THE IMPACT OF MOBILE COMMUNICATIONS INFRASTRUCTURE INVESTMENT ON ECONOMIC GROWTH IN SOUTH AFRICA

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Abstract

Mobile telecommunications networks provide the ability to access the internet and use telephony services, where the infrastructure exists. Because of its mobile nature a customer can always connect to the internet, even when not in the comfort of their home, unlike the case with fixed-line services. This paper studies the impact of mobile telecommunications investment on economic growth in South Africa. To test the impact of mobile telecommunications investment on economic growth, the dissertation examines the development of mobile telecommunications infrastructure in South Africa and the relationship between mobile communications infrastructure investment (MCII) on economic growth. It is hypothesised that MCII has a relationship with economic growth.

The methodology employed by this study is the autoregressive distributed lags (ARDL) approach with secondary data sourced from the World Bank Group and Global System Mobile Association (GSMA) databases over the period 1994 to 2016. To model the relationship, the study used a neoclassical growth model with proxies for economic growth as gross domestic product (GDP); capital as mobile operator capital expenditure and gross capital formation; and labour as the labour force and the unemployment rate.

Results of the study showed that there was a unidirectional Granger causality between GDP and MCII and therefore no bidirectional causal relationship between MCII and GDP. Furthermore, using the ARDL approach found no cointegration between the variables and consequently no long run relationship. Producing the short run model as a VAR (2) model using the Akaike information criteria (AIC) lag selection also resulted in no significant relationship between MCII and GDP. This result has very important implications for policy recommendations to government and for development. Firstly, government should investigate why there is no significant impact of MCII on GDP because this relationship does exist in other markets. From these findings, government can develop and adopt policies which could produce a positive effect of MCII on GDP.

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List of Acronyms and Abbreviations

$ - United States dollar

3G – Third generation

4G – Fourth generation

5G – Fifth generation

ADF – Augmented Dickey-Fuller

AIC – Akaike information criteria

ASEAN – Association of south east Asian nations

ARDL – Autoregressive distributed lags

BSC – Base station controller

CEE – Central and eastern European

d1 – First difference

diff.- First differenced

DPAT - Department of post and communications

FDI – Foreign direct investment

F-stat – Fisher statistic

F-statistic – Fisher statistic

GCIS – Government communication and information system

GDP – Gross domestic product

GSM – Global system mobile

GSMA – Global system mobile association

HIV – Human immunodeficiency virus

ICASA – Independent communications authority of South Africa

ICT – Information communications technology

ICT4D – Information communications technology for development

IMF - International monetary fund

IoT – Internet of things

IT – Information technology

ITU – International telecommunications union

JSE – Johannesburg stock exchange

K_0 – Gross capital formation

K_{MI} – Mobile communications infrastructure investment

L – Labour force

ln – Natural logarithm

mAgri – Mobile agriculture

mHealth – Mobile health

M4D – Mobile for development

MCII – Mobile communications infrastructure investment

MTN – Mobile telephone networks (Pty) Ltd

OECD – Organisation for economic cooperation and development

OLS – Ordinary least squares

OTT – Over the top

p-value – Probability value

PP – Phillips-Perron

PSTN – Public switched telephone network

SA – South Africa

SADC – Southern African development community

Sig. - Significance

SIM – Subscriber identity module

SMS – Short message service

TPF – Total production function

WDI – World development indicators

U – Unemployment rate

USA – United States of America

USD – United States dollar

VAR – Vector autoregressive

VECM – Vector error correction model

Chapter One
Introduction

1.1 Background of the Study

A co-operative of rural farmers is sitting in the local marketplace, after the harvest of their first crop. While busy that morning, planning their next farming cycle, one of the farmers receives a call notifying him that a truck will arrive within the next hour to collect the entire harvest for a large retailer. Immediately after that call, he takes out his mobile phone and confirms the location through an application installed on his phone. The truck arrives and confirms collection of the crop through the same mobile application. The farmers receive instantaneous payment, based on their individual contribution to the harvest, via a mobile banking platform. This simple example illustrates how the value offered by mobile telecommunications has transformed the way business happens and the speed of business. It also illustrates how, through mobile technology, individual farmers can now participate in a market, previously closed off to them because they were unbanked; did not have the necessary access to a broader market; or could not pool resources or harvest together in an organised manner. The example also illustrates that mobile telecommunication has significant technological, productivity and market reach gains to an economy.

Motlhanke (2016) notes that there are more cell phones than citizens and that South Africa (SA) has the most mature cellular market with 130% mobile penetration. Furthermore, three out of the four mobile telecommunications companies are directly listed on the Johannesburg stock exchange (JSE), with the third entrant (Cell C) being indirectly listed through its acquisition by Blue Label Telecoms (JSE, 2018). Due to this, there is a lot of data available on the mobile telecommunication's landscape because the JSE requires extensive reporting requirements for listed companies (LexisNexis, n.d.). Of interest, from this data, is the level of infrastructure investment (capital investment) in mobile telecommunications networks. By compiling the available data together, this investment had a cumulative magnitude, over the last five years (2012 to 2016), of $7.8 billion (GSMA, 2017a; World Bank Group, 2017c).

Mobile penetration rates are also very high in SA, when compared to the rest of Africa, with a figure of 159% of the population in 2015 (GSMA, 2017a). But gross domestic product (GDP) growth has not been high in SA and was estimated at 0.4% growth, for 2016, according to the World Bank Group (2017b).

The South African government has increasingly focused on the rollout of broadband and telecommunications through the broadband implementation plan. Former minister of Telecommunications and Postal Services from 2013 to 2014, Yunus Carrim, noted that there are five task teams and different government stakeholders that will accelerate the finalisation of the Broadband Implementation Plan which focuses on digital readiness, digital development, digital future and digital opportunity (Carrim, n.d.). The aim of this paper is to measure the impact of mobile telecommunications on economic growth, with specific reference to mobile infrastructure investment and GDP growth, to determine the industry's importance to the economy and provide governmental policy recommendations.

1.2 Problem Definition

Mobile network infrastructure comprises of base stations and towers which are the biggest capital expenditure items for a mobile operator (Nhlapo, 2017). This infrastructure is also one of the largest cost drivers for these operators in running their businesses. According to a report by GSMA (2007), the mobile network contributes about 30% to total annual costs. Furthermore, the number of subscribers that a mobile network can support is directly linked to the amount of capital expenditure spent on mobile infrastructure because that network only has a certain capacity. Once this capacity is used, additional capital expenditure is required (Orange, 2018). There are other large costs that operators incur in running a network but these are dependent and related to the infrastructure investment i.e. without the infrastructure investment, there would not be a need to provide power or lease a site for a mobile tower (GSMA, 2007).

It has been shown that telecommunications and information and communication (ICT) in general both contribute to economic growth within countries (Alleman et al., 1994; David, Beatrice, Mary, & Wilson, 2014; Haacker, 2010; Koutroumpis, 