periods between 1875 and 2001. The study model accounted for infrastructure by using railway goods and stock, locomotives, paved and un-paved roads, goods and passenger vehicles, and electricity outputs. Fedderke’s (2006) study found that public sector infrastructural investment had the effect of promoting private sector investment in physical capital, which, in turn, had a positive impact on GDP. According to Fedderke, the mechanics of it is that there exists a two way relationship, whereby investment in infrastructure stimulated economic growth and economic growth simultaneously required and provided funding for greater investment in economic infrastructure.

Perkins, Fedderke and Luiz (2005), analysed the long-term trends in the development of South Africa's economic infrastructure and discuss their relationship with the country’s long term economic growth. They collated a data-base of various infrastructure in South Africa encompassing of ports, telephone lines, electricity, railway and roads. Once collated, they applied F-tests to determine the direction of association between economic infrastructure and economic growth. Their findings were that there was a long run relationship between infrastructure investment and fixed capital stock on one hand and GDP on the other.

2.6. ICT infrastructure investment and economic growth.

Several scholars identify and discuss the channels through which ICT infrastructure investment translates into economic growth. Vu (2011) investigated the hypothesis that ICT penetration has a positive effect on economic growth. Vu postulates that ICT's effect on economic growth is manifested through technology diffusion and innovation; enhanced decision making by firms and households and lastly through increasing demand and in the reduction of production costs. All of this culminated in increased output within an economy.

According to Jalava and Pohjola (2002), based on the works of Solow (1947), and Jorgenson and Stiroh (2002), there are four channels through which ICT infrastructure investment impacts economic growth. Firstly, this occurs through the production of ICT services and goods, which directly contribute to the aggregate value added generated in an economy. Secondly, through improved productivity of the ICT sector, which channels into the holistic productivity of an economy. Thirdly, through the use of ICT capital investment as an input in the production of other goods and services within an economy and finally, through the contribution to the broader economies Total Factor Productivity in non-ICT producing sectors (a spill over effect).

van Ark's (2002) theoretical framework to explain how ICT infrastructure investment feeds into economic growth presents three channels through which ICT infrastructure translates into economic growth. Firstly ICT investment can have a direct effect on output growth of the ICT producing industry firms; secondly through the adoption of ICT and its productivity effect on other sectors of economy (Dolton & Makepeace, 2004) and thirdly through the spin-offs from ICT in terms of innovation as well as ICT diffusion.

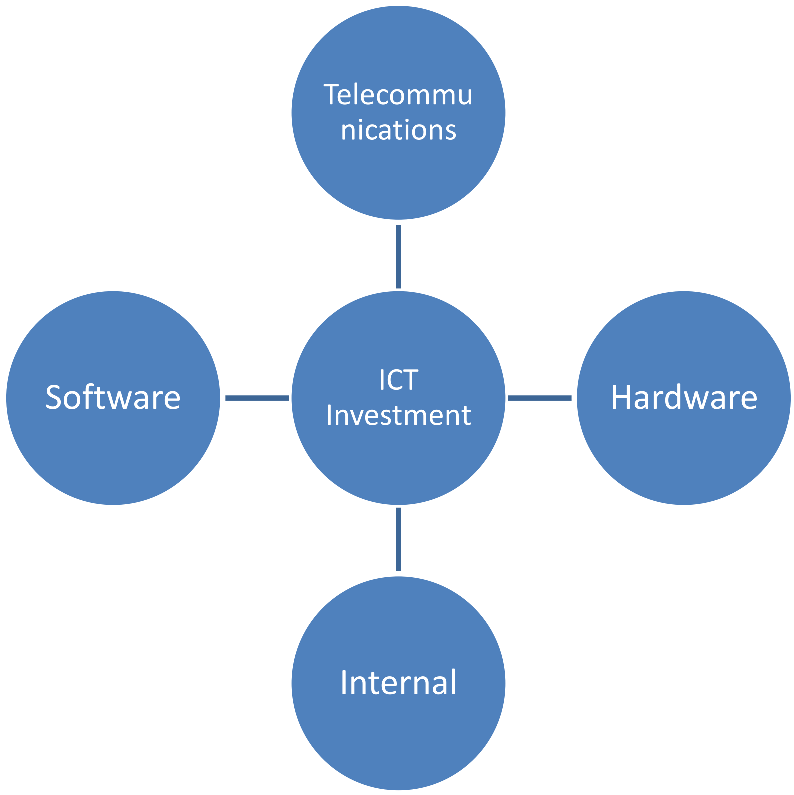
The other channels through which ICT infrastructure investment may channel may translate into economic growth is through labour productivity (Bollou & Ngwenyama, 2008). People using various ICT resources to do their work may become more efficient producing more output in a shorter space of time. Additionally, they may become more effective in decision making reduce error and wastage. Another theory is that ICT investment positively affects the economy by increasing market efficiency. ICT decreases barriers to market, reduces transaction costs as well as market information asymmetry (Toader, et al, 2018). All these increases aggregate demand and improves price efficiency in markets.

Lastly, the other channel that normally finds expression in the human development side of the ICT infrastructure debate is that ICT infrastructure investment's impact on economic growth can be accounted for in second order investment of country. Second order investment according Servon (2002), creates condition through which people can escape poverty as well promote their general social welfare (literacy, health, education).

2.6.1. Dimensions ICT infrastructure investment

According to WITSA (2008) and Bankole *et al* (2010), ICT infrastructure can fundamentally be divided and understood within the following four dimensions.

Figure 2.2: ICT Investment Dimensions



Source: WITSA (2008) and Bankole et al (2010)

- *Telecommunication investment* is the amount invested in an economy in voice and data communication infrastructure and services in a country. This includes local and long distance wire line telecommunications, wireless communication, paging, satellite communication , private line services and internet. Telecommunication investment is widely regarded as the most financially significant dimension of ICT infrastructure investment (Samoilenko & Osei-Bryson, 2008).

- *Software Investment* is the total value of all the purchased software products. This accounts for utility software, application tools, software packages and data systems in an economy. Software's role in the ICT infrastructure equation, is that it acts as the computing capacity backbone of an ICT ecosystem (Jorgenson & Vu, 2007).

- *Computer hardware investment* is the total computer hardware spending in a country. This accounts for leased and purchases computers, memory upgrades, printer, scanners, terminals, storage devises and input output devices. This dimension's effect on both total factor productivity and labour productivity at the firm level has been found to be highly robust (Gibson & van Meter, 2002).

- *Internal spending* describes the amount of internal software customisation, human capital development, IT-related internal spending such as outsourced domestic and offshore IT consulting, network systems integration, webhosting and equipment maintenance. Essentially it accounts for the human aspect of ICT investment that creates the quality of linkages between the other three investments (Kim *et al*, 2008).

The next section discusses empirical findings on the relationship between ICT investment and economic growth using cases from both the developed and developing economies.

2.7. Evidence from Developed Economies

Cronin (1991), explored the relationship between telecommunication infrastructure and GDP growth in America for the period 1958 to 1988. His research focused on the causal relationship between the above mentioned variables. In his study he employed the Granger causality test, and modified Sims tests. The findings of his study was that telecommunication investments promotes economic growth and also stimulated the demand for further investment in telecommunications.

Roller and Waverman (2001), using panel data from 21 OECD countries for the period 1970 to 1990 analysed the association that telecommunication infrastructure investments had with economic growth. Their approach was to use a model, that accounted for telecommunication investment in a microeconomic demand supply framework. Their findings were that there was both a causal and positive relationship between economic growth and telecommunication investment. In a similar study on the same 21 OECD countries by Datta and Agarwal (2002), Roller and Waterman's (2001) findings were reinforced.

Hardy (1980) integrated the effect of telecommunication investment on economic growth. His study spanned from the period 1960 to 1973 and included 45 developing nation and 15 developed nations. The study employed a regression model where GDP per capita was run against radio sets per capita and fixed telephone lines per capita. The study found that the impact was more significant in developing nation then it was in the case of developed nations.

Tong, Yu, and Roberts (2014) examined the dynamic relationship between the quantities of infrastructure, exports and economic growth in the United States using a multivariate time-series analysis. The findings of their paper were that investment in highways and streets affects economic growth indirectly by improving the capital stock of non-transport infrastructure, and through the crowding private capital to other investments.

Thompson and Garbacz (2007), investigated the panel data of 93 countries to determine if telecommunication penetration rate improved economic productivity. The study was limited to the period 1995 to 2003. The study found that the penetration rate of telecommunication service significantly improved efficiency; and that inefficiency gains were most notable in lower income countries. In a similar fashion, Seo, Lee and Oh (2006), analysed data from 29 countries for the period 1990 to 2000, their study found that ICT investment had a positive effect on GDP growth. One of the interesting findings of this study was that the relationship between ICT investment and economic growth did not run the other way.

Egert, Kozluk and Sutherland (2009) investigated if investment in network infrastructure boosted economic growth in OECD countries in the long term. The findings of their study were that infrastructure investment can have a positive effect on growth. This is because of economies of scale attributed to infrastructure investment, the existence of network externalities and its contribution to improving competition. Egert (2009*)* explains that the effect of infrastructure investment is non-linear, and that linearity is strongest at lower stock levels. Furthermore, many developed nations displayed characteristics of an oversupply of infrastructure, resulting in non-significant economic growth from infrastructure investment. This is indicative of either wasteful expenditure or sub-optimal infrastructure financial allocations.

2.8. Evidence from Emerging Markets

Misra (2015), examined the relationship between infrastructure and economic output in 28 Indian states, for the period 2001 to 2018.Their study developed a composite infrastructures index for each type of state special and general category states (general category refers to centres of economic significance and special category refers to remote rural areas) by considering both economic and social dimensions.

They found that infrastructure only influences economic output in general category states. However, in both categories, output influences infrastructure more than infrastructure influences output. Further analysis reveals unidirectional causality from output to infrastructure and from social infrastructure to economic infrastructure. These findings suggest the important need for additional funding to special category states. This is of relevance to many developing nations like Brazil, South Africa and Nigeria which have imbalanced regional economic growth, where certain areas are modern and vibrant economic centres while others are rural and economically stagnant or regressive.

Norton (1992) investigated the relationship between GDP growth, telecommunications as well as transaction costs. Using an approach previously applied by Kormendi and Maguire (1985), the study interrogated the cross national GDP growth of 47 nations over a period of 20 years for the period 1957 to 1977.

The findings of his study were that telecommunications impact was positive and significant for both GDP growth and transaction costs. The study further found that improvements in telecommunications stock lowered transaction costs which in turn bolstered economic output. Norton (1992), further adds that the compounding impact of telecommunications stock, explains to a large extent why poorer countries often do not reap the benefits of telecommunication investments. This latter notion finds support with Bollou (2006).

Madden and Savage (1998) performed an analysis on the relationship between gross fixed infrastructure investment and GDP, by using an OLS model. The study was focused on transitional economies, that were in the main located in both Central and Eastern Europe. The major findings of the study was that telephone line penetration was both positive and mostly significant. Madden and Savage's study (1998), proved that the extent of the impact that telecommunication investment could have on economic growth was high, and thus provided the sound economic case for the greater allocation of resources to ICT infrastructure, particularly in the context of developing nations. Bollou (2006) however highly disagreed with this view particularly in the context of Sub-Saharan African countries. Bollou (2006), employed a DEA analysis to cope with the absence of data, and was able to extract correlation between economic factors and ICT expansion. The results of the study found that the relationship between ICT expansion and economic growth in West African countries was weak and well below that of previous studies on the topic.

Tella, Amaghionyeodiwe and Adyedoye (2007) explored the relationship between GDP growth in Nigeria and telecommunications expansions for the period from 1970 to 2004. The study utilised the econometric method (3SLS equations). The findings from this study were that the relationship between GDP growth and telecommunication expansion was both positive and significant. More importantly the causality between these variables was bi-directional - an outcome that is prevalent in the body of the literature on ICT infrastructure-led economic growth (Rufael, 2007; Beil, Ford & Jackson, 2005).

Bollou (2006) states that to benchmark the output effect of ICT infrastructure investment of developing economies to that of developed economies was misleading. This is because to do so is to actually ignore the differences in transformative capacities between developed and developing countries. This was the very premises of the arguments made by Avegerou (1998). Adding to this narrative, Bollou and Ngwenyama (2008) found that despite increases in ICT infrastructure investment, the total factor productivity is declining in many African countries raising many questions for policymakers, as well as findings from previous studies that hailed the ICT investment as a solution to economic growth.

The earlier work of Dewan and Kraemer's (2001), vindicated many of the findings of Bollou (2006). In their study, they found that, in the case of developed countries there was both a positive and significant relationship between ICT infrastructure investment while in the case of developing countries the results were inconsistent and often no positive or significant relationship was found.

Kyem (2012) points out that besides the penetration that mobile communication has had in sub-Saharan Africa, most ICT development initiatives have frankly fallen short of their potential and have failed to realise their intended scope of benefit. He makes the point that most policies have had conflicting and irrational approaches to ICT development, which has resulted in a poor environment for innovation and in turn poor economic growth from ICT investment.

What makes the above opposing views interesting is that, there is a narrative within the discourse that ICT offered a great leap forward for developing nations, given the democratised nature and leveraging effect that ICT infrastructure creates (Chicru & Mahajan, 2009). Secondly the fact that developing nations were coming from such a low base, the body of infrastructure literature would suggest that the effects of ICT infrastructure should rather be more significant and pronounced than in the case of developed nations.

Pohjola's (2001) contribution was essential, because his work clarifies and validates the divergence within the literature. He analysed the impact of ICT on economic growth in 39 countries. The study employed and augmented variant of the neoclassical growth model. The findings of the study were that there was no definite positive relationship found between the variables, which stood in direct contrast with body of literature on the subject. The result however turned positive when, the study was narrowed down to only include the 23 OECD countries.

The value of Pohjola's work is that it cements the idea that the effect of ICT investment does not behave the same way in every country, and the line upon which divergence manifests is often on the basis of the degree and stage of development a nation is in. This then begs the question why the causal relationship between ICT investment and GDP growth is weaker in the developing world than it is in the developed world. Samoilneko and Osei-Bryson (2007), found that there were three major reasons that could answer this question. Firstly, ICT infrastructure alone cannot drive economic growth and African economies often had a lack of ICT complementing infrastructure. Secondly, African economies did not have the necessary base infrastructure or most importantly the infrastructure quality to capitalize on the ICT's productive capacity (Kodongo & Ojah, 2006). Thirdly as advanced by Bollou (2006), the human measures like ICT skills level and ICT readiness can heavily constrain the economic output effect of ICT investment.

What is apparent from the literature is that there is a divergence on findings of how ICT investment affects economic growth suggesting that every nation should be handled on a case by case basis. This is especially the case, as the variables that constitute both a nation's ICT infrastructure and economic performance are diverse and dynamic.

2.9. Explaining the divergence within the literature

Related to different contexts: Often, many of the studies we have mentioned cover different time periods and often the studies vary in their length of time. Meaning they vary on the basis of short term, long term. Another reason is the context differs is the geographical scale of the research endeavour, in that the focus often varies from national, to provincial to city levels data (Lynde& Richmond, 1992). Lastly nation or regions very in their capability and readiness to be able to enable economic growth, thus the impact of infrastructure investment does vary (Banister & Berechman, 2001).

Related to different phenomena that are being measured: Differences in economic sectors are measured within each study; in that the productivity gains vary across various economic sectors. For example, Fernald (1999) found that vehicle dependent industries (transportation) benefit much more from road infrastructure investment then non vehicle-dependent industries (e.g. textiles). Furthermore each study measures different types of infrastructure across a variety of nation states, which innately will vary in their existing stock, mix and the nature of their existing infrastructure (D*e*murger, 2001).Lastly infrastructure is not a homogeneous input, and quality levels of infrastructure are not always accounted for which can produce varying results (Jiwattankulpaisarn, 2010).

Related to Distinct ways of Measuring Similar phenomena: Studies often differ in the measure used to describe the dependent variable. According to Chatman and Noland (2011), many studies have looked at different ways to capture economic growth either through Gross Domestic Product, real and nominal, wages, GDP per capita and even land values. Secondly the studies also differ in their measure of the explanatory variable, in that some studies examine either physical stock, investment, subsets of each or have addressed the issue through index models.

Another reason is *functional specification*, in that different settings of functional specification (especially whether accounting for temporal lags in the productivity effect of expanding infrastructures capacity) could be likely a major contributor to diverging studies. Lastly the estimation method of econometric models, in that regression techniques applied in earlier techniques did not often account for endogeneity and spatial spill over effect.

2.10. Conclusion

From the literature above there is a general view that infrastructure has a positive effect on economic growth, and that the relationship runs both ways. However, these positive relationships were mainly in the contexts of developed nations. Developing nations generally yielded weak or no relationships between economic growth and ICT investments. The divergence within the literature stems from in the main, different temporal contexts; differences in the phenomena that are being measured; differences in ways similar phenomena are measured as well as differences in the functional specifications. ICT infrastructures investment is constituted by telecommunications infrastructures investment, software investment, computer hardware investment and internal spending.

CHAPTER 3. RESEARCH METHODOLOGY

3.1. Introduction

In this chapter, the methods and processes that were applied in the study as well as the rationale and philosophical bases for these are discussed. The chapter includes sections on the research design, research philosophies guiding the study, sampling procedures, data analysis and ethical matters.

3.2. Research design

According to Kumar (2011:64), "A research design is a plan, structure and strategy of investigation so conceived as to obtain answers to research questions or problems". Saunders et al. (2009) state that a research design involves the selection of methods that will be applied in gathering data and analysing in to understand a research matter of interest. To answer the research questions which included a hypothesis on whether ICT investments caused GDP growth, a causal research design was applied. This research design, sometimes referred to as an explanatory design involves assessing how one variable causes a change in another. The research design is strongly influenced by the causality principle.

Amongst the theoretical views that influenced the study design was the Theory of Causality also referred to as the causality principle (Guyon, et al., 2013). This theory is based on the belief that more often than not, one phenomenon is a direct result of another. The phenomenon that brings about change in another is the cause and that which is impacted or changed if the effect (Kumar, 2011; Guyon, et al., 2013).

Kumar (2011) asserts that the main premises of the theory is that cause and effect studies can be successful if three types of variables are present. Kumar states that these are the cause or the independent variable, the effect which is the dependent variable and an extraneous variable that can affect both the dependent and independent variable simultaneously during the change process.

The cause and effect relationship described above occurs within a defined time frame. Time is actually important in helping to decide if indeed the particular cause was responsible for the signified effect (Guyon, et al., 2013). However, time does not necessarily affect this relationship at the point of cause or effect but there may be delays called lags (Guyon, et al., 2013). These depend on the length that it takes for the effect to fully materialise with some effects taking shape instantly and others in years.

The causality principle is the driving force of many research processes and data analysis procedures in correlational tests, variance tests and time series tests (Kumar, 2011). However, causality approaches also hold the arguments that the mere fact that variables show a relationship does not necessarily mean they have a cause and effect relationships (Guyon, et al., 2013). Causality tests that are part of the chosen design however attempt to ensure that a cause and effect relationship is proven or disapproved on a given hypothesis.

3.3. Research methods

Research methods refers to the options and processes that are used to collect data and to analyse this data. Two broad types of data that are commonly discussed in research are qualitative data and quantitative data. The first type, quantitative data, exists in numerical form and can therefore be statistically or numerically analysed (Bryman & Bell, 2014). Qualitative methods involve the collection and analysis of non-numerical data (Babbie, 2016). This study relied on quantitative data as well as quantitative data analysis methods and can therefore be described as a quantitative study.

Quantitative data analysis was applied to the study because the objectives of the study could only be met through the analysis of numerical data on GDP, GFCF, real exchange rate, ICT investment, HDI and openness of trade. The need to assess causality amongst these variables naturally called for this method (Walker, 2010). These variables all yielded reliable data that was used in the analysis.

3.4. Research philosophy

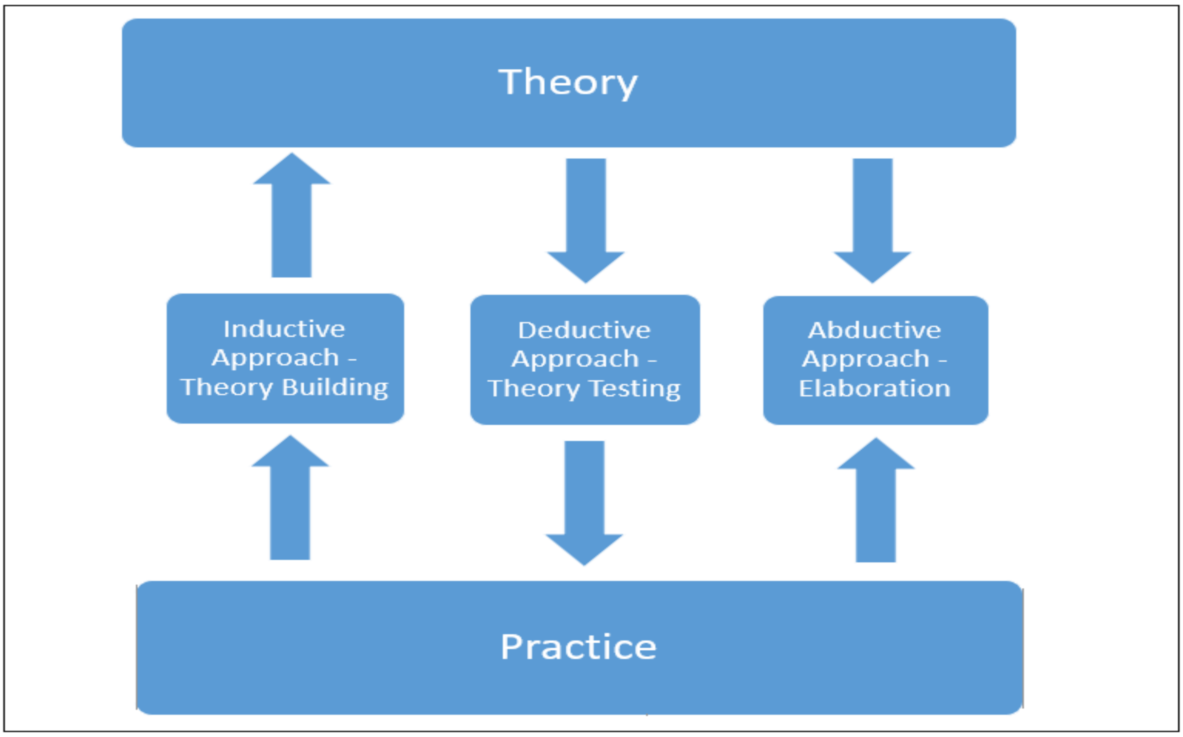
Quantitative studies are commonly discussed as yielding to the positivist school of thought in research. Positivism is a view that research is only meaningful if it is objective in nature (Walker, 2010). Results from a successful study must answer research questions in one best way, i.e. a single truth must emerge. To support this high level of objectivity, positivists believe that the researcher should be detached from the data collection process and should not influence how data is collected (Bryman & Bell, 2014; Beaudry & Miller, 2016). Additionally positivists believe in rigorous data tests for reliability and validity as well as systematic sampling procedures that are meant to reduce both bias and error (Bryman & Bell, 2014). This study

Another popular philosophical view that is discussed alongside positivism is interpretivism (Babbie, 2016). This views strongly supports subjectivity in research and is mostly applicable when human subjects are part of a study. This is because due to diversity issues, it is sometimes important to cater for these differences through allowing subjective thought to flow (Babbie, 2016; Burns & Grove, 2003). As this study did not rely on human subjects who can be subjective, it was not feasible to apply an interpretivist view in the study.

3.5. Research Approach

The study applied a deductive approach as opposed to an inductive approach. According to Babbie (2016) and Easterby-Smith et al. (2008) , a deductive approach starts with a set of theories and then establishes a research design that enables the testing of these theories. An inductive approach on the other hand does not aim to test a theory rather it attempts to develop one from the findings of the study. Figure 3.1 below illustrates this.

Figure 3.1: Deductive versus Inductive Approach:



Source: Easterby-Smith et al. (2008)

This study relied on a linear equation or model that needed to be tested as a way of answering the research questions. It therefore started from exploring this model (the theory) and worked towards establishing whether the model was applicable to real practice as shown above.

3.6. Data Sample

The dependent variable in this study was the Real GDP growth rate of South Africa between 1992-2013. The independent variable in this study was ICT infrastructure investment in South Africa for the period 1992-2013. Other dependent variables that were envisaged to affect this relationship were GFCF, real exchange rate, HDI and openness of trade. Data from the period between 1992 to 2013 was also collected for these. The main reason for selecting this sample was because the WITSA database that was used as a source of ICT data ran from 1992 to 2013.

3.7. Data collection

The study relied on secondary data. This is data that is already available in a public or private domain and can be ethically used to conduct further analyses to draw research conclusions (Cooper & Schindler, 2006; Burns & Grove, 2003). Secondary data is considered is naturally appropriate when it is not feasible for a researcher to get the same data using primary means. In this study it was not practical to get the GDP, ICT investment, GFCF data through any other means except relying on already collected data.

Secondary data can be applied in research if it meets three characteristics. These are reliability, relevance and availability (Saunders et al.,2009). They state that official government sources are generally considered reliable. Relevance relates to whether the available secondary data can be used to effectively answer the research questions of interest. Availability relates to rights of access and use of the data. The data that was required in answering the study's research questions met the above three characteristics.

The data on Real GDP growth rate and real exchange rate was sourced from the South African Reserve Bank (SARB) and Statistics South Africa (Statssa). ICT Investment data, Gross Fixed Capital Formation data, HDI data and openness was sourced from the WITSA databases. This data was readily available, deemed to be reliable and relevant for meeting the research needs. Several other ICT researches based on WITSA data include a study by Nasab and Aghaei (2009) on the relationship between ICT investment and economic growth in the OPEC.

3.7.1. Data variables

The dependent variable, real GDP growth rate, was in the form of time series data denominated in South African Rand covering the period 1992 to 2013. Real GDP growth rate is an inflation adjusted measure of the rate of change in the value of all goods and services produced in on year (Real GDP).

The independent variable in the study, ICT infrastructure investment, was in the form of annual data spanning from 1992 to 2007 within the WITSA methodological framework. This framework accounts for aggregate ICT investment in a country in a year through the following aspects: software investment; computer hardware investment; telecommunication investment and internal spending investment. This data is currently in dollar format and was converted into Rand. Within the discourse the WITSA database has been widely adopted by many studies (Seo, Lee & Oh 2006).

The other variable that was included in the study was gross fixed capital formation (GFCF). GFCF is essentially the measure of expenditure on gross domestic product, that is invested rather than consumed (Pettinger, 2016). Thus it accounts for total infrastructure investment (Nasab & Aghaei, 2009). In order not to double count , ICT investment was subtracted from GFCF. The other variables that were included in the study were real exchange rate and openness which were accounted for by adding total exports and imports together and dividing them by gross national product. The last variable that was added was human capital, measured using the UN Human Development Index. It that accounted for in the main: health, education and income of a nation's population and therefore the ability of the population to contribute towards economic growth (UNDP, 2019).

3.8. Model specification

In this study, the theoretical model based on the work of Perkins (2005) was used to identify variables for testing the relationship between ICT infrastructure investment and GDP growth. This is shown below:

Equation 6: Theoritical model of the study

$$G_t = a_t + \beta X_1 + \beta X_2 + \beta X_3 + \beta X_4 + \mu_t$$

G_t= Real GDP growth rate

X_1= ICT infrastructure Investment *(positive relationship with G)*

X_1= (ICT infrastructure Investment minus GFCF) *(positive relationship with G)*

X_3= Real exchange rate *(positive relationship with G)*

X_4= Openness *(positive relationship with G)*

X_4= Human development *(positive relationship with G)*

The study sought to establish whether the relationship between ICT and GDP would yield a model that can be used to forecast future movements in GDP as a result of changes in ICT investments.

3.9. Estimation techniques (Testing for stationarity)

The first step in data analysis was to test for the stationarity of our variables. The purpose of testing for stationarity, is in essence to determine the order of integration of each of the variables under consideration in a study and the number of times that a particular variable must be differenced to acquire stationarity. A stationary time series, as indicated by Gujarati (2009), is a stochastic time series that indicates that the mean and variance are constant over time. While a non-stationary time series is one with a varying mean or variance or both.

The analysis tested for stationarity to avoid spurious regression, which is regression that provides misleading statistical evidence of a linear relationship between independent and non-stationary variables (Gujarati, 2010). The tests for stationarity can therefore be qualified as a test for reliability of the data collected and its suitability to provide reliable results when further tested.

Data was found to be non-stationary therefore the analysis could not immediately go on to test for co-integration (Guyon, et al., 2013). Data was therefore transformed so that it met the stationarity requirements of the analysis. To test for stationarity the Augmented Dicker-Fuller Test (ADF) and the Phillips-Peron tests (PP) we used. These are briefly discussed below.

3.9.1. Augmented Dicker-Fuller test (ADF)

The ADF test is used to test for unit root in a time series sample (Chen, 2010). The ADF is used for more complicated sets of time series models. The Augmented Dickey-Fuller statistic used in ADF test is a negative number (Rossi, 2013; Chen, 2010). Therefore the more negative the number is, the more valid is the rejection of the hypothesis that there is a unit root at the selected level of confidence. Given that the ADF test has proven itself to be robust in handling large and complicated arrangements; it was considered highly suitable for this study (Brooks, 2008).

3.9.2. Philips Peron test (PP)

The PP is a unit root test similar to ADF test, but the test incorporates an automatic correction to the DF procedure to allow for auto-correlated residuals (Rossi, 2013). Though the PP unit root test is similar to the ADF test, the primary difference comes in how they each test and manage serial correlation. Where the PP test ignores any serial correlation, the ADF uses a parametric auto regression to approximate the structure of errors. One of the benefits of using the PP test is that its non-parametric, in that it does not require choosing the appropriate level of serial correlation as is the case with ADF test (Rossi, 2013). One major shortcoming of the PP test is that it is based on asymptotic theory (Gujarati, 2010). Both tests were applied for purposes of academic rigour and certainty.

3.10. Co-Integration testing (long run relationships)

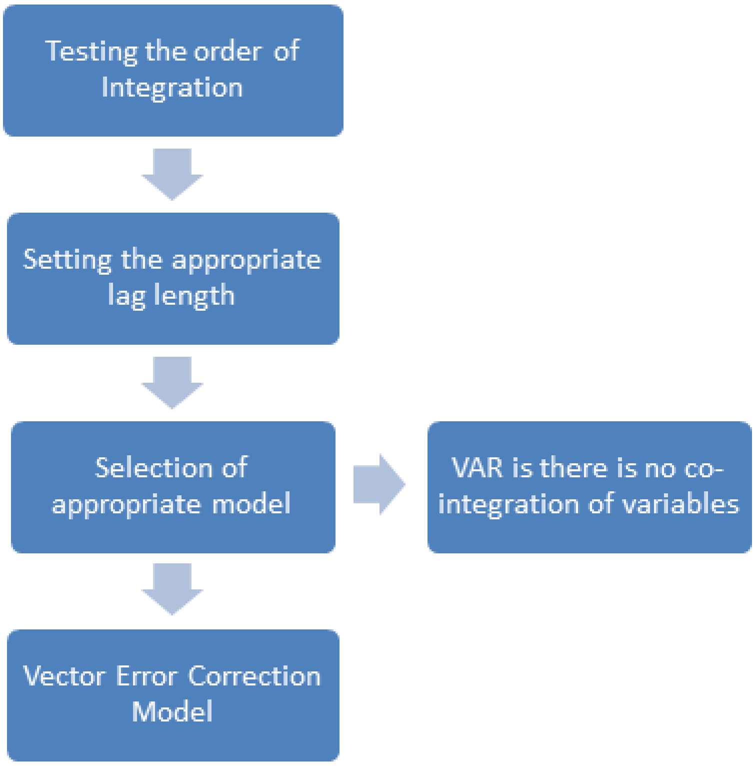
Co-integration is a statistical consequence of the existence of a long run relationship between economic variables. Its primary value is that it provides a background for both testing and estimating long -run and short-run relationships between variables (Chen, 2010; Guyon, et al., 2013). The underlying purpose of co-integration testing is to unveil a systematic co-movement among two or more economic variables over the long term (Engle & Granger, 1987). Economic variables can be said to be co-integrated if they have a long run, or equilibrium relationship. Granger (1986) adds that a test for co-integration can be understood as a pre-test, to avoid spurious or nonsensical regression out comes. It was therefore important to test for co-integration in order to actually make meaningful inferences as to the nature of causality between the data analysis variables.

3.10.1. Johansen's co-integration test

There are essentially two common ways for testing co-integration. These are Engle and Granger two-step test (EG) and the Johansen's co-integration test (JCT) based on maximum likelihood (Chen, 2010). The JCT was used instead of the EG model mainly because the former method is a more rounded technique in determining the co-integrating relationships (Guyon, et al., 2013). The EG test is most commonly applied if there is one integrating relation, making its value limited . The Johansen methodology is preferred because the maximum likelihood framework involved with it offers superior properties and strengths, compared to than the EG methodology which is residual based. The other benefit the JCT has is that it is stricter and produces less errors than the EG test (Brooks, 2008). Therefore to promote the robustness of the study, the Johansen's co-integration method was applied.

The Johansen methodology generally entails the following steps presented in Figure 3.2 below:

Figure 3.2: Johansen's co-integration Tests



Source: Johansen (1998)

Firstly, the data analysis process tested the order of integration of the variables under investigation. The tested variables were integrated in the same order and the analysis therefore proceeded to the next step. The second step involved setting an appropriate lag length for the model through the estimations of the model and determining the rank matrix. Thirdly, the appropriate model regarding the deterministic components in the tested relationship was selected. Finally, the analysis determined the number of co-integrating vectors by using causality tests on the error correction model to find a structural model as well as to determine whether the estimated model was reasonable (Johansen, 1998). As data was found to be co-integrated, there was no need to apply Vector autoregression (VAR) Model.

3.11. Appropriate Lag length

It was imperative for the robustness of the methodology to choose an appropriate lag length before moving on to testing for causality. Establishing the appropriate lag structure is not only important for causality testing in general, but also because inappropriate lag structures can affect the direction of causality between variables (Chen, 2010). To assist in this regard, this study used the Akaike and Schwarz information criterion (AIC and SIC). Once the AIC and SIC criterion were applied it was possible to then choose the lowest AIC and SIC values, so as to select the best lag structure (Gujarati, 2009).

3.12. Causality analysis

The critical stage in our study was that of testing for causality between the variables. The traditional form of testing for causality is the Granger causality test (Gujarati & Porter, 2009). The Granger causality test finds direct and functional interactions from a given time-series to establish nature of causation between two variables (Granger, 1969). This was used to test for causality in the study.

3.13. Impulse response

Impulse responses assesses the impact of an endogenous shock on the variables adjustments paths (Chen, 2010).An impulse response test was also done to establish if the derived model was stable enough to perform further tests. Impulses response measures the response of current and future values of each variable to a unit increase in the present value of one of the errors. If the system is stable then the shocks will gradually die, if it is not it the shock will not (Stock & Watson, 2006).

3.14. Variance Decomposition

Variance decomposition was conducted as the last major test in the study. This test was important for assessing the impact of shocks from other variables on the yearly variation of ICT Investment (Chen, 2010). It was thus applied on GFCF-ICT, real exchange rate and openness.

3.15. Diagnostic Tests of the VECM Residual

The estimated VEC model residual diagnostic tests were examined to determine the robustness of the model . The estimated VEC model passed all the three residual diagnostic tests that is the Serial LM test, Normality Test Jacque-Bera and the Heteroskedasticity test which was an indicator that the model was good and its results could be used to infer study conclusions. The results of these tests are shown below:

3.15.1. Serial LM Test

The LM test tests uses residuals of VECM to test for autocorrelation errors in an established regression model. It applies a null hypothesis that there is no auto-correlation in the established VECM.

3.15.2. Jacque-Bera Normality Test

The Jacque-Bera Normality Test was conducted to test for normal distribution in the data set. It held a null hypothesis that data in the set was not normally distributed and this was to be rejected at a 5% significance level.

3.15.3. Heteroskedasticity test

A test for Heteroskedasticity was also conducted. The null hypothesis of this test was that the variables of the model do not vary in relation to each other in time. A 5% significance level was also applied in deciding to reject or not to reject the hypothesis.

3.16. Limitations of the methodology

The methodology applied, like any other methodology in research had its weaknesses. The sample data used was from 1992 to 2013. Data up to 2018 was not obtainable from the same source. The model that was develop and tested was therefore exclusive of this data. This could have affected the outcomes of the developed model especially considering that after 2013 GDP generally took a negative growth direction.

3.17. Research Ethics

Research ethics are mostly discussed in association with the rights of participants in a study. (Kumar, 2011). This study did not involve biological participants whose rights to confidentiality, anonymity, voluntary participation could be undermined.

In secondary research too, there are ethics that must be followed. These include ensuring that identities of organisations and individuals are hidden. This study did not have any individuals or organisations that needed either anonymity or confidentiality because it relied on publicly available data. The public nature of the data and the non-existence of human participants also meant that there was no need for any informed consent. There was also no potential harm to any subjects.

The study therefore complied with the general research ethics and with the University's ethical requirements.

3.18. Conclusion

This chapter introduced the research methods and processes that were followed in the research. A causality or explanatory research design was applied in order to test if ICT investment had an impact on GDP growth. The research was guided by a quantitative approach which was in turn influenced by positivist ideologies. Data from 1992 to 2013 was collected for the study. It was subjected to rigorous tests starting with stationarity tests, co-integration and causality tests. The results that were produced from the methods and processes described above are presented in the next chapter.

CHAPTER 4. DATA ANALYSIS

4.1. Introduction

This chapter presented the results of the data analysis that was carried out applying the methodology discussed in Chapter 3. Causality tests using secondary data were conducted to meet the study's objectives, these being:

- To determine the impact of ICT infrastructure investment on GDP growth rate of South Africa.
- To assess if GDP growth in turn positively affects growth in ICT Investment (bi-directionality).
- To assess the growth/decline patterns in ICT Investment and GDP between 1992 and 2013.
- To make policy recommendations based on the findings.

The first two research objective of the study was further reduced to hypotheses that will be tested in this chapter. The following hypotheses were developed in order to meet the above objectives:

- Ha1: ICT infrastructure investment has a positive impact on South Africa's economic growth rates.
- Ho1: ICT infrastructure growth does not have a positive impact on economic growth rates in South Africa.
- Ha2: GDP growth in turn positively affects growth in ICT Investment (bi-directionality).
- Ho2: GDP growth in turn does not positively affect growth in ICT Investment (bi-directionality).

The chapter starts by a brief descriptive statistical analysis before the actual time series related tests. These are shown in Table 4.1 below.

Table 4.1: Descriptive Data

	EXC	GDP	GFCF	HDI	ICT	OPENESS
Mean	6.51	1,630,000,000,000	287,000,000,000	0.64	20,100,000,000	469,000,000,000
Median	6.86	1,370,000,000,000	200,000,000,000	0.64	12,900,000,000	375,000,000,000
Maximum	10.52	3,740,000,000,000	719,000,000,000	0.68	43,900,000,000	1,160,000,000,000

Minimum	2.85	416,000,000,000	65,800,000,000	0.61	6,950,000,000	86,200,000,000
Std. Dev.	2.11	1,040,000,000,000	212,000,000,000	0.02	12,600,000,000	339,000,000,000
Skewness	(0.15)	0.64	0.69	0.28	0.64	0.64
Kurtosis	2.22	2.09	1.97	2.40	1.89	2.06
Jarque-Bera	0.63	2.24	2.73	0.61	2.66	2.31
Probability	0.73	0.33	0.25	0.74	0.26	0.31
Observations	22.00	22.00	22.00	22.00	22.00	22.00

The study was based on 22 observations. This is data from 1992 to 2013 on Gross Domestic Product (GDP), Real Exchange Rate (EXC), Gross Fixed Capital Formation (GFCF), Human Development Index (HDI) and Openness.

The Mean GDP was R1.63 trillion with a standard deviation of R1.04t and the Mean (GFCF - ICT Investment) was R287 billion with a standard deviation of R212b. Mean ICT Investment was 20.1b with a standard deviation of R12.6b.

The Kurtosis and Skewness of the data generally resembled a normal distribution. Skewness ranged from -0.15 to 0.69 across the above variables. The kurtosis ranged from 1.89 to 2.40. The probability of the

4.2. Stationarity tests at levels

The Augmented Dickey Fuller unit root tests and the Philip Peron test s were conducted to test for stationarity in the data. The raw data was transformed in to log form before performing the Augmented Dickey Fuller unit root tests.

4.2.1. Augmented Dickey Fuller unit root tests al levels

The Augmented Dickey Fuller unit root tests was performed on the logs of GDP, GFCF-ICT, ICT, openness and the results are shown in Table 4.2 below:

Table 4.2: Augmented Dickey Fuller Test

Variable	P value	ADF statistic	Critical value 1%	Critical value 5%	Critical value 10%
Ln GDP	0.1614	-2.979766	-4.498307	-3.658446	-3.268973
Ln (GFCF –ICT)	0.1603	-2.984	-4.498307	-3.658446	-3.268973
Ln ICT	0.4398	-2.249217	-4.498307	-3.658446	-3.268973
Ln Openness	0.2095	-2.808676	-4.498307	-3.658446	-3.268973
Ln HDI	0.9981	0.431878	-4.467895	-3.644963	-3.2612452

Ln Exchange Rate	0.4481	-2.232439	-4.498307	-3.658446	-3.268973

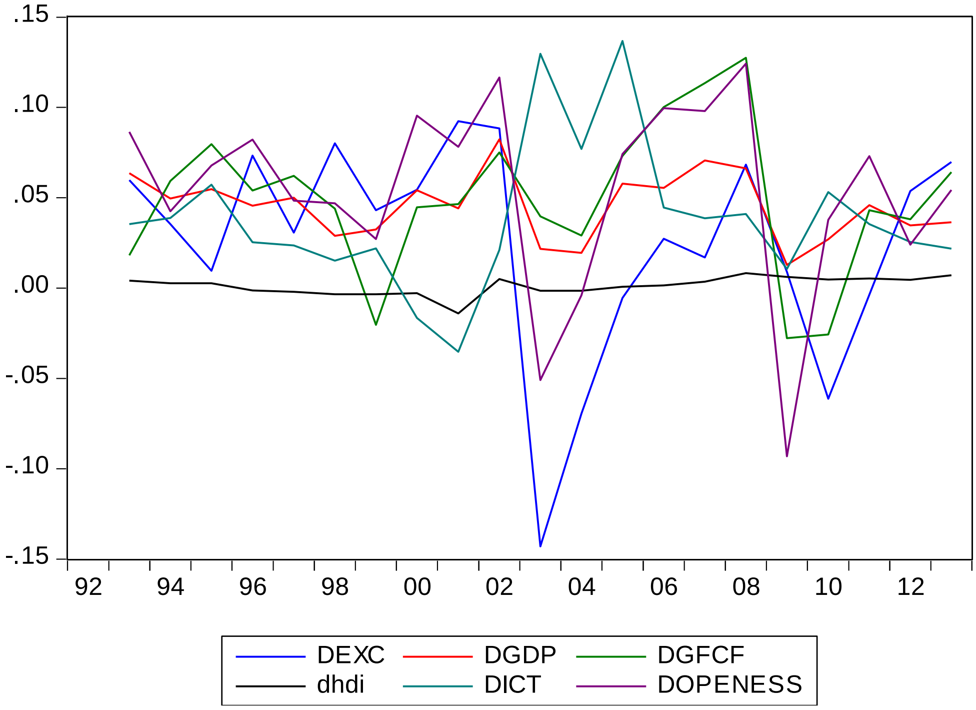
The absolute values of the ADF statistics that is at 1 %, 5% and 10% were smaller than the critical values which means that there was a unit root. This means that the all data series were not stationary at these levels. This is also supported by the p values which are over 0.05. Applying the p values, the analysis cannot reject the null hypothesis that the series has a unit a unit root at 1%, 5% and 10% levels. However, tests were repeatedly conducted after differencing the data and the results showed that there was still a unit root in the series at first difference which means that the differenced data was again not stationary at 1%, 5% and 10% significant level. Only the series on GDP and openness of trade were stationary at first difference with a p value of .00243 and 0.0334 and ADF statistics absolute of 4.041468 and 3.894590 respectively, which were less than the critical values at 5% and 10% significant levels. The results are shown in the table below.

Table 4.3: Augmented Dickey Fuller unit root tests at first difference

Variable	P value	ADF statistic	Critical value 1%	Critical value 5%	Critical value 10%
DlnGDP	0.0243	-4.041468	-4.498307	-3.658446	-3.268973
Dln(GFCF –ICT)	0.1049	-3.249170	-4.532598	-3.673616	-3.277364
DlnICT	0.5350	-2.057186	-4.532598	-3.673616	-3.277364
Dlnopenness	0.0334	-3.894590	-4.532598	-3.673616	-3.277364
Ln HDI	0.0590	-3.568311	-4.498307	-3.658446	-3.268973
Ln Exchange Rate	0.1292	-3.162276	-4.532598	-3.673616	-3.277364

These results are further diagrammatised below.

Figure 4.1: Augmented Dickey Fuller unit root tests at first difference

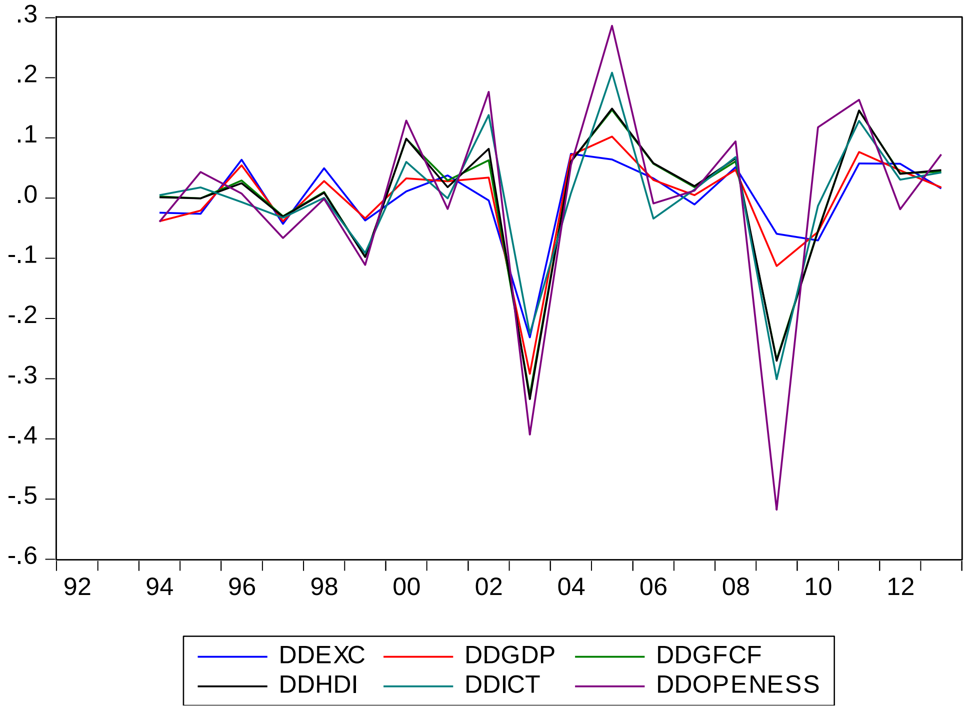


Philip Peron Test was done to confirm results for GDP and openness of trade. The results also confirmed that the series for openness of trade was actually stationary at first difference at 5% and 10% but not at 1%.

Table 4.4: Augmented Dickey Fuller unit root tests at Second difference

Variable	**P value**	**ADF statistic**	**Critical value 1%**	**Critical value 5%**	**Critical value 10%**
DDlnGDP	0.0141	-4.469702	-4.667883	-3.733200	-3.310349
DDln(GFCF –ICT)	0.0482	-5.754932	-4.667883	-3.733200	-3.310349
DDlnICT	0.0018	-5.435023	-4.532598	-3.673616	-3.277364
DDlnopenness	0.0036	-5.350624	-4.728363	-3.759743	-3.324976
Ln HDI	0.0057	-4.878868	-4.571559	-3.690814	-3.286909
Ln Exchange Rate	0.0248	-4.079128	-4.571559	-3.286909	3.286909

Figure 4.2: Augmented Dickey Fuller unit root tests at Second difference



All the series were stationary at second difference. The variables, Exchange Rate (DDEXC), had a test static of -4.879 ($p<0.05$); GFCF-ICT, -5.755 ($p<0.05$), ICT, -5.435 ($p<0.05$) and HDI, -4.879 ($p<0.05$). These were smaller that the critical values at 5% at a p value of 0.05 indicating stationarity at second difference.

4.2.2. Philip Peron Test

As discussed in Chapter 3, this test was performed to confirm stationarity at second difference as shown in the Table 4.5 below.

Table 4.5: Philip Peron test for stationarity

Variable	P value	Philip Peron statistic	Critical value 1%	Critical value 5%	Critical value 10%
DDlnGDP	0.0001	14.14550	-4.532598	-3.673616	-3.227364
DDln(GFCF –ICT)	0.0009	-5.784991	-4.532598	-3.673616	-3.227364
DDlnICT	0.0019	-5.435023	-4.532598	-3.673616	-3.227364
DDlnopenness	0.0001	-16.61688	-4.532598	-3.673616	-3.227364
Ln HDI	0.0000	-9.508072	-4.532598	-3.673616	-3.227364
Ln Exchange Rate	0.0039	-5.024040	-4.532598	-3.673616	-3.227364

The data series were found to be stationary at second difference as indicated by a Philip Peron test statics that was smaller than the critical value at -3.673616 at p-values below 0.05 ($p<0.05$).

The above findings qualify the data analysis process to move on to testing for co-integration using the first order lag.

4.3. Vector Autoregression (VAR) Lag Order Selection Criteria

Prior to determining the optimal number of lags to be selected, estimation of the VAR framework for variables was first performed, with results presented in Appendix 1. Subsequent to econometric estimation of the VAR model, the VAR-based Lag Order Selection Criteria was used to determine the maximum number of lags applied during the econometric estimation process. The test results for this procedure are shown in Table 4.6 below.

Table 4.6: Optimum lag selection - VAR

VAR Lag Order Selection Criteria
Endogenous variables: LNEXC LNGDP LNGFCF LNHDI LNICT LNOPENESS
Exogenous variables: C
Date: 02/08/19 Time: 20:15
Sample: 1992 2013
Included observations: 21

Lag	LogL	LR	FPE	AIC	SC	HQ
0	233.4354	NA	1.58e-17	-21.66051	-21.36208	-21.59575
1	375.4936	189.4109*	7.59e-22*	-31.76130*	-29.67225*	-31.30792*

* 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

Based on the results presented in the table above, Likelihood Ratio (LR) test statistic, Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC) and Hannan-Quinn Information Criterion (HQIC), 1 lag was the optimal lag length selected at 5 percent level of significance. Therefore, the maximum lag length that is equal to 1 was used for all variables in all equations of the model.

4.4. Johansen's co-integration test

To recap, co-integration is a statistical consequence of the existence of a long run relationship between economic variables. Its primary value is that it provides a background for both testing and estimating long -run and short-run relationships between variable. The Johansen's co-integration test conducted, and its results are shown in Table 4.7 below.

Table 4.7: Johansen's co-integration test

Date: 02/17/19 Time: 19:36
Sample (adjusted): 1992 2013
Included observations: 24 after adjustments
Trend assumption: Linear deterministic trend
Series: LNICT LNOPENESS LNEXC LNGDP LNGFCF
Lags interval (in first differences): 1 to 1
Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.897669	117.4876	69.81889	0.0000
At most 1 *	0.748452	62.77844	47.85613	0.0011
At most 2	0.517891	29.65554	29.79707	0.0519
At most 3	0.311079	12.14551	15.49471	0.1501
At most 4	0.124915	3.202431	3.841466	0.0735

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.897669	54.70913	33.87687	0.0001
At most 1 *	0.748452	33.12290	27.58434	0.0087
At most 2	0.517891	17.51003	21.13162	0.1493
At most 3	0.311079	8.943078	14.26460	0.2909
At most 4	0.124915	3.202431	3.841466	0.0735

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

LNICT	LNOPENESS	LNEXC	LNGDP	LNGFCF
-4.511809	-48.54436	11.45516	39.90504	14.83200
23.73724	22.38491	3.827530	-20.34885	-25.56305
-14.68986	-20.01489	-7.612371	37.87725	1.751338
-0.980578	13.66978	-3.727100	3.523276	-14.18793
0.926488	5.782177	-3.591324	-6.508252	1.550209

Unrestricted Adjustment Coefficients (alpha):

D(LNICT)	0.007572	-0.030964	0.013221	0.023032	-0.016613
D(LNOPENESS)	0.010904	0.074233	0.017203	-0.020511	-0.018217
D(LNEXC)	-0.008043	0.047796	0.045624	-0.036177	0.008993
D(LNGDP)	-0.011925	0.022530	0.004785	-0.003742	-0.009974
D(LNGFCF)	0.011385	0.051677	0.019000	0.008141	-0.010677

1 Cointegrating Equation(s): Log likelihood 213.2111

Normalized cointegrating coefficients (standard error in parentheses)

LNICT	LNOPENESS	LNEXC	LNGDP	LNGFCF
1.000000	10.75940	-2.538929	-8.844577	-3.287374
	(0.83929)	(0.25798)	(0.72856)	(0.40433)

Adjustment coefficients (standard error in parentheses)

D(LNICT)	-0.034163
	(0.08145)
D(LNOPENESS)	-0.049197
	(0.11965)
D(LNEXC)	0.036286
	(0.11954)
D(LNGDP)	0.053804
	(0.04350)
D(LNGFCF)	-0.051368
	(0.08045)

2 Cointegrating Equation(s): Log likelihood 229.7726

Normalized cointegrating coefficients (standard error in parentheses)

LNICT	LNOPENESS	LNEXC	LNGDP	LNGFCF
1.000000	0.000000	0.420643	-0.089936	-0.864566
		(0.04344)	(0.14825)	(0.11876)
0.000000	1.000000	-0.275069	-0.813674	-0.225181
		(0.01257)	(0.04289)	(0.03436)

Adjustment coefficients (standard error in parentheses)

D(LNICT)	-0.769153	-1.060689
	(0.39663)	(0.87752)
D(LNOPENESS)	1.712884	1.132362
	(0.47050)	(1.04094)
D(LNEXC)	1.170827	1.460326
	(0.57565)	(1.27357)
D(LNGDP)	0.588601	1.083230
	(0.19191)	(0.42459)
D(LNGFCF)	1.175294	0.604085
	(0.30648)	(0.67806)

3 Cointegrating Equation(s): Log likelihood 238.5276

Normalized cointegrating coefficients (standard error in parentheses)

LNICT	LNOPENESS	LNEXC	LNGDP	LNGFCF
1.000000	0.000000	0.000000	1.138929	-1.801558
			(0.30985)	(0.26915)
0.000000	1.000000	0.000000	-1.617257	0.387541
			(0.17188)	(0.14931)
0.000000	0.000000	1.000000	-2.921394	2.227522
			(0.60613)	(0.52652)

Adjustment coefficients (standard error in parentheses)

D(LNICT)	-0.963373	-1.325312	-0.132423

	(0.45524)	(0.91896)	(0.22984)	
D(LNOPENESS)	1.460179	0.788052	0.278083	
	(0.53784)	(1.08570)	(0.27154)	
D(LNEXC)	0.500619	0.547169	-0.256495	
	(0.59661)	(1.20433)	(0.30121)	
D(LNGDP)	0.518304	0.987451	-0.086800	
	(0.22219)	(0.44851)	(0.11218)	
D(LNGFCF)	0.896185	0.223800	0.183579	
	(0.33417)	(0.67455)	(0.16871)	

4 Cointegrating Equation(s): Log likelihood 242.9991

Normalized cointegrating coefficients (standard error in parentheses)

LNICT	LNOPENESS	LNEXC	LNGDP	LNGFCF
1.000000	0.000000	0.000000	0.000000	-0.871567
				(0.04655)
0.000000	1.000000	0.000000	0.000000	-0.933029
				(0.05701)
0.000000	0.000000	1.000000	0.000000	-0.157938
				(0.11210)
0.000000	0.000000	0.000000	1.000000	-0.816549
				(0.03460)

Adjustment coefficients (standard error in parentheses)

D(LNICT)	-0.985957	-1.010477	-0.218264	1.514163
	(0.42722)	(0.88624)	(0.22279)	(0.88733)
D(LNOPENESS)	1.480292	0.507676	0.354528	-0.496098
	(0.51943)	(1.07754)	(0.27088)	(1.07886)
D(LNEXC)	0.536094	0.052636	-0.121659	0.307116
	(0.54290)	(1.12621)	(0.28311)	(1.12760)
D(LNGDP)	0.521974	0.936297	-0.072853	-0.766258
	(0.22083)	(0.45810)	(0.11516)	(0.45867)
D(LNGFCF)	0.888202	0.335086	0.153237	0.151125
	(0.32967)	(0.68388)	(0.17192)	(0.68472)

The results show that there was cointegrating equations at the 0.05 level. The trace statistics were higher than the critical values and the p value that were less than 0.05. (p value =0.0000). Therefore, the analysis could reject the null hypothesis that there is no cointegrating equation. The results further show that the analysis cannot reject the null hypothesis that there are 2 cointegrating equations at 5% level. The conclusion on the results was that there were 2 cointegration equations in the series.

The Normalized cointegrating coefficients (standard error in parentheses) showed that there was a statistically significant and positive relationship between that LNICT and LNEXC, LNGFCF and LNGDP while LNICT and LNOPENESS had a significant but negative relationship.

Since there were cointegrating equations the data analysis skipped the VAR and proceeded to do the VECM.

4.5. Vector Error Correction Estimates

Engle-Granger revealed that there is a vector error correction mechanism which eliminated the short term imbalances if there is co-integration between two variables. A long term equilibrium model and a short term error correction model are generally proposed for the causality tests. Error correction models provide an opportunity for integrating both long run relationships among the variables (equilibrium relations) and short term matching behaviour (imbalance).

Table 4.8: Vector Error Correction Estimates

Vector Error Correction Estimates
Date: 02/17/19 Time: 20:38
Sample (adjusted): 1992-2013
Included observations: 24 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1	CointEq2
LNICT(-1)	1.000000	0.000000
LNOPENESS(-1)	0.000000	1.000000
LNEXC(-1)	0.420643	-0.275069
	(0.04478)	(0.01295)
	[9.39407]	[-21.2333]
LNGDP(-1)	-0.089936	-0.813674
	(0.15282)	(0.04421)
	[-0.58852]	[-18.4041]
LNGFCF(-1)	-0.864566	-0.225181
	(0.12241)	(0.03541)
	[-7.06285]	[-6.35842]
C	0.764580	2.513665

Error Correction:	D(LNICT)	D(LNOPENESS)	D(LNEXC)	D(LNGDP)	D(LNGFCF)
CointEq1	-0.769153	1.712884	1.170827	0.588601	1.175294
	(0.40884)	(0.48498)	(0.59336)	(0.19782)	(0.31591)
	[-1.88130]	[3.53187]	[1.97321]	[2.97547]	[3.72035]
CointEq2	-1.060689	1.132362	1.460326	1.083230	0.604085
	(0.90453)	(1.07298)	(1.31276)	(0.43766)	(0.69892)
	[-1.17264]	[1.05535]	[1.11241]	[2.47507]	[0.86431]
D(LNICT(-1))	0.582672	-1.505008	-1.365554	-0.389190	-0.869895
	(0.42704)	(0.50657)	(0.61977)	(0.20662)	(0.32997)
	[1.36445]	[-2.97100]	[-2.20331]	[-1.88357]	[-2.63628]
D(LNOPENESS(-1))	0.187543	-0.874720	-0.160016	-0.383262	-0.480315
	(0.46131)	(0.54722)	(0.66951)	(0.22320)	(0.35645)
	[0.40654]	[-1.59849]	[-0.23901]	[-1.71709]	[-1.34749]
D(LNEXC(-1))	-0.097441	-0.727579	-0.356594	-0.147093	-0.565453
	(0.29443)	(0.34926)	(0.42732)	(0.14246)	(0.22751)

	[-0.33095]	[-2.08318]	[-0.83450]	[-1.03252]	[-2.48545]
D(LNGDP(-1))	0.913649	1.760876	-1.265471	0.357777	1.763352
	(0.97104)	(1.15188)	(1.40930)	(0.46984)	(0.75032)
	[0.94090]	[1.52870]	[-0.89794]	[0.76149]	[2.35013]
D(LNGFCF(-1))	-0.238663	0.375246	0.759470	0.048553	0.489703
	(0.33256)	(0.39449)	(0.48265)	(0.16091)	(0.25697)
	[-0.71766]	[0.95122]	[1.57354]	[0.30174]	[1.90572]
C	-0.044702	0.168362	0.250469	0.132909	0.047789
	(0.08209)	(0.09738)	(0.11914)	(0.03972)	(0.06343)
	[-0.54453]	[1.72890]	[2.10225]	[3.34610]	[0.75338]
R-squared	0.419447	0.525327	0.422501	0.568937	0.688359
Adj. R-squared	0.165454	0.317658	0.169846	0.380347	0.552016
Sum sq. resids	0.109943	0.154705	0.231578	0.025739	0.065642
S.E. equation	0.082894	0.098331	0.120306	0.040108	0.064052
F-statistic	1.651415	2.529633	1.672242	3.016792	5.048726
Log likelihood	30.57565	26.47695	21.63618	47.99914	36.76454
Akaike AIC	-1.881305	-1.539746	-1.136349	-3.333262	-2.397045
Schwarz SC	-1.488620	-1.147061	-0.743664	-2.940577	-2.004361
Mean dependent	0.076820	0.103165	0.058510	0.087484	0.100340
S.D. dependent	0.090740	0.119039	0.132041	0.050952	0.095697
Determinant resid covariance (dof adj.)		2.53E-14			
Determinant resid covariance		3.33E-15			
Log likelihood		229.7726			
Akaike information criterion		-14.98105			
Schwarz criterion		-12.52677			

The VECM produced two co-integrating equations showing how ICT impacted the other variables in the model. These are shown below:

Equation 7: Co-Integrating Model 1

$$X_1 = 0.420643\ X_3 - 0.089936Gt - 0.864566X_2 + 0.764580$$

Equation 8: Co-Integrating Model 2

$$X_1 = 1X_4 - 0.275069X_3 - 0.813674Gt - 0.225181X_2 + 2.513665$$

Below are the short-run VECM for the relationship between ICT investment and GDP. Equation 9 shows that a 1% increase in GDP results in a 0.91 change in ICT Investment. Equation 10 shows that a 1% change in ICT results in a 0.87 change in GDP. Thus the below relationships show a short-run relationship between ICT and GDP but do not show causality.

Equation 9: ICT as dependent – short run

$$X_{1t} = -0.769153 + 0.582672X_{1t-1} + 0.187543X_4 - 0.097441X_3 + 0.913649G_t - 0.238663X_2 - 0.044702$$

Equation 10: GDP as dependent – short run

$$GDP_t = 1{,}175 - 0.869895X_1 - 0.480315X_4 - 0.565453X_3 - 1{,}7633G_{t-1} + 0{,}489703X_2 + 0{,}047789$$

Where:

G_t= Real GDP growth rate
X_1= ICT infrastructure Investment
X_2= (GFCF-ICT infrastructure investment)
X_3= Real exchange rate
X_4= Openness

As a rule, VECM equations are interpreted through inverting the signs (Guyon, et al., 2013). This means that negative signs have to be interpreted as positive signs and vice versa. Going by the first equation, mainly because it presents a more realistic relationship between ICT and GDP investment it can be concluded that ICT investment has positive long-term relationships with GDP, GFCF-ICT and a negative relationship with real exchange rate.

Results on the long run component of the cointegrating equation indicate that for every 1 percent deviation in GDP there was a statistically significant corresponding increase in ICT by approximately 0.09% during the period 1992-2013.

In terms of the GFCF-ICT, for every 1 percent deviation in GFCF-ICT there was a corresponding 0,86% increase in ICT Investment.

In terms of the real exchange rate term, for every 1 percent deviation in real exchange rate there was a corresponding 0,42% decrease in ICT Investment. The negative sign in front of the parameter of the long run component of the cointegrating equation depicts a positive relationship between the variable to which the parameter relates and the variable on which the vector was normalized.

Furthermore, the results for the error correction component of the LNICT equation reveal that the previous period's deviation from long run equilibrium was corrected in the current period at an adjustment speed of 77%. The occurrence of steady adjustment to the long run equilibrium through the short run partial adjustment mechanism was confirmed by the estimated GDP growth response to deviations from the long-run equilibrium path. The computed t-statistics for both the error correction and cointegration equations were statistically significant. They therefore show short run and long run relationships between ICT investment and GDP but not causality.

4.6. Diagnostic Tests of the VECM Residual

The estimated VEC model residual diagnostic tests were examined to determine the robustness of the model is in Table 4.9 below:

Table 4.9: Diagnostic Tests of the VECM Residual

Residual Test	Measurement	Chi-square	Df	Prob.
†Serial LM Test	LM Test	25.92435	25	0.4116
†Normality Test Jacque-Bera	Jacque-Bera	7.127827	5	0.2113
†Heteroskedasticity	No Cross Terms	211.1642	210	0.4645

† indicates that results reported are for the joint tests

‡ The detailed results and graphs on the residual diagnostic tests are provided in Appendices

The estimated VEC model passed all the three residual diagnostic tests that is the Serial LM test, Normality Test Jacque-Bera and the Heteroskedasticity test which was an indicator that the model was good. The results of these tests are shown below:

4.6.1. Serial LM Test

The LM test tests uses residuals of VECM to test for autocorrelation errors in the established regression model. As it applies a null hypothesis that there is no auto-correlation in the established VECM, at a statistic of $X=25.92$, $p>0.05$, the analysis rejects this null this hypothesis. It could therefore be concluded that autocorrelation features of the model were met.

4.6.2. Jacque-Bera Normality Test

This test showed that the data applied in the model construction met the skewness and kurtosis of a normal distribution. At a test statistic of $X=7.128$, $p<0.05$, it led to the rejection of the null hypothesis that the data in tests was not normally distributed.

4.6.3. Heteroskedasticity test

The test for Heteroskedasticity produced a statistic , $X=211.164$, $p<0.05$. The null hypothesis that the variables of the model do not vary in relation to each other in time was thus rejected.

The diagrams on the residual tests, including correlograms, are presented in Appendices. The correlograms show that there was potentially no substantial autocorrelation left behind in the residuals.

4.7. Causality Analysis

Causality analysis is used to determine causation between two variables and to determine the direction of the relationship if there is a relationship. The data analysis process examined the relationship by the VAR Granger Causality/Block Exogeneity Wald Test after it was determined through co-integration that there was a short and a long term relationship among the variables.

The Granger Causality tests the null hypothesis that there is no Granger-causality amongst variables of interest. The decision to reject the null hypothesis was made at $p<0.05$. Table 4.10 below shows the tests.

Table 4.10: Granger Causality

VEC Granger Causality/Block Exogeneity Wald Tests
Date: 02/17/19 Time: 21:13
Sample: 1992 2013
Included observations: 24

Dependent variable: D(LNICT)

Excluded	Chi-sq	df	Prob.
D(LNOPENESS)	0.165278	1	0.6843
D(LNEXC)	0.109527	1	0.7407
D(LNGDP)	0.885283	1	0.3468
D(LNGFCF)	0.515034	1	0.4730
All	1.519186	4	0.8232

Dependent variable: D(LNOPENESS)

Excluded	Chi-sq	df	Prob.
D(LNICT)	8.826832	1	0.0030
D(LNEXC)	4.339659	1	0.0372
D(LNGDP)	2.336920	1	0.1263

D(LNGFCF)	0.904818	1	0.3415
All	9.356954	4	0.0528

Dependent variable: D(LNEXC)

Excluded	Chi-sq	df	Prob.
D(LNICT)	4.854583	1	0.0276
D(LNOPENESS)	0.057123	1	0.8111
D(LNGDP)	0.806302	1	0.3692
D(LNGFCF)	2.476043	1	0.1156
All	8.186682	4	0.0850

Dependent variable: D(LNGDP)

Excluded	Chi-sq	df	Prob.
D(LNICT)	3.547845	1	0.0496
D(LNOPENESS)	2.948396	1	0.0860
D(LNEXC)	1.066090	1	0.3018
D(LNGFCF)	0.091050	1	0.7628
All	7.449930	4	0.1139

Dependent variable: D(LNGFCF)

Excluded	Chi-sq	df	Prob.
D(LNICT)	6.949948	1	0.0084
D(LNOPENESS)	1.815731	1	0.1778
D(LNEXC)	6.177449	1	0.0129
D(LNGDP)	5.523123	1	0.0188
All	12.44000	4	0.0144

Outcomes that are important for testing the studies hypotheses as shown in the table above were:

- ICT was the Granger cause of GDP (X^2=3.547845, p=0.0496)
- ICT was the Granger cause of GFCF-ICT (X^2=6.949948, p=0.0084)
- ICT was a Granger cause of Openness of Trade (X^2=8.826832, p = 0.0030
- ICT was a Granger cause of real exchange rate (X^2=4.854583, p=0.0276)
- GDP was not a Granger cause of ICT investment (Therefore there was no bi-directionality (X^2=0.885283, p=0.3468)

The null hypotheses that the above Granger-causalities did not exist were rejected at p<0.005.

4.7.1. Hypothesis testing

- Ho1: ICT infrastructure growth does not have a positive impact on economic growth rates in South Africa. The null hypothesis was therefore rejected as ICT was the Granger cause of GDP (X^2=3.547845, p=0.0496)
- Ho2: GDP growth in turn does not positively affect growth in ICT Investment (bi-directionality). The null hypothesis could not be rejected as GDP was not a Granger cause of ICT investment (Therefore there was no bi-directionality (X^2=0.885283, p=0.3468)

4.7.2. Further discussion on findings

The findings made above confirm various studies that showed that ICT investment had a positive impact in economic growth. These findings include those by Norton (1992) who investigated the relationship between GDP growth, telecommunications as well as transaction costs in 47 nations over a period of 20 years for the period 1957 to 1977. The findings of his study were that telecommunications impact was positive and significant for both GDP growth and transaction costs. The results also agree with those of Tella, Amaghionyeodiwe and Adyedoye (2007) explored the relationship between GDP growth in Nigeria and telecommunications expansions for the period from 1970 to 2004. The findings from this study were that the relationship between GDP growth and telecommunication expansion was both positive and significant. Positive findings were also made by Madden and Savage (1998).These findings make a positive case that there is a positive relationship between ICT investment and GDP growth in emerging African economies, referring to Nigeria and South Africa.

The above results show that while ICT was a Granger cause for GDP growth in South Africa, the relationship was not bi-directional as argued in some sources in the literature. It was ICT that caused an increase in GDP and not GDP increase that caused the same incremental effect on ICT investment. Rufael (2007) and Beil, Ford and Jackson (2005) are among the scholars who hold this bi-directionality view. In their argument, increases in GDP growth prompted demand for ICT infrastructure therefore positively affecting the latter.

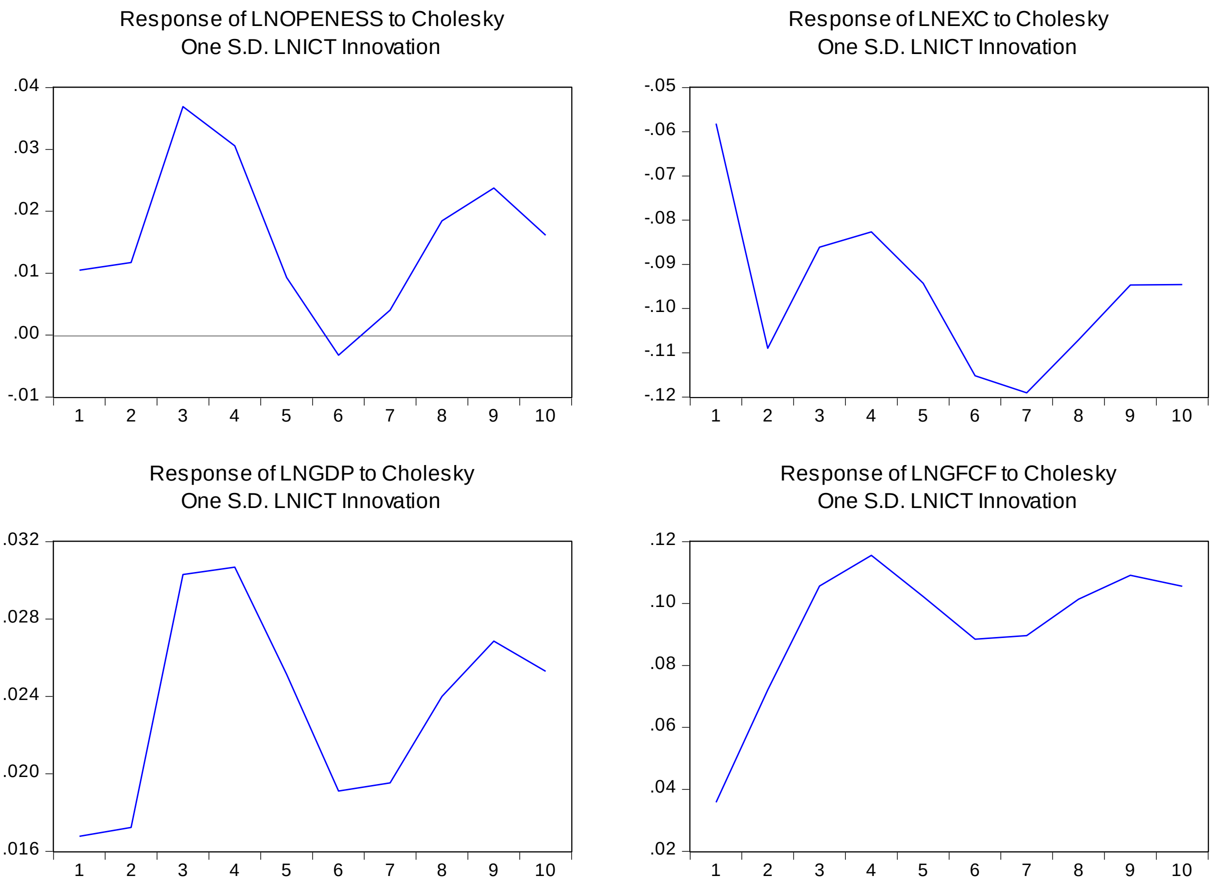
Some views from the literature were that this relationship existed only in developed economies with the developing economies lacking the capacity to transform ICT infrastructure growth into meaningful economic development (Bollou, 2006). Kyem (2012) like Bollou (2006) also points out that besides the penetration that mobile communication has had in sub-Saharan Africa, most ICT development initiatives have frankly fallen short of their potential and have failed to realise their intended scope of benefit. Kyem lists lack of innovation and poor policy development on ICT as major causes.

Going back to the theoretical model by Perkins (2005), it can be concluded that the findings from the study meets the important ICT, GDP relationship. As envisaged in the model, ICT growth had a positive and significant relationship with GDP as was proven by the Granger Causality tests.

4.8. Impulse Response Function

The impulse response functions computed from the estimated VECM model were derived using orthogonalized Cholesky decomposition, and results are presented below.

Table 4.11: Impulse Response Functions - Orthogonalized Cholesky Decomposition,



4.8.1. Impulse Response on LNGDP

A one SD shock (innovation) to LNICT initially results in a small increase in LNGDP in the first two periods. From period 2 the response rises sharply to until period 3. From 3rd period to 4th the response becomes gradual again until period 4. After fourth period LNGDP suddenly fall back until period 6. From period 6 to period 7 there is a gradual rise. After 7th period there is sharp up to the 9th period after which there is a sudden. The shock in other words causes a sharp rise in the short run and a gradual rise in the long run.

Like in LNGDP, a shock in ICT results in an initially small increase on Openness that goes to Period 2 after which it rises sharply to up to Period 3. It falls steeply from Period 3 to Period 6 before rising again from Period 6 to Period 9. The shock also causes a sharp rise in the short term and a gradual long-run rise.

The Real Exchange Rate (EXC) exhibits a different pattern to an SD shock. If falls steeply in the short term up to Period 2 after which it rises steeply up to Period 3. From Period 3 it mimics the shock response patterns of GDP, Openness and GFCF, falling steeply before rising again and then experiencing a less steep fall.

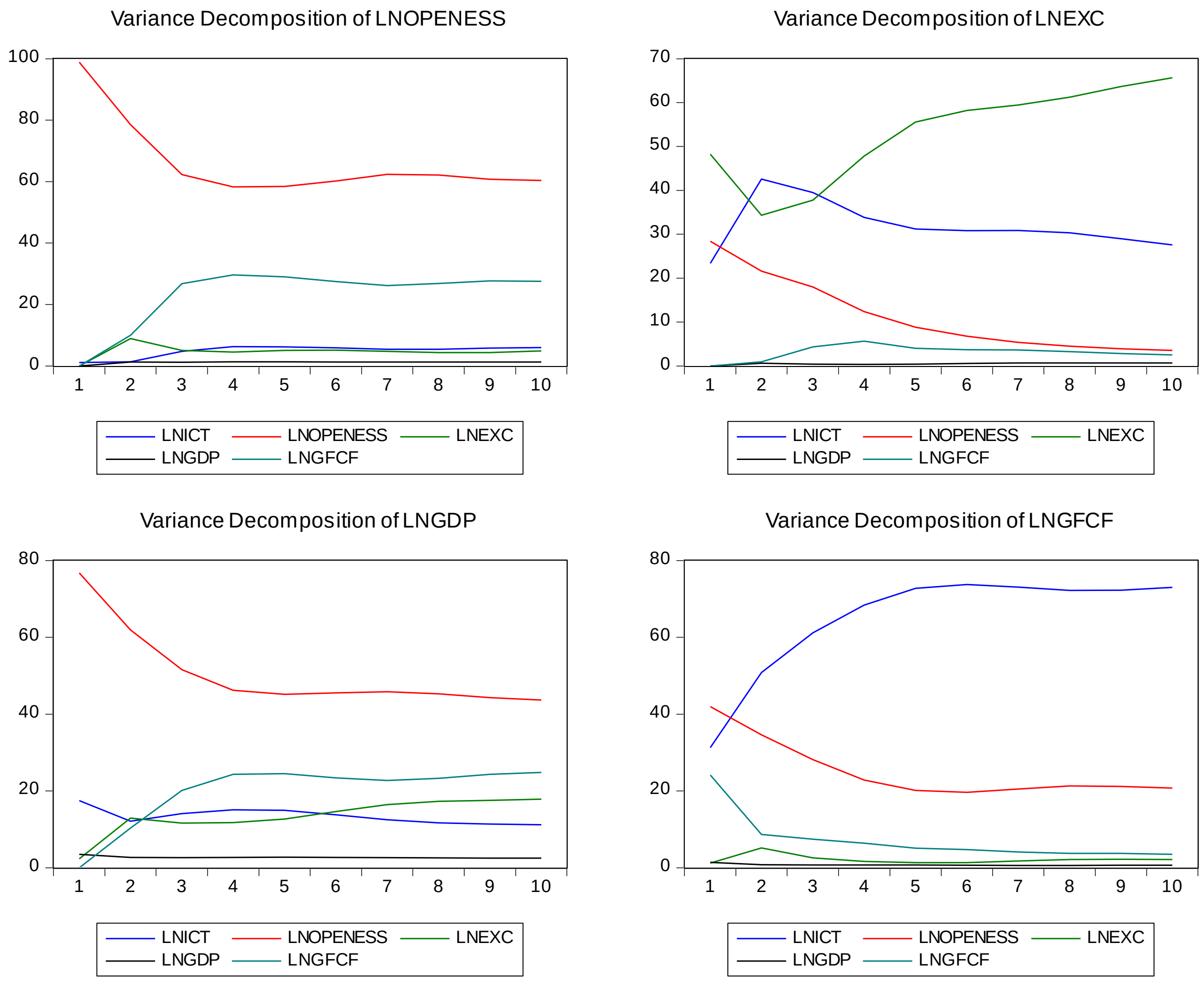
GFCF starts with a steep rising response to ICT shocks that goes to period 3. It skips the slow rise in Period 1 that is notable in Openness and GDP. Between Period 3 and Period 4, the rise becomes less steep and falls steeply from Period 4 to 7. It rises again in Period 8 after which it experiences a less steep fall just like GDP, Openness and Real Exchange Rate.

Except for Real Exchange Rate (EXC), above variables response to ICT shocks sharply in the short term but gradually in the long term. They all experience a mid-term dip before rising again. Real Exchange Rate experienced a steep fall in the short-term and a gradual fall in the long term.

4.9. Variance decompositions

To assess the impact of shocks from other variables on the yearly variation of ICT investment, variance decomposition was applied. It produced the results below.

Figure 4.3: ICT Variance decomposition



4.9.1. Openness

The results in graph the red line for LNOPENESS shows that fluctuations in the LNOPENESS were explained mainly by shocks to itself both in the short and in the long run. LNOPENESS shock accounted for 100% variation in the first year, while its proportion in the variance of LNOPENESS marginally decreased over time and reached 58% in the 10th year. The role played by other variables was increasing but not significant.

ICT Investment accounted for less than 5% variation in Openness over the reviewed period.

4.9.2. Gross Domestic Period

Similarly, results presented in the graph below the first one shows that the fluctuations in LNGDP were explained mainly by shocks to LNGDP itself. LNGDP shocks accounted for approximately 4% variance in LNGDP during the 1st year and remained stable up to the 10th year. Results therefore suggest that little variance in LNGDP can be explained by LNGDP as time progresses.

ICT accounted for 18% variance in GDP in Year 1. This had declined to 12% by Year 2. From Year 3 to Year 10, it maintained a stable 11% to 13% variance to GDP.

4.9.3. GFCF-ICT

The results above show that fluctuations or variances in GFCF-ICT were mainly explained by fluctuations in ICT investment. In year 1, GFCF-ICT accounted for 40% of its own variation. This decreased over the years, reaching 20% in Year 5 after which it remained stable at 20%.

Most of the remaining variance was accounted for by changes in ICT investment which accounted for 30% of the variation in GFCF in Year 1, increasing to 70% by year 5 onwards. Like GFCF-ICT, it remained stable at around 70% until 2012.

4.9.4. Real Exchange Rate

Real Exchange Rate was responsible for 48% of its own fluctuations in Year 1 and 35% in Year 2. An upward trend in noted from Year 3 where it accounted for 38% of its own fluctuations. In year 5 it accounted for 55% and in Year 10, 62%.

ICT accounted for a 24% of the variance in Real Exchange rate in Year 1. This increased to 42% in Year 2 before beginning a steadily declining trend that continued to Year 10 where this variance was 29%.

4.10. Conclusion

The study concluded that ICT investment had a short term and long term impact on economic growth which was assessed in terms of GDP, GFCF and Real Exchange Rate. The null hypothesis that ICT Investment had no impact on economic growth was also rejected. It was also noted that the model $\boldsymbol{G_t} = \boldsymbol{a_t} + \boldsymbol{\beta X_1} + \boldsymbol{\beta X_2} + \boldsymbol{\beta X_3} + \boldsymbol{\beta X_4} + \boldsymbol{\mu_t}$ however required to be modified to exclude X4 , The Human Development Index was also removed from the model through iterative processes as its presence resulted in the failure to develop a model with a good fit. The next chapter discusses these findings in detail.

CHAPTER 5. Conclusions and Recommendations

5.1. Introduction

This chapter concludes the study and provides recommendations for policymakers. It also recommends further study areas that can help to enhance the understanding of this research. The chapter starts by recapping the study's objectives: These were:

- To determine the impact of ICT infrastructure investment on GDP growth rate of South Africa.
- To assess if GDP growth in turn positively affects growth in ICT Investment (bi-directionality).
- To assess the growth/decline patterns in ICT Investment and GDP between 1992 and 2013
- To make policy recommendations based on the findings.

The following hypotheses were developed in order to meet the above objectives:

- Ha1: ICT infrastructure investment has a positive impact on South Africa's economic growth rates.
- Ho1: ICT infrastructure growth does not have a positive impact on economic growth rates in South Africa.
- Ha2: GDP growth in turn positively affects growth in ICT Investment (bi-directionality).
- Ho2: GDP growth in turn does not positively affect growth in ICT Investment (bi-directionality).

Various tests that led to the derivation of findings and conclusions on the above were carried out. These are presented after the summary below.

5.2. Study summary

The study sought to find the causality relationship between economic growth, as measured through GDP and the investment in ICT infrastructure in South Africa using data from 1992 to 2013. It identified GDP as an independent variable and ICT Investment as the dependent variable relying on various theories and models including the one by Perkins (2005). The study relied on a model by Perkins (2005) as its theoretical framework. The model stated that ICT Investment as well as the real exchange rate, openness of trade and the Human Development

Index (HDI) had a positive linear relationship with GDP. The study applied a deductive approach towards testing the veracity and applicability of the above as a means of meeting research objectives.

The rationality behind carrying out the study was the need to establish the true state of the causal relationship between GDP and ICT investment. This was because of the existence of multiple views in the literature and because of limited research in the specific South African ICT context. Knowledge developed from the study was deemed important for policy building given the economic growth challenges South Africa is going through.

To test if the developed linear model was true, and therefore accept the hypothesis that infrastructure growth has a positive impact on economic growth rates in South Africa, Time Series Analysis was performed on the data. The results of the analysis showed that there was a positive causality between GDP and ICT Investment, GFCF and Openness. Real Exchange Rate had a negative relationship with GDP. This led to the conclusion that ICT investment resulted in GDP growth. HDI was however dropped from the model through iterative processes. It was proven that its presence in the model resulted in the model failing to maintain a good fit.

5.3. Conclusions

The conclusions herein are made based on an objective-by-objective basis starting with the first objective.

5.3.1. To assess the relationship between GDP growth and ICT Investment

The study showed that GDP growth was positively related to ICT investment over the period of analysis (1992-2013). An increase in ICT investment can be used to explain positive changes in GDP. The study results therefore confirmed a common view in the literature that ICT had a positive causal effect on GDP. This view was discussed by various scholars including Egert, Kozluk and Sutherland (2009), Hardy (1980), Rufael, (2007) and Beil, Ford and Jackson, (2005). The null hypothesis that GDP or economic growth can be explained by ICT investment growth could therefore not be rejected.

The study also led to the rejection of the views that ICT investment in developing economies did not result in economic growth. Several scholars including Bollou (2006), Bollou and Ngwenyama (2008) and Dewan and Kraemer (2001), argue that developing African economies lacked infrastructure to complement ICT investments and therefore failed to see the transformation of ICT investment into GDP growth. Findings from the study points to a different direction where ICT investment had a positive impact on GDP.

5.3.2. To assess if GDP growth in turn positively affects growth in ICT Investment (bi-directionality).

Granger causality tests proved that there was no bi-directional relationship between ICT Investment and GDP growth. The null hypothesis that GDP growth in turn does not positively affect growth in ICT Investment (bi-directionality) could not be rejected. This therefore means that it was ICT positively affected by GDP and not the other way around. Various sources in the literature including Rufael (2007), Fedderke and Bogetic (2006) and Calderon and Server (2004) put across a view that GDP sometimes pushed ICT investment rather than ICT investment influencing GDP growth. They reject the linear relationships that points out at GDP being the dependent variables that is influenced by changes in ICT infrastructure. These arguments therefore fail to hold in the South Africa ICT infrastructure and economic growth relationship as shown by the Granger Causality test results.

5.3.3. To assess the growth/decline patterns in ICT and GDP between 1992 and 2012

Using ICT and GDP data that had been untransformed or non-stationary data, a positive, smooth growth curve was noted in GDP growth rate from 1992 to 2012. An almost similar smooth curve was also noted in ICT Investment over the same period. Using stationary data however, a notable change in growth trend was evident in both GDP and ICT Investment.

GDP exhibited short term volatile movements but long term growth increases. ICT also showed up and down movements within the short term (0 to 2.5years) but long term positive growth trends between the period under study. The above results help to reinforce the view that ICT Investment and GDP growth were positively related over time.

5.3.4. To make policy recommendations based on the findings

This objective was met by the inclusion of the recommendations section below.

5.4. Recommendations

The following recommendations were made:

5.4.1. Removal of ICT investment barriers in South Africa

The Department of Communications (South Africa, 2016) listed various investment barriers that made the ICT sector less attractive to both local and foreign direct investments. These included skills shortages, labour law restrictions, government bureaucracy and corruption. It is important for the government to ensure that these barriers should be addressed as their existence does not only affect the ICT sector but the economy at large.

5.4.2. Incentivisation of investment

It is also important to provide both local and foreign investors with incentives to move into the sector. These incentives could include tax breaks for specific types and sizes of investments as well as subsidies and industry grants for small businesses. Incentives can also be used in directing ICT investment to specific parts of the country especially those that are underserved by the current ICT infrastructure.

5.4.3. Supporting ICT education, research and development

Supporting ICT research , education and development can help to eliminate ICT investment barriers that were discussed as hindrances to ICT development by the Department of Communications. The provision of skilled labour to the sector will not only attract investors but will also breed entrepreneurs who could bring growth to the sector.

5.4.4. ICT Investment forecasting

The study also recommends the regular forecasting of ICT investments and determining the impact that this could have on GDP growth. Using the model derived from this study, the impact of future ICT investment can be projected to see if they will support projected GDP growth. This enables the necessary ICT investment stimulus to be applied well in time to enabled them to have the expected growth impact on GDP.

5.5.Recommendations for further study

The following studies were recommended for the future.

An assessment of short term and long term factors that affect the relationship between ICT and GDP growth is recommended. This study would be important in identifying individual factors that interacted to bring noted fewer stable patterns in ICT and GDP movements in the short term and more stable positive trends in the long term. The study did not focus on individual factors or individual causes of these movements.

A study that break down the various components of ICT investments i.e., by ICT sub-sector, ICT products and services and ICT investment by geography is also recommended. This study is necessary for the further specification of important ICT investment contributors and how these contributors individually affect GDP. For instance, the study could attempt to explore variance caused by the communications industry, the hardware manufacturing industry and so on. This will help to direct the recommendations made in this study to sub-sectors where they are most needed.

Given the wide discussions on the disparities relating to ICT access in South Africa, the researcher recommends a study that will assess how these disparities have affected ICT investment and therefore economic growth. These disparities could be by race, gender, location and industry.

Finally, studies that assess the various financial factors that affect GDP growth should be assessed in relation to how they affect the ICT industry. For instance, the impact of interest rates, taxation, inflation, employment amongst others need to be assessed with specific reference to the ICT sector. This ensures that government monetary and fiscal policy can be specifically directed towards specific ICT needs.

5.6. Conclusion

To conclude, the study sought to find the causality relationship between economic growth, as measured through GDP and the investment in ICT infrastructure in South Africa using data from 1992 to 2013. It concluded that there was a statistically significant causal relationship between economic growth and ICT infrastructure investment. The study was able to conduct various tests that enabled it to attain its objectives. As a deductive study, it was able to test various theoretical views and one model to ascertain if they were applicable to the South African ICT sector and economic growth situations. This was important for the sake of policy implementation purposes considering that there were various views that also presented a contradictory picture that there was no causality between GDP and ICT investment. The absence of a dedicated research that assessed the ICT/GDP relationships from a South African perspective and that provided a model that can be used to forecast relationships between the two also necessitated this research.

At the end of the study, a model that could be used to predict the relationship between these variables had been effectively tested and related research questions answered. The study was therefore able to provide a tool that can be applied in forecasting the relationship between ICT investment and GDP, in assessing the extent of the relationship between these variables and highlighting causal patterns in the relationship.

Reference List

Arslanalp, F., Bornhorst, F., Gupta, S., & Sze, E. (2010). *Public Capital and Growth* . New York: International Monetary Fund.

Aschauer, D. (1989). Is Public Expenditure Productive?. *Journal of Monetary Economics*, 23 (1), 177 –200.

Babbie, E. R. (2016). *The Basics of Social Research.* Boston: Cengage.

Banister, D. (2012). Transport and economic development: reviewing the evidence. *Transport Reviews , 32*(1), 1-2.

Banister, D., & Berechman, J. (2000). Transport Investment and Economic Development., London, United Kingdom: UCL Press.

Bankole, F, O., Brown, I., & Osei-Bryson, K. (2010). Does investments in ICT impact Trade in Africa ? a trend analysis of trade flows in Africa. GlobDev. Paper 17.

Barro, R. (1998). Note on Growth Accounting. *National Bureau of Economic Research*.

Barro, R. (2000). Inequality and growth in a panel of Countries. *Journal of Economic Growth, 5*(1), 5-32.

Beaudry, J. S., & Miller, L. (2016). *Research Literacy: A Primer for Understanding and Using Research.* London and New York: Guilford Publications.

Beil, R., Ford, G., & Jackson, J. (2005). On the Relationship between Telecommunications Investment and Economic Growth in the United States,". *International Economic Journal, 19*(1), 3-9.

Beinart, W., & Dubow, S. (2013). *Segregation and Apartheid in Twentieth Century South Africa.* London and New York: Routledge.

Bhorat, H., & Hodge, J. (1999). Decomposing shifts in labour demand in South Africa. *South African Journal of Economics*, 67(3).

Bhorat, H., Naidoo, K., & Yu, D. (2014). *Trade Unions in an emerging economy: The case of South Africa.* University of Cape Town. Cape Town: DPRU Working Paper 201402.

Blaikie, N., & Priest, J. (2017). *Social Research: Paradigms in Action.* Cambridge: Polity Press.

Blignaut, P. (2009). A Bilateral Perspective on the Digital Divide in South Africa. *Perspectives on global developments and technology,* 581 - 601.

Bollou, F. (2006). ICT Infrastructure Expansion in Sub-Saharan Africa: An analysis of Six west African Countries from 1995-2002. *Electronic Journal of IS in Developing Countries, 26*(5), 1-16.

Bollou, F.,& Ngwenyama, O. (2008). Are ICT Investments Paying off in Africa ? an Analysis of Total Factor Productivity in Six West African Countries from 1995 to 2002. *Information Technology for Development,* 20(9), 1-14.

Breitenbach, M.C., Aderibigbe, O.A., & Muzungu, D. (2005).The Impact of ICT on Economic Growth in South Africa: Analysis of Evidence. *Working Paper*. University of Pretoria, Pretoria.

Brooks, C. (2008). *Introductory Econometrics for Finance: 2nd Edition*, Cambridge University Press, Cambridge.

Bryman, A., & Bell, E. (2014). *Business Research Methods* (4 ed.). Oxford : Oxford University Press.

Burns, N., & Grove, S. K. (2003). *Understanding Nursing Research* (3 ed.). Philadelphia: Saunders Company.

Calderon, C., & Servon, L. (2004). *The Effects of Infrastructure Development on Growth and Income Distribution*. World Bank Policy Research Working Paper No. 3400.

Canning, D., & Pedroni, P. (2004). *The Effect of Infrastructure on Long-Run Economic Growth.* Mimeo: Harvard University.

Cantos, P, M., Gumbau,. & J. (2005) Maudos Transport infrastructures, spill over effects and regional growth: evidence of the Spanish case. *Transport Reviews*, 25, 25-50.

Castells, M. (2002). *The Internet Galaxy.* Oxford: Oxford University Press.

Chandra, A ,. & Thompson, E. (2002) Does public infrastructure affect economic activity?: Evidence from the rural interstate highway system **.** *Regional Science and Urban Economics,.* 30(4), 457-490.

Chatman, D. G., & Noland, R. B. (2011). Do public transport improvements increase agglomeration economies? A review of literature and an agenda for research, *Transport Reviews*, 31(6), 725–742.

Chen, P. ,. (2010). *A time series causal model.* Munich: University Library of Munich, Germany.

Chicru, M. A., & Mahahan, B. (2009). Revisiting the Digital Divide: An Analysis of Mobile Technology Depth and Service Breadth in the Brics Countries. *Product Innovation management*, 455-466.

Chipkin, I., & Lipietz, B. (2012). *Transforming South Africa's racial bureaucracy: New Public Management and public sector reform in contemporary South Africa.* London: London School of Economics.

Chowdhury, S.K., & Wolf, S. (2003), Use of ICTs and the Economic Performance of SMEs in East Africa", World Institute for Development Economics Research, *Discussion Paper No*, 20003/2006/

Clifton, C. (2002). *The Politics of Evil: Magic, State Power and the Political Imagination in South Africa.* Ohio: Cambridge University Press.

Collier, P., & Gunning, W. (1999). Explaining African Economic Performance. *Journal of Economic Literature, 37*(1), 64-111.

Cooper, D., & Schindler, P. (2006). *Business Research Methods.* Dakar: Irwin McGraw Hill.

Creamer, T. (2018, April 10). *Extreme inequality in South Africa is constraining growth and investment.* Retrieved December 10, 2018, from https://www.engineeringnews.co.za/article/extreme-inequality-is-constraining-south-african-investment-and-growth-2018-04-10/rep_id:4136

Cronin, F., Parker, E., Colleran, E., & Gold, M. (1991). Telecommunications infrastructure and economic growth: An analysis of causality. *Telecommunications Policy , December*, 529-53.

Datta, A,. & Agarwal, S. (2004).Telecommunications and economic growth: Panel data approach. *Applied Economics, 36(3)*, 1649-1654.

Demurger, S. (2001). Infrastructure Development and Economic Growth: An Explanation for Regional Disparities in China? *Journal of Comparative Economics*, 29(1), 95-117.

Deng, Z. (2011). *Foreign direct investment in China. Spillovers effect on domestic enterprises.* . London: Routledge.

Dewan, S. & Kreamer, K. (2002). Information technology and productivity: Evidence from country level data. *Management Science*, 46(4), 548-562.

Dijk, J.A.G.M., & Hacker, K. (2003) The digital divide as a complex and dynamic phenomenon, *Information Society*, 19 (1), 315–326.

Dolton, P., & Makepeace, G. (2004). Computer Use and Earnings in Britain. *The Economic Journal, 494(114)*, 117-129.

Dowrick, S. (1994), Fiscal policy and investment: the new supply side economics, *Centre for Economic Policy Research, Australian National University*, Canberra, ACT No.311.

Dramani, L., Lay. Relationship between investment in ICT and growth and employment in Senegal. Paper presented. *Policy Brief # ICT NO. 03* (July) AERC/CREA.

Easterby-Smith, M., Thorpe, R., Jackson, P., & Lowe, A. (2008). *Management Research.* London: Sage.

Echui, A., & Keho, Y. (2012) Transport Infrastructure Investment and Sustainable Economic Growth in Côte d'Ivoire: A Cointegration and Causality Analysis. *Journal of Sustainable Development* , 4(6), 23-35.

Engle R.F & Granger C.W. J (1987). Co-integration and error correction representation, estimation and testing Econometric a p 55, 351-276.

Esselaar, P., & Miller, J. (2001). Towards Electronic Commerce in Africa: A Perspective from three country studies. *Southern African Journal of Information and Communication*, (2)1.

Faulkner, D. & Loewald, C., 2008. *Policy Change and Economic Growth - A Case Study of South Africa :Policy Paper Number 14* , Pretoria: Government of South Africa.

Faulkner, D., & Loewald, C. (2008). *Policy Change and Economic Growth: A Case Study of South Africa.* Washington DC: The International Bank for Reconstruction and Development / The World Bank.

Fedderke, J., & Bogetic, Ž. (2006). *Infrastructure and Growth in South Africa: Direct and Indirect Productivity Impacts of 19 Infrastructure Measures.* Washington DC: World Bank.

Fedderke, J., & Garlic, R. (2008). Infrastructure development and economic growth in South Africa: A review of the accumulated evidence. *Policy Paper, Number 12*,. Cape Town: University of Cape Town and Economic Research Southern Africa.

Fernald, J. G. (1999). "Roads to Prosperity? Assessing the Link between Public Capital and Productivity." *American Economic Review*, 89(3): 619–38.

Fourie, J. (2006). Economic Infrastructure: A Review of Definitions, Theory and Empirics. . *South African Journal of Economics, 74(3), 530-555, 74*(3), 530-555.

Frankel, J., Smit, B., & Sturzenegger, F. (2006). *South Africa: Macroeconomic Challenges After a Decade of Success. Centre for International Development Working Paper,* 133, September 2006.

Geweke, J. (1982). Measurement of Linear Dependence and Feedback between Time Series. *Journal of the American Statistical Association* ,79, 304-24.

Gibson, G. v. (2000). Network Attached Storage Architecture. Communication of Theacm. *Communications of the ACM*, *43*(11), 37-45.

Gramlich, E. (1994). "Infrastructure Investment: A Review Essay." *Journal of Economic Literature*, 32, 1176 –1196.

Granger, C.W.J (1986) Developments in the study of Co-integrated Economic variables. *Oxford Bulletin of Economics and Statistics,* .48 (1), p226.

Granger, C.W.J.(1969) *Investigating Causal Relations by Econometric Models and Cross-spectral Methods*. Econometrica, Vol. 37, No. 3. (Aug. 1969), pp. 424-438

Gruber, H., & Koutroumpis, P. (2010). Mobile Communications: Diffusion Facts and

Gujarati, D. N. (2003). *Basic economists (4th edition*). New York: McGraw-Hill International.

Gujarati, D.N. & Porter, D.C. (2009). *Basic Econometrics. 5th Edition,* McGraw Hill Inc., New York.

Gujarati, D.N. & Dawn, C. (2009). *Essential of econometrics (4th edition).* New York: McGraw-Hill International.

Guyon, I., Statnikov, A., & Aliferis, C. (2013). Time Series Analysis with the Causality Workbench. In F. Popescu, & I. Guyo (Eds.), *Causality in Time Series.* Massachusetts: Microtome Publishing.

Hardy, A. P. (1980). The Role of the Telephone in Economic Development. *Telecommunications Policy,* 4(4), 278-286.

Holmner, M., & Britz, J. (2011). The Road Less Travelled: a critical reflection on infrastructure development in Africa from a perspective of the new economics of information. *Mousaion*, 29(1) 1 - 16.

Seo, H.,Lee, S & Oh, J,H.(2009). Does ICT investment widen the growth gap? *Telecommunications Policy*, 2009, 33(8) 422-431

ICASA. (2018). *Our Mandate.* Retrieved January 4, 2019, from https://www.icasa.org.za/pages/our-mandate

International Telecommunications Union. (2018). *Measuring the Information Society Volume 1.* Geneva: ITU Publications. Retrieved January 4, 2019, from https://www.itu.int/en/ITU-D/Statistics/Documents/publications/misr2018/MISR-2018-Vol-1-E.pdf

Jacobsen, K. (2003). *Telecommunications – A Means to Economic Growth in Developing Countries?* Development Studies and Human Rights.

Jalava, J., & Pohjola, M. (2002). Economic growth in the new economy: Evidence from advanced economies. , 14(2), 189-210. *Information Economics and Policy, 14*, 189-210.

Jiwattanakulpaisarn, P. (2010). Causal linkages between highways and sector-level employment. *Transportation Research* Part A.

Johansen, S. `(1998). Statistical Analysis of co integrative Vectors. *Journal of Economic Dynamics ad control*, 112, 231-254.

Jorgenson, D., & Vu, K. (2007). Information technology and the world growth resurgence. *German Economic Review*, *8*(2), 125-45

Jorgenson, D.W., Ho, M.S., & Strioh (2002). Projecting Productivity Growth: Lessons from the U.S Growth Resurgence. *Economic Review, Federal Reserve Bank of Atlanta*, 87(3), 1-13.

Kayode, O., & Adegbemi, B.(2002) An Empirical Analysis of Transport Infrastructure Investment and Economic Growth in Nigeria. *Social Sciences*, 2(6). 37(44).

Kim, Y. J., Kang, H., Sanders, G., & Lee, S. T. (2008). Deferential effects of IT investments: Complementarily and the effect of GDP level . *International Journal of Information Management, 28*(3), 508-516.

Klasen, S. (2000). Measuring Poverty and Deprivation in South Africa. *Review of Income and Wealth, 46*(1), 33-58.

Kodongo, O., & Ojah, K. (2016). *Does Infrastructure Really Explain Economic Growth in Sub-Saharan Africa?* Pretoria: Economic Research Southern Africa.

Kumar, R. (2011). *Research Methodology - a step-by-step guide.* Delhi: Sage.

Kuralatne, C. (2006). Social and Economic Infrastructure Impacts on Economic Growth in South Africa. *Infrastructure and Growth Conference.* Retrieved February 14, 2019, from https://slideplayer.com/slide/6631495/

Kuralatne, C., (2006). *Social and Economic Infrastructure Impacts on Economic Growth in South Africa.* Johannesburg: Econrsa

Kwaku Kyem, P. A. (2012). The ICT Development Index and the digital divide: How are they related ? *Technological Forecasting & Social Change*, 79(1), 587-594.

Kyem, K , P. A, . (2012). The ICT Development Index and the digital divide: How are they related ? *Technological Forecasting & Social Change*, 79(1), 587-594.

Labaree, R. (2009). *Organizing Your Social Sciences Research Paper: Qualitative Methods*. Retrieved January 10, 2019, from https://libguides.usc.edu/writingguide/theoreticalframework

Lynde. C., & Richmon, J. (1992) The Role of Public Capital in Production . *The Review of Economics and Statistics*, 74(1), 37-44.

Madden, G., & Savage, S, J,. (1998). CEE Telecommunication Investment and Economic Growth. *International Economic Policy*. 10(2). 13-195.

Mafelane, M., & Odhiambo, N. (2016). The role of international trade in Lesotho’s economic growth: A review. *Acta Universitatis Danubius, 12*(5), 2011-226.

Mahyideen, J. M., & Ismail, N. W. (2012). *ICT infrastructure and economic growth: Evidence from Asean-5 using panel dynamic OLS analysis.* Bandug: ICBER.

Malefane, M. R., & Odhiambo, N. M. (2018). *Impact of trade openness on economic growth: Empirical evidence from South Africa.* Retrieved February 12, 2018, from http://uir.unisa.ac.za/handle/10500/23654

Mankiw, G., Romer, D., & Weil, D. (1992). A Contribution to the Empirics of Economic Growth. *Quarterly Journal of Economics*, 407-437.

Mariotti, M. (2002). "An Examination of the Impact of Economic Policy on Long-Run Economic Growth: An Application of a VECM Structure to a Middle-Income Country Context. *South African Journal of Economics, 74*(4), 647-687.

Marleny, A. (2018) "Q2 unemployment rate rises to 27.2%". *Engineering News* http://www.engineeringnews.co.za/article/unemployment-2018-07-31.

Misra, B. S. (2015). Which infrastructure matters more for growth: economic or social? evidence from Indian states during 2001–2010. *Review Urban &Regional Development*, 177-196. doi:10.1111/rurd.12039

Mosala, S. J., Venter, J. C., & Bain, E. G. (2017). South Africa's Economic Transformation Since 1994: What Influence has the National Democratic Revolution (NDR) Had? *The Review of Black Political Economy, 44*(3-4), 327–340.

Moyo, T., & Mamobolo, M. (2014). The National Development Plan (NDP) : a comparative analysis with the Reconstruction and Development Programme (RDP), the Growth, Employment And Redistribution (GEAR) programme and the Accelerated and Shared-Growth Initiative (ASGISA). *Journal of Public Administration, 49*(3), 946-949.

Munell, A. (1990). Why Has Productivity Growth Declined? Productivity and Public Investment. *New England Economic Review, Jan/Feb* 3-22.

Nasab, E. H., & Aghaei, M. (2009). The Effect of ICT on Economic Growth: Further Evidence. *International Bulletin of Business Administration, 5*(1).

Nattrass, G. (2018). *A Short History of South Africa.* London: Biteback Publishing.

Negota, G. M. (2001,). *The Impact of Transport Investment on Infrastructure and Economic Development : The Debate*. Paper presented at the 20th South Africa Transport Conference Meeting the Transport Challenges in South Africa . Retrieved

Ngwenyama, O., & Morawczynski, O. (2009). Factors Affecting ICT Expansion in Emerging Economies: An Analysis of ICT Infrastructure Expansion in Five Latin American Countries. *Journal of Management 27(3),* 607 - 615.

Norton, S. W. (1992). Transaction cost, Telecommunications Investment and Economic Growth. *Information Economics and Policy, 41(1), ., 41*(1), 175-196.

Oyedemi, T. D., (2009). Social Inequalities and the South African ICT Access Policy Agendas. *International Journal of Communication* , Volume 3, pp. 151-168.

Papaioannou, S., & Dimelis, S. (2007). Information technology as a factor of economic development: Evidence from developed and developing countries. *Economic Innovation and new technology*, 16(3), 179-194.

Perkins, P. (2003). An Analysis of Economic Infrastructure Investment in South Africa. University of Witwatersrand working paper 2003-04.

Perkins, P. (2010). *The role of economic infrastructure in economic growth: building on experience*. Retrieved January 5, 2019, from hsf.org.za/resource-centre/focus/focus-60-january-2011-making-south-africa-work-rules-of-the-game/PPerkins.pdf/download

Perkins, P., Fedderke, J. and Luiz, J. (2005).An Analysis of Economic Infrastructure Investment in South Africa. South African Journal of Economics, 73(2), 211-227.

Perkins, W. C. (2010). *An Introduction to the Economic Method.* New York: Sage Publications.

Pettinger, T. (2016). *Gross Fixed Capital Formation*. Retrieved from Economics Help: https://www.economicshelp.org/blog/6536/economics/gross-fixed-capital-formation/

Plepys, A. (2002).Sustainability in the Information Society: The grey side of ICT. *Environmental Impact Assessment Review*, 22(5), 509-523.

Pohjola, M. (2001) *Information and economic growth: A Cross country analysis. In M. Pohjola (Ed.). Information technology and economic development*. Oxford, Oxford University Press

Ramdhani, J. (2017). A Jacana pocket history - Poverty in South Africa: past and present. *Communications and Strategies, 77*(1), 133-34. Retrieved from http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2223-03862017000100011

Reddy, P. S. (2016). The politics of service delivery in South Africa: The local government sphere in context. *The Journal for Transdisciplinary Research in Southern Africa, 12*(1). Retrieved from https://www.researchgate.net/publication/311331116_The_politics_of_service_delivery_in_South_Africa_The_local_government_sphere_in_context

Roller, L.H., & Waverman, L. (2001). Telecommunications infrastructure and economic development: A simultaneous approach. *American Economic Review,* 91(4), 909-923.

Romer, C. D. (2004). A New Measure of Monetary Shocks: Derivation and Implications. *American Economic Review, 94*(4), 1055-1084.

Romer, D. (2004). *Advanced Macroeconomics.* New York : McGraw-Hill.

Rossi, E. (2013). *Unit Root Tests.* University of Patvia. Retrieved February 10, 2018, from http://economia.unipv.it/pagp/pagine_personali/erossi/Econometria_Finanziaria_2013/Rossi_unit_roots_Ec_Fin_2013.pdf

Rufael, Y, W.(2007) Another look at the Relationship between Telecommunication Investment and Economic Activity in the United States, International Journal, International Economic Journal.

Samoilenko, S., & Osei-Bryson, K. (2008). An exploration of the effect of the interaction between ICT and labour force on economic growth in transition economies. *International Journal of production Economies, 118*(8), 471-481.

Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research Methods for Business Students. 5th ed.* Essex: Pearson Education Limited.

Seo, H.-J., Lee, Y. S., & Oh, J. H. (2009). Does ICT investment widen the growth gap? . *Telecommunications Policy, 33*(8), 422-431.

Servon, L. (2002) Bridging *the Digital Divide: Technology, Community, and Public Policy*. Malden, Oxford: Blackwell.

Solow, R. (1957) .Technical Change and the Aggregate Production Function. *Review of Economics and Statistics*, 39(3), 312-320.

Stock, J, H., & Watson, W.(2006). *Forecasting with Many Predictors. In Handbook of Forecasting, edited by Hashem M. Pesaran and Martin Weal*e. Amsterdam: Elsevier.

Swiegers, G. M. (2014). Britain and the Labour Question in South Africa: The Interaction of State, Capital, Labour and Colonial Power, 1867-1910. Bloemfontein: University of Free State.

Tella, S.A., Amaghionyeodiwe, B, A., & Adeyesoye. (2007). *Telecommunications investment and economic growth: Evidence from Nigeria.* Paper presented at UN-IDEP and AFEA joint conference on "Sector-led Growth in Africa and Implications for Development for Development, Dakar. Retrieved.

Thompson, H., & Garbacz., C. (2007). Mobile, fixed line and internet service effects on global productive efficiency. . *Information Economics and Policy, 19(2),* 189-214.

Toader, E., Firtescu, B. N., Roman, A., & Anton, S. G. (2018). Impact of Information and Communication Technology Infrastructure on Economic Growth: An Empirical Assessment for the EU Countries. *Sustainability , 10(1),* 1-22.

Tong, T., Yu, E., & Roberts, R. (2014). Dynamics of Transport Infrastructure, Exports and Economic Growth in the United States . *Journal of the Transportation Research Forum*, 53(1).33-42

UNDP. (2019,). *Human Development Index (HDI)*. Retrieved from United Nations Development Programme - Human Development Reports: http://hdr.undp.org/en/content/human-development-index-hdi

Van Ark, B., Melka, J., Mulder, N., Timmer, M., & Yapma, G. (2002). *ICT investment and growth accounts for the European Union, 1980-2000*. Research Memorandum GD-56, revised March 2003, Groningen Growth and Development Centre

Visser, D. (2017). *Fourth Industrial Revolution is upon us: Is South Africa ready?* Retrieved January 4, 2019, from https://mg.co.za/article/2017-12-15-00-fourth-industrial-revolution-is-upon-us-is-south-africa-ready

Vu, K. M. (2011). ICT as a source of economic growth in the information age: Empirical evidence from the 1996-2005 period. *Telecommunications Policy*, 357-372.

Walker, I. (2010). *Research Methods and Statistics.* Hampshire: Palgrave Macmillan.

Wang, X., Deng, D., & Wu, X. (2014). Stimulate economic growth by improving transport infrastructure –a lesson from China. *Transport problems, 9*(4), 63-72.

Wang, Y. K., & Grace, M. (2018). The impact of trade openness on economic growth: The case of Cote d'Ivoire. *Cogent Economics & Finance, 5*(1).

WITSA. (2008). *WITSA's Digital Planet report on Global ICT Spending.* Arlington: The World Information Technology Service Alliance.

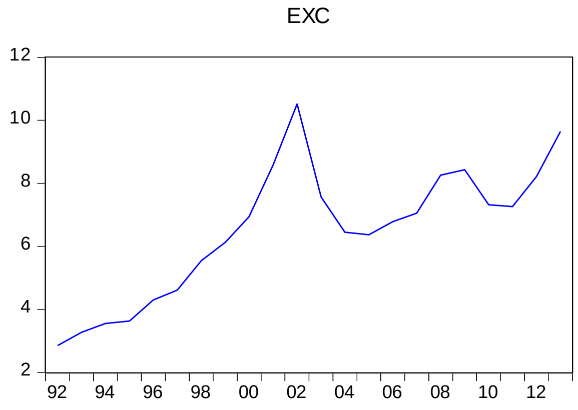
World Bank. (2018). *Policy Interventions Skilled Jobs Can Reduce Inequality in South Africa.* World Bank. Retrieved January 4, 2019, from erventions-skilled-jobs-can-reduce-inequalwww.worldbank.org/en/country/southafrica/publication/south-africa-economic-update-policy-intity-in-south-africa

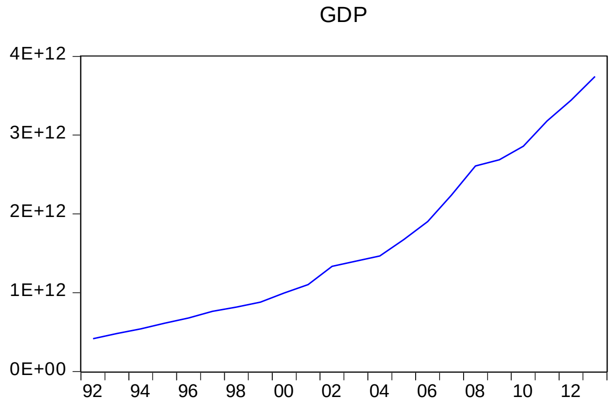
APPENDICES

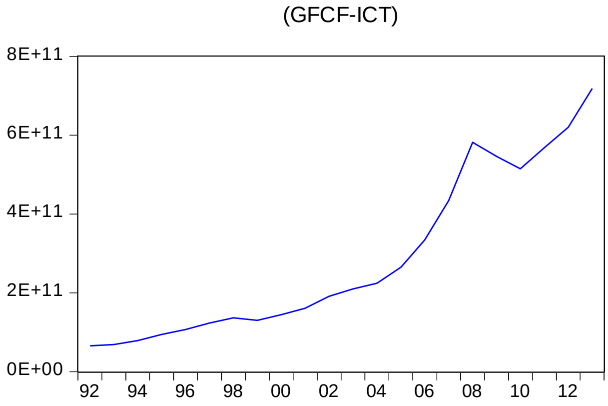
Appendix 1: Raw Data

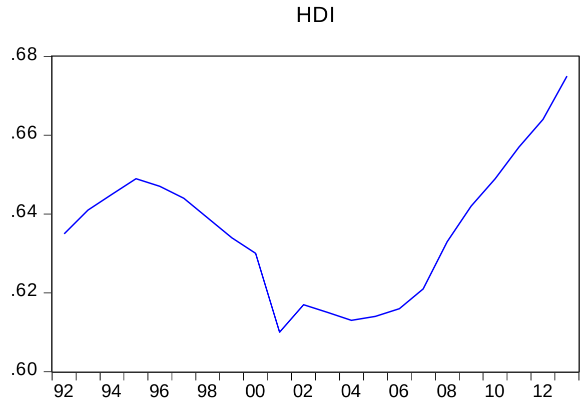
Column1	Gt	X1	X2	X3	X4	X5
Year	Real GDP	ICT	(GFCF-ICT)	Real exchange rate	Openess	HDI
1992	R 416 342 112 384,93	R 6 947 439 360,89	R 65 842 420 234,62	2,850606299	R 86 198 375 178,05	0.635
1993	R 482 014 092 711,79	R 7 536 491 525,09	R 68 648 453 889,26	3,270969291	R 105 200 198 454,74	0.641
1994	R 540 278 828 121,26	R 8 240 111 435,75	R 78 705 025 984,13	3,548762651	R 116 020 483 285,65	0.645
1995	R 612 878 451 396,90	R 9 399 770 067,88	R 94 544 032 695,15	3,627467742	R 135 664 314 096,50	0.649
1996	R 680 661 778 160,04	R 9 965 683 781,75	R 107 079 084 120,94	4,295391633	R 163 905 148 652,23	0.647
1997	R 763 774 795 835,63	R 10 523 123 985,02	R 123 562 767 087,97	4,6092396	R 183 209 186 082,66	0.644
1998	R 816 270 624 795,13	R 10 898 609 942,06	R 136 741 241 294,36	5,543283267	R 204 108 916 737,10	0.639
1999	R 879 748 112 785,60	R 11 462 678 540,37	R 130 464 237 388,79	6,1216249	R 217 255 637 250,91	0.634
2000	R 996 743 292 095,32	R 11 036 256 618,35	R 144 616 275 667,16	6,939072581	R 270 704 315 059,90	0.630
2001	R 1 103 245 864 086,40	R 10 175 922 378,45	R 160 937 580 322,01	8,5832744	R 324 076 574 325,69	0.610
2002	R 1 333 529 689 218,56	R 10 682 632 066,94	R 191 350 788 557,16	10,521936	R 423 806 890 843,05	0.617
2003	R 1 401 835 677 206,11	R 14 401 568 376,13	R 209 632 490 258,19	7,5688784	R 376 884 379 244,64	0.615
2004	R 1 466 310 484 072,72	R 17 197 260 448,91	R 224 157 300 447,70	6,449487251	R 373 426 701 647,65	0.613
2005	R 1 675 185 116 377,30	R 23 561 005 310,51	R 265 348 834 047,13	6,369845	R 443 030 581 674,89	0.614
2006	R 1 903 619 259 625,05	R 26 109 969 757,88	R 334 148 474 502,08	6,783416935	R 557 263 477 772,55	0.616
2007	R 2 239 705 933 030,00	R 28 540 595 884,34	R 433 890 555 979,63	7,054031076	R 698 202 579 441,86	0.621
2008	R 2 608 873 789 798,61	R 31 367 076 041,50	R 582 012 506 644,34	8,25674741	R 929 344 450 079,79	0.633
2009	R 2 687 245 366 098,05	R 32 138 929 903,58	R 545 928 995 227,10	8,429034	R 750 060 921 540,84	0.642
2010	R 2 859 391 811 873,60	R 36 316 510 084,96	R 514 573 686 141,56	7,321476494	R 818 221 741 667,09	0.649
2011	R 3 178 465 031 997,36	R 39 406 008 164,71	R 568 201 293 784,65	7,260190763	R 968 190 374 888,78	0.657
2012	R 3 442 926 363 637,69	R 41 791 406 242,25	R 620 207 193 634,69	8,216644	R 1 023 371 278 726,09	0.664
2013	R 3 744 094 071 008,71	R 43 943 326 228,29	R 718 877 424 720,43	9,649256	R 1 159 596 146 708,40	0.675

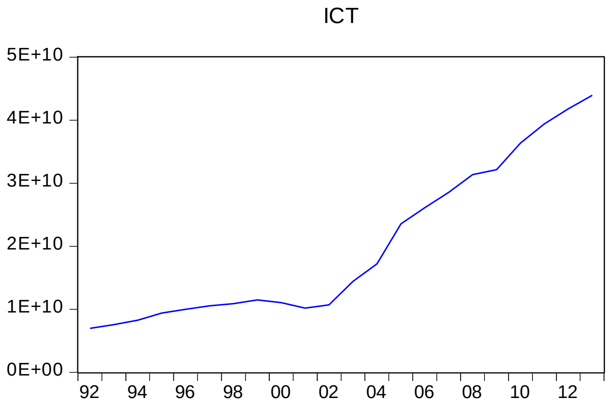
Appendix 2: Non Stationary series raw data

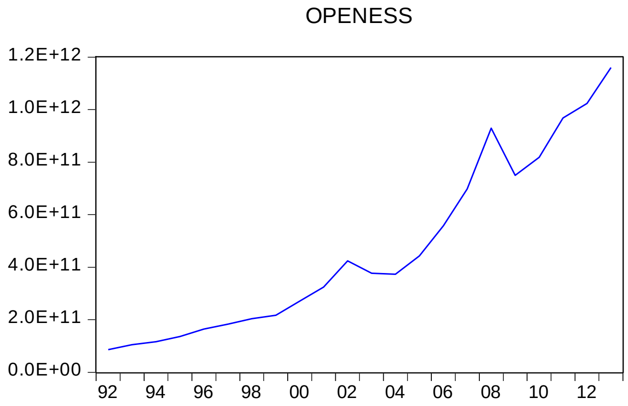




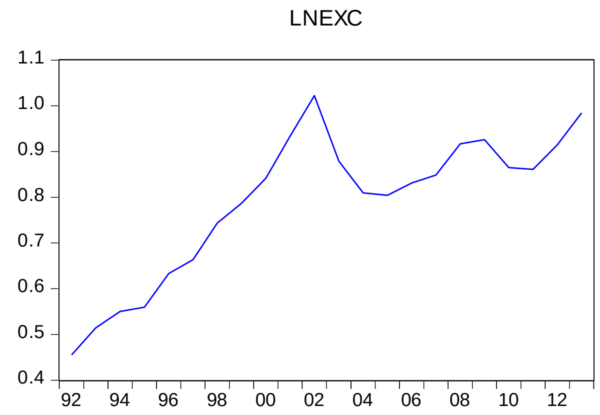


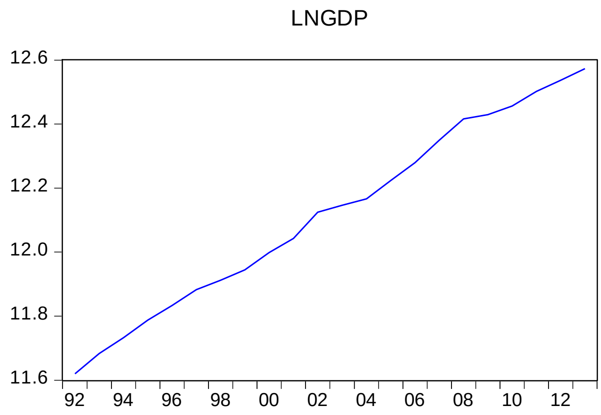


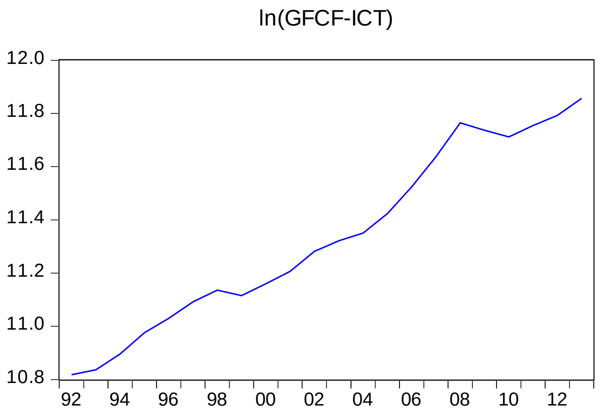


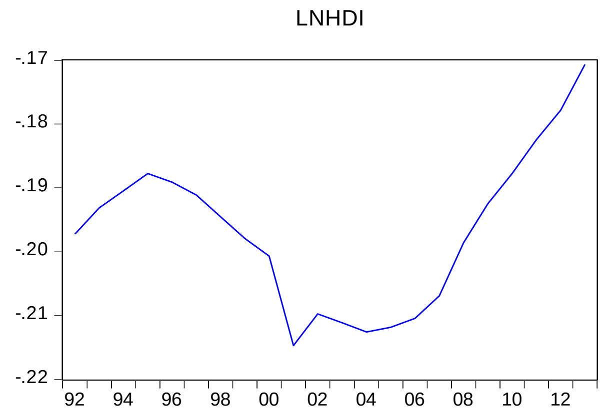


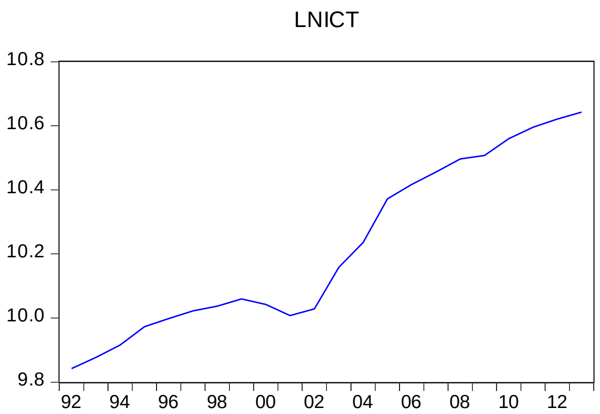
Appendix 3: Non Stationary series at levels log Transformed data

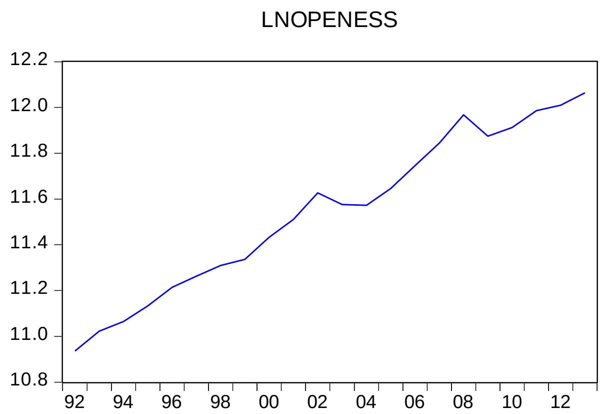




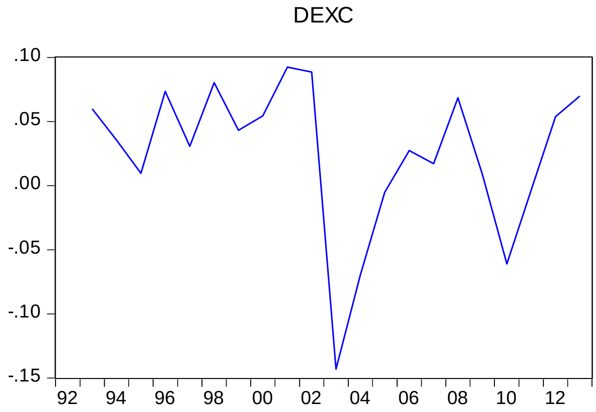


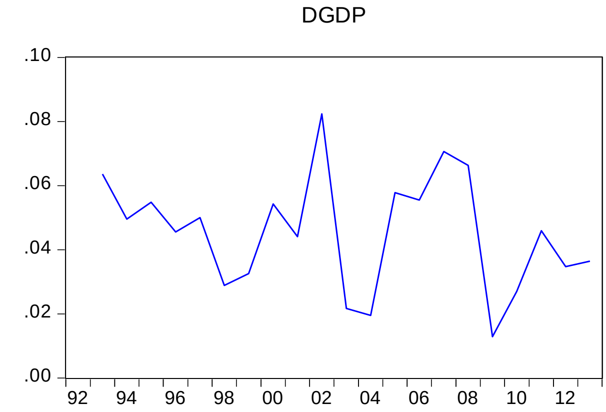


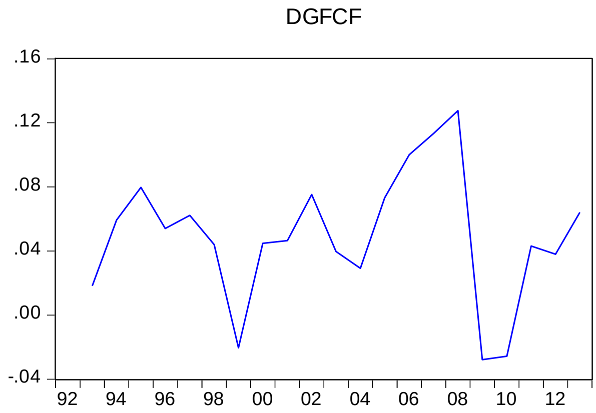


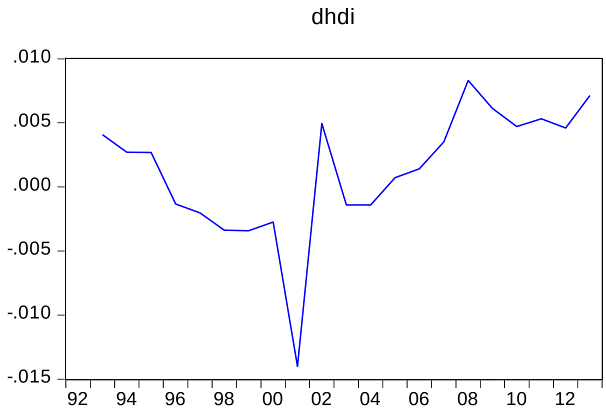


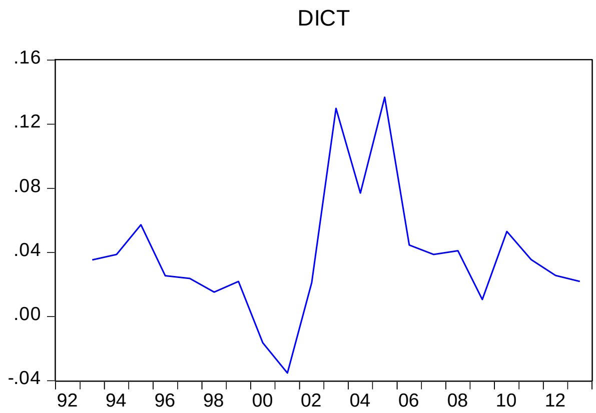
Appendix 4: Non Stationary series at first difference

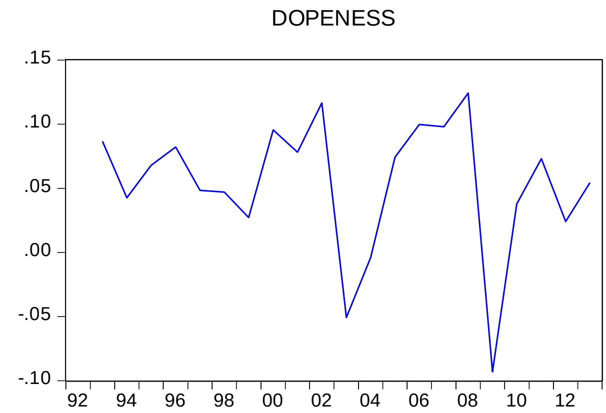




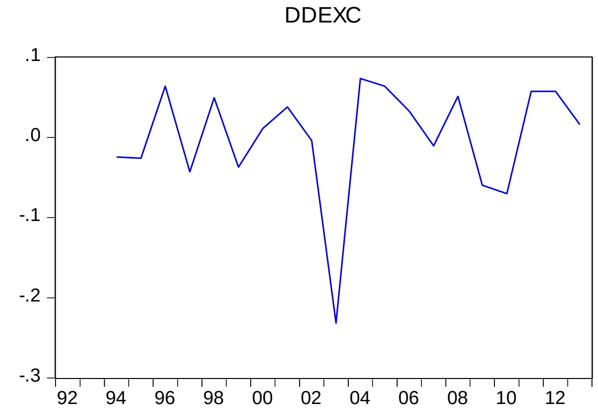


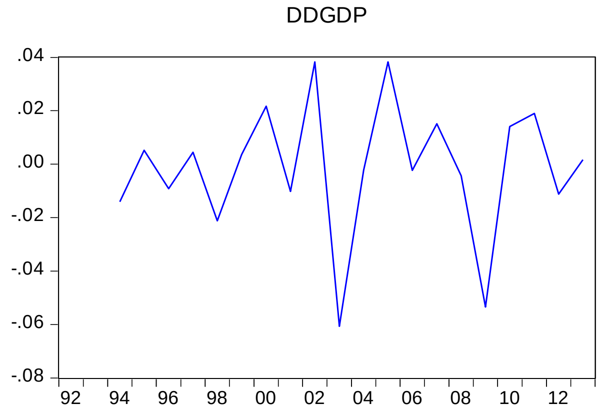


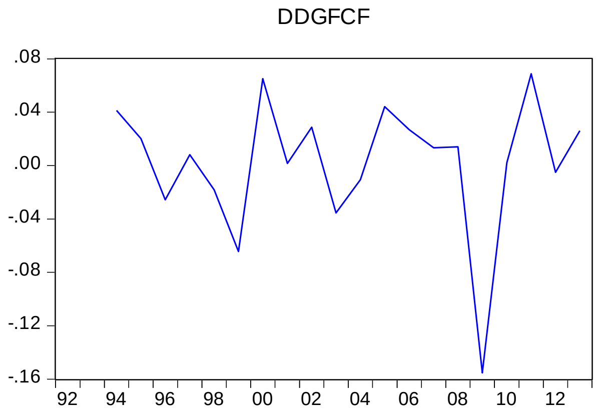


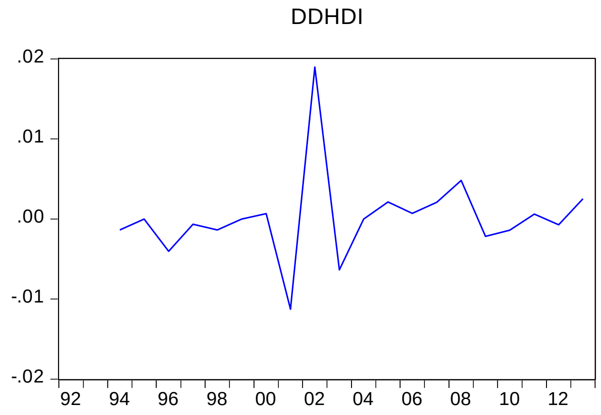


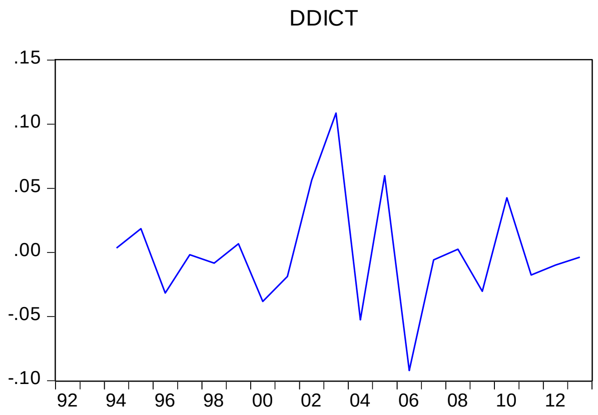
Appendix 5: Stationary series at second difference

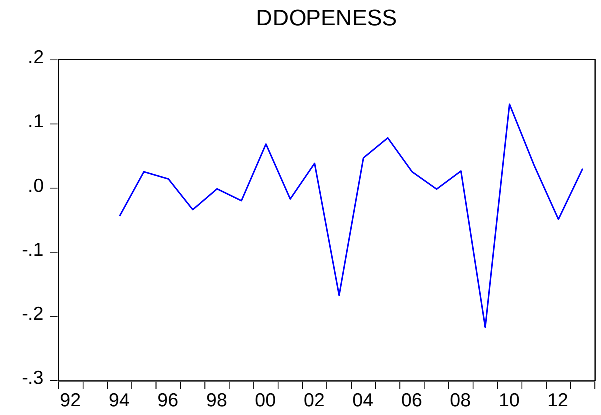












Appendix 6: VAR Lag Order Selection Criteria

VAR Lag Order Selection Criteria
Endogenous variables: LNEXCHANGE LNGDP LNGFCF LNHDI LNICT LNOPENESS
Exogenous variables: C
Date: 02/08/19 Time: 15:56
Sample: 1992 2013
Included observations: 21

Lag	LogL	LR	FPE	AIC	SC	HQ
0	233.4354	NA	1.58e-17	-21.66051	-21.36208	-21.59575
1	375.4936	189.4109*	7.59e-22*	-31.76130*	-29.67225*	-31.30792*

* 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

Date: 02/08/19 Time: 16:04
Sample (adjusted): 1994 2013
Included observations: 20 after adjustments
Trend assumption: Linear deterministic trend
Series: LNICT LNOPENESS LNEXCHANGE LNGDP LNGFCF LNHDI
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.951364	204.7480	95.75366	0.0000
At most 1 *	0.907382	144.2802	69.81889	0.0000
At most 2 *	0.878709	96.69483	47.85613	0.0000
At most 3 *	0.778668	54.50361	29.79707	0.0000
At most 4 *	0.547408	24.34181	15.49471	0.0018
At most 5 *	0.345790	8.486537	3.841466	0.0036

Trace test indicates 6 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.951364	60.46784	40.07757	0.0001
At most 1 *	0.907382	47.58534	33.87687	0.0007
At most 2 *	0.878709	42.19121	27.58434	0.0003
At most 3 *	0.778668	30.16180	21.13162	0.0021
At most 4 *	0.547408	15.85528	14.26460	0.0278
At most 5 *	0.345790	8.486537	3.841466	0.0036

Max-eigenvalue test indicates 6 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

LNICT	LNOPENESS	LNEXCHANGE	LNGDP	LNGFCF	LNHDI
33.88312	13.31819	22.90842	-54.19966	1.179269	143.5581
9.473325	-88.52977	21.78690	76.09616	8.714691	-55.88834
14.02078	109.4684	-40.70524	-63.45657	-53.59889	-61.06426
69.03816	93.88408	25.78129	-117.4406	-61.68204	30.13180
9.130449	8.491573	2.223451	-48.07727	25.83063	-81.15701
14.11703	4.532438	6.318335	8.367393	-23.00301	-43.98221

Unrestricted Adjustment Coefficients (alpha):

D(LNICT)	-0.027087	-0.001463	-0.003229	-0.009386	-0.005829	0.007591
D(LNOPENESS)	0.013219	0.035772	0.014456	-0.006704	0.004709	0.004967
D(LNEXCHANGE)	0.028225	0.018333	0.017967	-0.007164	-0.001468	-0.013475
D(LNGDP)	-0.000933	0.008820	0.007606	-0.002053	0.002902	0.003027
D(LNGFCF)	0.002908	0.020109	0.016544	-0.002688	-0.004530	0.008802
D(LNHDI)	0.000210	-0.000816	0.002366	-0.002381	0.000912	0.001204

1 Cointegrating Equation(s): Log likelihood 367.9467

Normalized cointegrating coefficients (standard error in parentheses)

LNICT	LNOPENESS	LNEXCHANGE	LNGDP	LNGFCF	LNHDI
1.000000	0.393063	0.676101	-1.599606	0.034804	4.236862
	(0.26963)	(0.09726)	(0.21222)	(0.12382)	(0.35610)

Adjustment coefficients (standard error in parentheses)

D(LNICT)	-0.917786
	(0.19405)
D(LNOPENESS)	0.447913
	(0.41803)
D(LNEXCHANGE)	0.956364
	(0.36249)
D(LNGDP)	-0.031602
	(0.13795)
D(LNGFCF)	0.098543
	(0.31367)
D(LNHDI)	0.007099
	(0.04385)

2 Cointegrating Equation(s): Log likelihood 391.7394

Normalized cointegrating coefficients (standard error in parentheses)

LNICT	LNOPENESS	LNEXCHANGE	LNGDP	LNGFCF	LNHDI
1.000000	0.000000	0.741639	-1.210820	0.070530	3.827727
		(0.04132)	(0.10546)	(0.08626)	(0.34714)
0.000000	1.000000	-0.166736	-0.989121	-0.090891	1.040889
		(0.02228)	(0.05687)	(0.04652)	(0.18719)

Adjustment coefficients (standard error in parentheses)

D(LNICT)	-0.931647	-0.231215
	(0.20094)	(0.51133)
D(LNOPENESS)	0.786789	-2.990793
	(0.23752)	(0.60440)
D(LNEXCHANGE)	1.130037	-1.247090
	(0.32711)	(0.83238)
D(LNGDP)	0.051949	-0.793218
	(0.11177)	(0.28441)

D(LNGFCF)	0.289042	-1.741509
	(0.25371)	(0.64559)
D(LNHDI)	-0.000635	0.075058
	(0.04477)	(0.11393)

3 Cointegrating Equation(s): Log likelihood 412.8350

Normalized cointegrating coefficients (standard error in parentheses)

LNICT	LNOPENESS	LNEXCHANGE	LNGDP	LNGFCF	LNHDI
1.000000	0.000000	0.000000	0.184302	-0.937205	-1.334795
			(0.17059)	(0.15416)	(0.54552)
0.000000	1.000000	0.000000	-1.302774	0.135669	2.201533
			(0.07668)	(0.06929)	(0.24520)
0.000000	0.000000	1.000000	-1.881133	1.358794	6.960965
			(0.21780)	(0.19681)	(0.69647)

Adjustment coefficients (standard error in parentheses)

D(LNICT)	-0.976913	-0.584637	-0.520975
	(0.21341)	(0.79686)	(0.29042)
D(LNOPENESS)	0.989473	-1.408313	0.493750
	(0.20099)	(0.75048)	(0.27352)
D(LNEXCHANGE)	1.381949	0.719732	0.314662
	(0.29225)	(1.09124)	(0.39771)
D(LNGDP)	0.158590	0.039388	-0.138815
	(0.08696)	(0.32469)	(0.11834)
D(LNGFCF)	0.521002	0.069540	-0.168692
	(0.20463)	(0.76407)	(0.27847)
D(LNHDI)	0.032538	0.334053	-0.109291
	(0.04067)	(0.15185)	(0.05534)

4 Cointegrating Equation(s): Log likelihood 427.9159

Normalized cointegrating coefficients (standard error in parentheses)

LNICT	LNOPENESS	LNEXCHANGE	LNGDP	LNGFCF	LNHDI
1.000000	0.000000	0.000000	0.000000	-0.734291	-0.138258
				(0.01875)	(0.57625)
0.000000	1.000000	0.000000	0.000000	-1.298668	-6.256438
				(0.03052)	(0.93800)
0.000000	0.000000	1.000000	0.000000	-0.712309	-5.251876
				(0.04681)	(1.43879)
0.000000	0.000000	0.000000	1.000000	-1.100987	-6.492279
				(0.02434)	(0.74813)

Adjustment coefficients (standard error in parentheses)

D(LNICT)	-1.624884	-1.465804	-0.762950	2.663888
	(0.38906)	(0.83866)	(0.28473)	(0.80502)
D(LNOPENESS)	0.526648	-2.037703	0.320914	1.875577
	(0.38911)	(0.83878)	(0.28477)	(0.80513)
D(LNEXCHANGE)	0.887386	0.047183	0.129975	-0.433576
	(0.58541)	(1.26191)	(0.42843)	(1.21129)
D(LNGDP)	0.016868	-0.153337	-0.191739	0.480125
	(0.17467)	(0.37653)	(0.12783)	(0.36143)
D(LNGFCF)	0.335422	-0.182827	-0.237994	0.638447
	(0.42105)	(0.90761)	(0.30814)	(0.87120)
D(LNHDI)	-0.131862	0.110488	-0.170684	0.056052
	(0.06496)	(0.14002)	(0.04754)	(0.13440)

5 Cointegrating Equation(s): Log likelihood 435.8436

Normalized cointegrating coefficients (standard error in parentheses)

LNICT	LNOPENESS	LNEXCHANGE	LNGDP	LNGFCF	LNHDI
1.000000	0.000000	0.000000	0.000000	0.000000	30.72214
					(4.20011)
0.000000	1.000000	0.000000	0.000000	0.000000	48.32327
					(6.71109)
0.000000	0.000000	1.000000	0.000000	0.000000	24.68465
					(3.42948)
0.000000	0.000000	0.000000	1.000000	0.000000	39.77941
					(5.70062)
0.000000	0.000000	0.000000	0.000000	1.000000	42.02746
					(5.51169)

Adjustment coefficients (standard error in parentheses)

D(LNICT)	-1.678105	-1.515301	-0.775911	2.944130	0.556714
	(0.36825)	(0.78951)	(0.26791)	(0.78916)	(0.40021)
D(LNOPENESS)	0.569644	-1.997716	0.331385	1.649178	0.087649
	(0.37661)	(0.80742)	(0.27399)	(0.80706)	(0.40929)
D(LNEXCHANGE)	0.873983	0.034718	0.126711	-0.362999	-0.366016
	(0.58837)	(1.26144)	(0.42805)	(1.26087)	(0.63943)
D(LNGDP)	0.043360	-0.128698	-0.185287	0.340628	-0.130339
	(0.16283)	(0.34909)	(0.11846)	(0.34893)	(0.17696)
D(LNGFCF)	0.294065	-0.221291	-0.248065	0.856221	-0.659267
	(0.41100)	(0.88116)	(0.29901)	(0.88076)	(0.44667)
D(LNHDI)	-0.123531	0.118236	-0.168655	0.012183	0.036775
	(0.06197)	(0.13286)	(0.04508)	(0.13280)	(0.06735)

Date: 02/08/19 Time: 20:14
Sample (adjusted): 1994 2013
Included observations: 20 after adjustments
Trend assumption: Linear deterministic trend
Series: LNGDP LNGFCF LNHDI LNICT LNOPENESS LNEXC
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.951364	204.7480	95.75366	0.0000
At most 1 *	0.907382	144.2802	69.81889	0.0000
At most 2 *	0.878709	96.69483	47.85613	0.0000
At most 3 *	0.778668	54.50361	29.79707	0.0000
At most 4 *	0.547408	24.34181	15.49471	0.0018
At most 5 *	0.345790	8.486537	3.841466	0.0036

Trace test indicates 6 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.951364	60.46784	40.07757	0.0001
At most 1 *	0.907382	47.58534	33.87687	0.0007
At most 2 *	0.878709	42.19121	27.58434	0.0003

At most 3 *	0.778668	30.16180	21.13162	0.0021
At most 4 *	0.547408	15.85528	14.26460	0.0278
At most 5 *	0.345790	8.486537	3.841466	0.0036

Max-eigenvalue test indicates 6 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

LNGDP	LNGFCF	LNHDI	LNICT	LNOPENESS	LNEXC
-54.19966	1.179269	143.5581	33.88312	13.31819	22.90842
-76.09616	-8.714691	55.88834	-9.473325	88.52977	-21.78690
-63.45657	-53.59889	-61.06426	14.02078	109.4684	-40.70524
-117.4406	-61.68204	30.13180	69.03816	93.88408	25.78129
48.07727	-25.83063	81.15701	-9.130449	-8.491573	-2.223451
-8.367393	23.00301	43.98221	-14.11703	-4.532438	-6.318335

Unrestricted Adjustment Coefficients (alpha):

D(LNGDP)	-0.000933	-0.008820	0.007606	-0.002053	-0.002902	-0.003027
D(LNGFCF)	0.002908	-0.020109	0.016544	-0.002688	0.004530	-0.008802
D(LNHDI)	0.000210	0.000816	0.002366	-0.002381	-0.000912	-0.001204
D(LNICT)	-0.027087	0.001463	-0.003229	-0.009386	0.005829	-0.007591
D(LNOPENESS)	0.013219	-0.035772	0.014456	-0.006704	-0.004709	-0.004967
D(LNEXC)	0.028225	-0.018333	0.017967	-0.007164	0.001468	0.013475

1 Cointegrating Equation(s): Log likelihood 367.9467

Normalized cointegrating coefficients (standard error in parentheses)

LNGDP	LNGFCF	LNHDI	LNICT	LNOPENESS	LNEXC
1.000000	-0.021758	-2.648690	-0.625154	-0.245725	-0.422667
	(0.08189)	(0.22396)	(0.06281)	(0.09245)	(0.06986)

Adjustment coefficients (standard error in parentheses)

D(LNGDP)	0.050551
	(0.22066)
D(LNGFCF)	-0.157630
	(0.50175)
D(LNHDI)	-0.011355
	(0.07015)
D(LNICT)	1.468096
	(0.31041)
D(LNOPENESS)	-0.716484
	(0.66868)
D(LNEXC)	-1.529806
	(0.57984)

2 Cointegrating Equation(s): Log likelihood 391.7394

Normalized cointegrating coefficients (standard error in parentheses)

LNGDP	LNGFCF	LNHDI	LNICT	LNOPENESS	LNEXC
1.000000	0.000000	-2.343070	-0.505469	-0.392236	-0.309475
		(0.18693)	(0.04912)	(0.05800)	(0.05869)
0.000000	1.000000	14.04643	5.500774	-6.733704	5.202340
		(2.27453)	(0.59770)	(0.70573)	(0.71412)

Adjustment coefficients (standard error in parentheses)

D(LNGDP)	0.721688	0.075760
	(0.29680)	(0.02794)
D(LNGFCF)	1.372586	0.178673
	(0.67371)	(0.06342)
D(LNHDI)	-0.073474	-0.006867
	(0.11889)	(0.01119)
D(LNICT)	1.356756	-0.044694
	(0.53359)	(0.05023)
D(LNOPENESS)	2.005596	0.327327
	(0.63073)	(0.05937)
D(LNEXC)	-0.134748	0.193050
	(0.86863)	(0.08176)

3 Cointegrating Equation(s): Log likelihood 412.8350

Normalized cointegrating coefficients (standard error in parentheses)

LNGDP	LNGFCF	LNHDI	LNICT	LNOPENESS	LNEXC
1.000000	0.000000	0.000000	0.688578	-1.584382	0.633128
			(0.11404)	(0.13261)	(0.12714)
0.000000	1.000000	0.000000	-1.657392	0.413075	-0.448454
			(0.23038)	(0.26791)	(0.25685)
0.000000	0.000000	1.000000	0.509608	-0.508797	0.402294
			(0.05504)	(0.06400)	(0.06136)

Adjustment coefficients (standard error in parentheses)

D(LNGDP)	0.239043	-0.331908	-1.091255
	(0.25931)	(0.12471)	(0.38049)
D(LNGFCF)	0.322758	-0.708069	-1.716594
	(0.61021)	(0.29347)	(0.89536)
D(LNHDI)	-0.223607	-0.133678	-0.068775
	(0.12127)	(0.05832)	(0.17794)
D(LNICT)	1.561627	0.128352	-3.609610
	(0.63640)	(0.30606)	(0.93379)
D(LNOPENESS)	1.088266	-0.447500	-0.984218
	(0.59935)	(0.28825)	(0.87943)
D(LNEXC)	-1.274874	-0.769962	1.930248
	(0.87149)	(0.41913)	(1.27874)

4 Cointegrating Equation(s): Log likelihood 427.9159

Normalized cointegrating coefficients (standard error in parentheses)

LNGDP	LNGFCF	LNHDI	LNICT	LNOPENESS	LNEXC
1.000000	0.000000	0.000000	0.000000	-0.489753	-0.652751
				(0.05038)	(0.09706)
0.000000	1.000000	0.000000	0.000000	-2.221675	2.646630
				(0.12595)	(0.24264)
0.000000	0.000000	1.000000	0.000000	0.301324	-0.549369
				(0.03480)	(0.06705)
0.000000	0.000000	0.000000	1.000000	-1.589696	1.867443
				(0.06033)	(0.11622)

Adjustment coefficients (standard error in parentheses)

D(LNGDP)	0.480125	-0.205287	-1.153109	0.016868
	(0.36143)	(0.18231)	(0.37362)	(0.17467)
D(LNGFCF)	0.638447	-0.542263	-1.797590	0.335422
	(0.87120)	(0.43946)	(0.90060)	(0.42105)
D(LNHDI)	0.056052	0.013205	-0.140527	-0.131862
	(0.13440)	(0.06780)	(0.13894)	(0.06496)
D(LNICT)	2.663888	0.707281	-3.892417	-1.624884
	(0.80502)	(0.40607)	(0.83219)	(0.38906)

D(LNOPENESS)	1.875577	-0.033989	-1.186219	0.526648
	(0.80513)	(0.40613)	(0.83230)	(0.38911)
D(LNEXC)	-0.433576	-0.328096	1.714395	0.887386
	(1.21129)	(0.61101)	(1.25217)	(0.58541)

5 Cointegrating Equation(s): Log likelihood 435.8436

Normalized cointegrating coefficients (standard error in parentheses)

LNGDP	LNGFCF	LNHDI	LNICT	LNOPENESS	LNEXC
1.000000	0.000000	0.000000	0.000000	0.000000	-1.611504
					(0.08248)
0.000000	1.000000	0.000000	0.000000	0.000000	-1.702575
					(0.10858)
0.000000	0.000000	1.000000	0.000000	0.000000	0.040511
					(0.00791)
0.000000	0.000000	0.000000	1.000000	0.000000	-1.244585
					(0.10225)
0.000000	0.000000	0.000000	0.000000	1.000000	-1.957624
					(0.08985)

Adjustment coefficients (standard error in parentheses)

D(LNGDP)	0.340628	-0.130339	-1.388589	0.043360	-0.128698
	(0.34893)	(0.17696)	(0.38403)	(0.16283)	(0.34909)
D(LNGFCF)	0.856221	-0.659267	-1.429976	0.294065	-0.221291
	(0.88076)	(0.44667)	(0.96934)	(0.41100)	(0.88116)
D(LNHDI)	0.012183	0.036775	-0.214582	-0.123531	0.118236
	(0.13280)	(0.06735)	(0.14615)	(0.06197)	(0.13286)
D(LNICT)	2.944130	0.556714	-3.419354	-1.678105	-1.515301
	(0.78916)	(0.40021)	(0.86853)	(0.36825)	(0.78951)
D(LNOPENESS)	1.649178	0.087649	-1.568392	0.569644	-1.997716
	(0.80706)	(0.40929)	(0.88823)	(0.37661)	(0.80742)
D(LNEXC)	-0.362999	-0.366016	1.833534	0.873983	0.034718
	(1.26087)	(0.63943)	(1.38769)	(0.58837)	(1.26144)

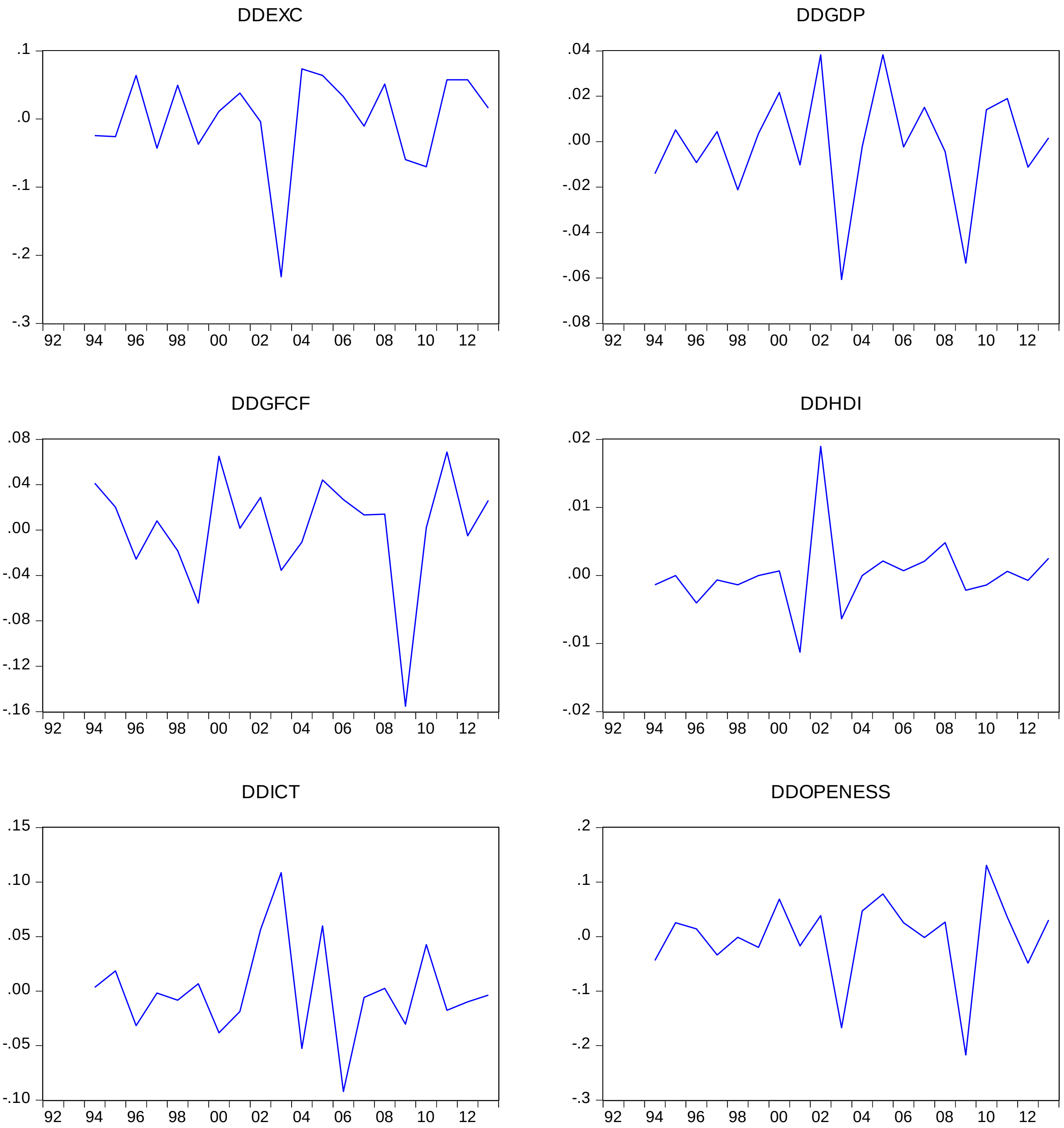
Appendix 7: Vector Autoregression Estimates

Vector Autoregression Estimates
Date: 02/09/19 Time: 08:00
Sample (adjusted): 1994 2013
Included observations: 20 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	LNGDP	LNGFCF	LNHDI	LNICT	LNOPENESS	LNEXC
LNGDP(-1)	1.493140	2.685004	0.102126	1.080732	4.287983	1.306617
	(0.59485)	(1.44621)	(0.22408)	(1.31076)	(1.44940)	(2.02283)
	[2.51010]	[1.85658]	[0.45575]	[0.82451]	[2.95844]	[0.64593]
LNGDP(-2)	-0.127183	-1.755132	-0.079872	1.926918	-2.597245	-1.782367
	(0.46977)	(1.14212)	(0.17697)	(1.03515)	(1.14464)	(1.59750)
	[-0.27073]	[-1.53673]	[-0.45134]	[1.86148]	[-2.26904]	[-1.11572]
LNGFCF(-1)	-0.233584	0.443970	-0.054167	0.523944	-0.009877	0.151092
	(0.21303)	(0.51791)	(0.08025)	(0.46940)	(0.51906)	(0.72441)
	[-1.09650]	[0.85723]	[-0.67499]	[1.11619]	[-0.01903]	[0.20857]
LNGFCF(-2)	0.033612	-0.305713	0.063254	-0.141856	-0.016726	-0.207142
	(0.13245)	(0.32202)	(0.04990)	(0.29186)	(0.32273)	(0.45042)
	[0.25376]	[-0.94935]	[1.26772]	[-0.48604]	[-0.05182]	[-0.45989]
LNHDI(-1)	-3.025033	-4.755131	0.365127	2.739848	-9.837732	-10.18168
	(1.06427)	(2.58745)	(0.40091)	(2.34512)	(2.59317)	(3.61910)
	[-2.84237]	[-1.83776]	[0.91074]	[1.16832]	[-3.79371]	[-2.81332]
LNHDI(-2)	1.503304	2.938016	0.367352	-6.493091	8.050889	12.60788
	(1.17347)	(2.85296)	(0.44205)	(2.58575)	(2.85926)	(3.99046)
	[1.28107]	[1.02981]	[0.83101]	[-2.51110]	[2.81573]	[3.15950]
LNICT(-1)	-0.189793	-0.119795	-0.036004	-0.125678	-0.384386	0.089938
	(0.18030)	(0.43834)	(0.06792)	(0.39729)	(0.43931)	(0.61312)
	[-1.05266]	[-0.27329]	[-0.53010]	[-0.31634]	[-0.87497]	[0.14669]
LNICT(-2)	0.275888	0.538120	-0.070535	-0.445258	1.024146	0.593818
	(0.15017)	(0.36510)	(0.05657)	(0.33091)	(0.36591)	(0.51067)
	[1.83714]	[1.47389]	[-1.24684]	[-1.34557]	[2.79892]	[1.16282]
LNOPENESS(-1)	-0.088862	-0.492699	0.047655	-0.980819	-0.918198	-0.048286
	(0.29367)	(0.71398)	(0.11063)	(0.64711)	(0.71555)	(0.99865)
	[-0.30259]	[-0.69008]	[0.43077]	[-1.51570]	[-1.28320]	[-0.04835]
LNOPENESS(-2)	-0.026116	0.311303	0.076037	-0.500074	-0.057006	0.021929
	(0.18909)	(0.45972)	(0.07123)	(0.41667)	(0.46074)	(0.64302)
	[-0.13811]	[0.67715]	[1.06745]	[-1.20018]	[-0.12373]	[0.03410]
LNEXC(-1)	-0.118863	-0.306878	-0.063294	-0.176437	-0.086811	0.686549
	(0.11356)	(0.27610)	(0.04278)	(0.25024)	(0.27671)	(0.38618)
	[-1.04666]	[-1.11148]	[-1.47952]	[-0.70507]	[-0.31373]	[1.77779]
LNEXC(-2)	-0.047297	0.114428	-0.097756	-0.551509	0.449578	0.355022
	(0.11642)	(0.28305)	(0.04386)	(0.25654)	(0.28367)	(0.39590)
	[-0.40626]	[0.40427]	[-2.22898]	[-2.14983]	[1.58485]	[0.89675]

C	-1.839866	-3.889801	-0.637957	-7.738319	-4.568642	0.143647
	(0.94584)	(2.29953)	(0.35630)	(2.08416)	(2.30461)	(3.21638)
	[-1.94523]	[-1.69157]	[-1.79050]	[-3.71293]	[-1.98240]	[0.04466]
R-squared	0.999392	0.997330	0.961278	0.996811	0.997386	0.970602
Adj. R-squared	0.998350	0.992753	0.894896	0.991344	0.992904	0.920207
Sum sq. resids	0.000829	0.004902	0.000118	0.004027	0.004923	0.009590
S.E. equation	0.010884	0.026462	0.004100	0.023984	0.026521	0.037013
F-statistic	959.0732	217.9094	14.48115	182.3366	222.5526	19.25957
Log likelihood	72.52790	54.76012	92.05377	56.72691	54.71599	48.04909
Akaike AIC	-5.952790	-4.176012	-7.905377	-4.372691	-4.171599	-3.504909
Schwarz SC	-5.305564	-3.528786	-7.258151	-3.725465	-3.524373	-2.857683
Mean dependent	12.16698	11.38838	-0.196923	10.25735	11.60465	0.818694
S.D. dependent	0.267964	0.310857	0.012647	0.257789	0.314836	0.131031

Determinant resid covariance (dof adj.)	1.69E-24
Determinant resid covariance	3.11E-27
Log likelihood	440.0868
Akaike information criterion	-36.20868
Schwarz criterion	-32.32533


DDEXC
.1
.0
-.1
-.2
-.3
92 94 96 98 00 02 04 06 08 10 12
DDGDP
.04
.02
.00
-.02
-.04
-.06
-.08
92 94 96 98 00 02 04 06 08 10 12
DDGFCF
.08
.04
.00
-.04
-.08
-.12
-.16
92 94 96 98 00 02 04 06 08 10 12
DDHDI
.02
.01
.00
-.01
-.02
92 94 96 98 00 02 04 06 08 10 12
DDICT
.15
.10
.05
.00
-.05
-.10
92 94 96 98 00 02 04 06 08 10 12
DDOPENESS
.2
.1
.0
-.1
-.2
-.3
92 94 96 98 00 02 04 06 08 10 12

Appendix 8: Unrestricted Cointegration Rank Test (Trace)

Date: 02/17/19 Time: 18:44
Sample (adjusted): 1992 2013
Included observations: 24 after adjustments
Trend assumption: Linear deterministic trend
Series: LNEXC LNGDP LNGFCF LNICT LNOPENESS
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.897669	117.4876	69.81889	0.0000
At most 1 *	0.748452	62.77844	47.85613	0.0011
At most 2	0.517891	29.65554	29.79707	0.0519
At most 3	0.311079	12.14551	15.49471	0.1501
At most 4	0.124915	3.202431	3.841466	0.0735

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.897669	54.70913	33.87687	0.0001
At most 1 *	0.748452	33.12290	27.58434	0.0087
At most 2	0.517891	17.51003	21.13162	0.1493
At most 3	0.311079	8.943078	14.26460	0.2909
At most 4	0.124915	3.202431	3.841466	0.0735

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

LNEXC	LNGDP	LNGFCF	LNICT	LNOPENESS
-11.45516	-39.90504	-14.83200	4.511809	48.54436
-3.827530	20.34885	25.56305	-23.73724	-22.38491
7.612371	-37.87725	-1.751338	14.68986	20.01489
-3.727100	3.523276	-14.18793	-0.980578	13.66978
-3.591324	-6.508252	1.550209	0.926488	5.782177

Unrestricted Adjustment Coefficients (alpha):

D(LNEXC)	0.008043	-0.047796	-0.045624	-0.036177	0.008993

D(LNGDP)	0.011925	-0.022530	-0.004785	-0.003742	-0.009974
D(LNGFCF)	-0.011385	-0.051677	-0.019000	0.008141	-0.010677
D(LNICT)	-0.007572	0.030964	-0.013221	0.023032	-0.016613
D(LNOPENESS)	-0.010904	-0.074233	-0.017203	-0.020511	-0.018217

1 Cointegrating Equation(s):		Log likelihood	213.2111	

Normalized cointegrating coefficients (standard error in parentheses)

LNEXC	LNGDP	LNGFCF	LNICT	LNOPENESS
1.000000	3.483586	1.294788	-0.393867	-4.237771
	(0.41998)	(0.22959)	(0.18942)	(0.37960)

Adjustment coefficients (standard error in parentheses)

D(LNEXC)	-0.092129
	(0.30350)
D(LNGDP)	-0.136605
	(0.11044)
D(LNGFCF)	0.130421
	(0.20427)
D(LNICT)	0.086737
	(0.20679)
D(LNOPENESS)	0.124908
	(0.30379)

2 Cointegrating Equation(s):		Log likelihood	229.7726	

Normalized cointegrating coefficients (standard error in parentheses)

LNEXC	LNGDP	LNGFCF	LNICT	LNOPENESS
1.000000	0.000000	-1.861616	2.217064	-0.245054
		(0.40097)	(0.22295)	(0.24712)
0.000000	1.000000	0.906079	-0.749495	-1.146151
		(0.11241)	(0.06250)	(0.06928)

Adjustment coefficients (standard error in parentheses)

D(LNEXC)	0.090811	-1.293528
	(0.28774)	(1.06718)
D(LNGDP)	-0.050371	-0.934333
	(0.09593)	(0.35578)
D(LNGFCF)	0.328215	-0.597229
	(0.15320)	(0.56817)
D(LNICT)	-0.031777	0.932229
	(0.19826)	(0.73531)
D(LNOPENESS)	0.409036	-1.075423
	(0.23518)	(0.87225)

3 Cointegrating Equation(s):		Log likelihood	238.5276	

Normalized cointegrating coefficients (standard error in parentheses)

LNEXC	LNGDP	LNGFCF	LNICT	LNOPENESS
1.000000	0.000000	0.000000	0.999238	-1.102690
			(0.06846)	(0.05308)
0.000000	1.000000	0.000000	-0.156759	-0.728726
			(0.02963)	(0.02297)
0.000000	0.000000	1.000000	-0.654177	-0.460694
			(0.04775)	(0.03702)

Adjustment coefficients (standard error in parentheses)

D(LNEXC)	-0.256495	0.434578	-1.261192
	(0.30121)	(1.23767)	(0.62465)
D(LNGDP)	-0.086800	-0.753074	-0.744426
	(0.11218)	(0.46093)	(0.23263)
D(LNGFCF)	0.183579	0.122442	-1.118871
	(0.16871)	(0.69323)	(0.34987)
D(LNICT)	-0.132423	1.433017	0.926985
	(0.22984)	(0.94441)	(0.47664)
D(LNOPENESS)	0.278083	-0.423833	-1.705759
	(0.27154)	(1.11576)	(0.56312)

4 Cointegrating Equation(s):	Log likelihood	242.9991

Normalized cointegrating coefficients (standard error in parentheses)

LNEXC	LNGDP	LNGFCF	LNICT	LNOPENESS
1.000000	0.000000	0.000000	0.000000	-0.169275
				(0.09956)
0.000000	1.000000	0.000000	0.000000	-0.875159
				(0.01841)
0.000000	0.000000	1.000000	0.000000	-1.071778
				(0.05920)
0.000000	0.000000	0.000000	1.000000	-0.934127
				(0.09494)

Adjustment coefficients (standard error in parentheses)

D(LNEXC)	-0.121659	0.307116	-0.747913	0.536094
	(0.28311)	(1.12760)	(0.62993)	(0.54290)
D(LNGDP)	-0.072853	-0.766258	-0.691334	0.521974
	(0.11516)	(0.45867)	(0.25623)	(0.22083)
D(LNGFCF)	0.153237	0.151125	-1.234375	0.888202
	(0.17192)	(0.68472)	(0.38252)	(0.32967)
D(LNICT)	-0.218264	1.514163	0.600216	-0.985957
	(0.22279)	(0.88733)	(0.49571)	(0.42722)
D(LNOPENESS)	0.354528	-0.496098	-1.414756	1.480292
	(0.27088)	(1.07886)	(0.60270)	(0.51943)

Vector Error Correction Estimates
Date: 02/17/19 Time: 15:46
Sample (adjusted): 1992 2013
Included observations: 24 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1	CointEq2
LNEXC(-1)	1.000000	0.000000

LNGDP(-1)	0.000000	1.000000
LNICT(-1)	2.217064	-0.749495
	(0.22982)	(0.06443)
	[9.64712]	[-11.6332]
LNOPENESS(-1)	-0.245054	-1.146151
	(0.25472)	(0.07141)
	[-0.96204]	[-16.0503]
LNGFCF(-1)	-1.861616	0.906079
	(0.41331)	(0.11587)
	[-4.50418]	[7.81990]
C	1.079139	-3.454089

Error Correction:	D(LNEXC)	D(LNGDP)	D(LNICT)	D(LNOPENESS)	D(LNGFCF)
CointEq1	0.090811	-0.050371	-0.031777	0.409036	0.328215
	(0.29660)	(0.09888)	(0.20436)	(0.24242)	(0.15791)
	[0.30618]	[-0.50941]	[-0.15549]	[1.68730]	[2.07849]
CointEq2	-1.293528	-0.934333	0.932229	-1.075423	-0.597229
	(1.10002)	(0.36673)	(0.75794)	(0.89909)	(0.58566)
	[-1.17591]	[-2.54773]	[1.22995]	[-1.19612]	[-1.01976]
D(LNEXC(-1))	-0.356594	-0.147093	-0.097441	-0.727579	-0.565453
	(0.42732)	(0.14246)	(0.29443)	(0.34926)	(0.22751)
	[-0.83450]	[-1.03252]	[-0.33095]	[-2.08318]	[-2.48545]
D(LNGDP(-1))	-1.265471	0.357777	0.913649	1.760876	1.763352
	(1.40930)	(0.46984)	(0.97104)	(1.15188)	(0.75032)
	[-0.89794]	[0.76149]	[0.94090]	[1.52870]	[2.35013]
D(LNICT(-1))	-1.365554	-0.389190	0.582672	-1.505008	-0.869895
	(0.61977)	(0.20662)	(0.42704)	(0.50657)	(0.32997)
	[-2.20331]	[-1.88357]	[1.36445]	[-2.97100]	[-2.63628]
D(LNOPENESS(-1))	-0.160016	-0.383262	0.187543	-0.874720	-0.480315
	(0.66951)	(0.22320)	(0.46131)	(0.54722)	(0.35645)
	[-0.23901]	[-1.71709]	[0.40654]	[-1.59849]	[-1.34749]
D(LNGFCF(-1))	0.759470	0.048553	-0.238663	0.375246	0.489703
	(0.48265)	(0.16091)	(0.33256)	(0.39449)	(0.25697)
	[1.57354]	[0.30174]	[-0.71766]	[0.95122]	[1.90572]
C	0.250469	0.132909	-0.044702	0.168362	0.047789
	(0.11914)	(0.03972)	(0.08209)	(0.09738)	(0.06343)
	[2.10225]	[3.34610]	[-0.54453]	[1.72890]	[0.75338]
R-squared	0.422501	0.568937	0.419447	0.525327	0.688359
Adj. R-squared	0.169846	0.380347	0.165454	0.317658	0.552016
Sum sq. resids	0.231578	0.025739	0.109943	0.154705	0.065642
S.E. equation	0.120306	0.040108	0.082894	0.098331	0.064052
F-statistic	1.672242	3.016792	1.651415	2.529633	5.048726
Log likelihood	21.63618	47.99914	30.57565	26.47695	36.76454
Akaike AIC	-1.136349	-3.333262	-1.881305	-1.539746	-2.397045
Schwarz SC	-0.743664	-2.940577	-1.488620	-1.147061	-2.004361
Mean dependent	0.058510	0.087484	0.076820	0.103165	0.100340
S.D. dependent	0.132041	0.050952	0.090740	0.119039	0.095697

Determinant resid covariance (dof adj.)	2.53E-14
Determinant resid covariance	3.33E-15
Log likelihood	229.7726
Akaike information criterion	-14.98105
Schwarz criterion	-12.52677

Appendix 9: VEC Residual Serial Correlation LM Tests

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Date: 02/17/19 Time: 20:42
Sample: 1992 2013
Included observations: 24

Lags	LM-Stat	Prob
1	25.92435	0.4116
2	29.90509	0.2279
3	27.72888	0.3205
4	35.79437	0.0748
5	38.53065	0.0410
6	44.46481	0.0096
7	34.18997	0.1039
8	25.95530	0.4100
9	24.29261	0.5025
10	22.71778	0.5940
11	26.13568	0.4004
12	37.48482	0.0519

Appendix 10: VEC Residual Normality Tests

VEC Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)
Null Hypothesis: residuals are multivariate normal
Date: 02/17/19 Time: 20:43
Sample: 1992 2013
Included observations: 24

Component	Skewness	Chi-sq	df	Prob.
1	0.926234	3.431641	1	0.0640
2	0.238203	0.226963	1	0.6338
3	0.018771	0.001409	1	0.9701
4	-0.354912	0.503849	1	0.4778
5	-0.860808	2.963964	1	0.0851
Joint		7.127827	5	0.2113

Component	Kurtosis	Chi-sq	df	Prob.
1	3.521695	0.272166	1	0.6019
2	2.180130	0.672187	1	0.4123
3	2.157663	0.709532	1	0.3996
4	2.413252	0.344273	1	0.5574
5	3.690151	0.476309	1	0.4901
Joint		2.474467	5	0.7803

Component	Jarque-Bera	df	Prob.
1	3.703807	2	0.1569
2	0.899150	2	0.6379
3	0.710941	2	0.7008
4	0.848123	2	0.6544
5	3.440273	2	0.1790
Joint	9.602294	10	0.4760

VEC Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)
Date: 02/17/19 Time: 20:44
Sample: 1992 2013
Included observations: 24

Joint test:

Chi-sq	df	Prob.
211.1642	210	0.4645

Individual components:

Dependent	R-squared	F(14,9)	Prob.	Chi-sq(14)	Prob.
res1*res1	0.379706	0.393518	0.9428	9.112946	0.8237
res2*res2	0.619517	1.046725	0.4882	14.86841	0.3872
res3*res3	0.815240	2.836568	0.0602	19.56577	0.1444
res4*res4	0.696732	1.476909	0.2821	16.72157	0.2713
res5*res5	0.776040	2.227551	0.1147	18.62495	0.1798
res2*res1	0.594690	0.943232	0.5553	14.27257	0.4296
res3*res1	0.811249	2.762994	0.0648	19.46998	0.1478
res3*res2	0.805607	2.664135	0.0717	19.33456	0.1526
res4*res1	0.367862	0.374100	0.9517	8.828688	0.8419
res4*res2	0.682288	1.380539	0.3189	16.37491	0.2910
res4*res3	0.639894	1.142331	0.4325	15.35745	0.3542
res5*res1	0.289404	0.261815	0.9875	6.945684	0.9368
res5*res2	0.787260	2.378939	0.0970	18.89424	0.1690
res5*res3	0.852919	3.727906	0.0265	20.47005	0.1160
res5*res4	0.759826	2.033773	0.1431	18.23582	0.1963

Variance Decomposition of LNOPENESS:

Period	S.E.	LNICT	LNOPENESS	LNEXC	LNGDP	LNGFCF
1	0.082894	1.140353	98.85965	0.000000	0.000000	0.000000
2	0.149086	1.342324	78.56004	8.862150	1.286924	9.948559
3	0.196283	4.747027	62.25253	5.014072	1.200424	26.78594
4	0.240763	6.277033	58.28012	4.503767	1.323111	29.61597
5	0.287438	6.182616	58.41688	5.070117	1.355803	28.97458
6	0.335097	5.871379	60.22218	5.147539	1.292591	27.46631
7	0.377979	5.424660	62.39148	4.742443	1.263770	26.17764
8	0.414338	5.417243	62.12287	4.328975	1.268962	26.86195
9	0.447587	5.833512	60.76191	4.391324	1.294001	27.71925
10	0.480896	5.939389	60.37611	4.862418	1.302900	27.51919

Variance Decomposition of LNEXC:

Period	S.E.	LNICT	LNOPENESS	LNEXC	LNGDP	LNGFCF
1	0.098331	23.37073	28.40036	48.22890	0.000000	0.000000
2	0.135776	42.58002	21.57978	34.30282	0.601808	0.935572
3	0.184137	39.50039	17.98700	37.76303	0.387040	4.362549
4	0.201355	33.82899	12.38460	47.80214	0.344826	5.639452
5	0.206298	31.20531	8.835186	55.55332	0.403531	4.002648
6	0.212122	30.80914	6.752897	58.22560	0.539371	3.672995
7	0.221355	30.87316	5.371211	59.46136	0.649151	3.645124
8	0.235307	30.32019	4.504776	61.25418	0.678137	3.242711
9	0.247170	28.98171	3.897307	63.63795	0.674936	2.808105
10	0.253767	27.60657	3.522059	65.65965	0.677708	2.534013

Variance Decomposition of LNGDP:

Period	S.E.	LNICT	LNOPENESS	LNEXC	LNGDP	LNGFCF
1	0.120306	17.48666	76.74166	2.315360	3.456325	0.000000
2	0.189262	12.13788	61.94005	12.93313	2.677554	10.31138
3	0.239548	14.06441	51.56379	11.62630	2.642327	20.10316
4	0.295280	15.05479	46.20358	11.74544	2.710681	24.28551
5	0.350752	14.92094	45.11929	12.68745	2.751066	24.52126
6	0.409492	13.78290	45.50414	14.61606	2.698747	23.39815
7	0.461762	12.47030	45.80652	16.41426	2.603741	22.70517
8	0.504890	11.65012	45.24215	17.27912	2.531444	23.29716
9	0.545523	11.36168	44.27394	17.53800	2.506808	24.31958
10	0.587210	11.17957	43.67201	17.83004	2.501779	24.81661

Variance Decomposition of LNGFCF:

Period	S.E.	LNICT	LNOPENESS	LNEXC	LNGDP	LNGFCF
1	0.040108	31.28626	41.95374	1.219007	1.394491	24.14650
2	0.069029	50.84093	34.62795	5.123794	0.745207	8.662123
3	0.103135	61.17406	28.11218	2.568495	0.717047	7.428215
4	0.127239	68.39241	22.86296	1.658844	0.723336	6.362451
5	0.143425	72.78272	20.12534	1.337445	0.690692	5.063806
6	0.157859	73.72880	19.61933	1.301529	0.618281	4.732068
7	0.174931	73.05571	20.49531	1.779250	0.580937	4.088795
8	0.194169	72.22531	21.31832	2.145214	0.593622	3.717527
9	0.212156	72.25028	21.19976	2.180144	0.622601	3.747220
10	0.226871	72.97840	20.74623	2.135006	0.632933	3.507430

Cholesky Ordering: LNICT LNOPENESS LNEXC LNGDP LNGFCF

Appendix 11: VEC Granger Causality/Block Exogeneity Wald Tests

VEC Granger Causality/Block Exogeneity Wald Tests

Date: 02/17/19 Time: 21:13

Sample: 1992 2013

Included observations: 24

Dependent variable: D(LNICT)

Excluded	Chi-sq	df	Prob.
D(LNOPENESS)	0.165278	1	0.6843
D(LNEXC)	0.109527	1	0.7407
D(LNGDP)	0.885283	1	0.3468
D(LNGFCF)	0.515034	1	0.4730
All	1.519186	4	0.8232

Dependent variable: D(LNOPENESS)

Excluded	Chi-sq	df	Prob.
D(LNICT)	8.826832	1	0.0030
D(LNEXC)	4.339659	1	0.0372
D(LNGDP)	2.336920	1	0.1263
D(LNGFCF)	0.904818	1	0.3415
All	9.356954	4	0.0528

Dependent variable: D(LNEXC)

Excluded	Chi-sq	df	Prob.
D(LNICT)	4.854583	1	0.0276
D(LNOPENESS)	0.057123	1	0.8111
D(LNGDP)	0.806302	1	0.3692
D(LNGFCF)	2.476043	1	0.1156
All	8.186682	4	0.0850

Dependent variable: D(LNGDP)

Excluded	Chi-sq	df	Prob.
D(LNICT)	3.547845	1	0.0496
D(LNOPENESS)	2.948396	1	0.0860
D(LNEXC)	1.066090	1	0.3018
D(LNGFCF)	0.091050	1	0.7628
All	7.449930	4	0.1139

Dependent variable: D(LNGFCF)

Excluded	Chi-sq	df	Prob.
D(LNICT)	6.949948	1	0.0084
D(LNOPENESS)	1.815731	1	0.1778
D(LNEXC)	6.177449	1	0.0129
D(LNGDP)	5.523123	1	0.0188
All	12.44000	4	0.0144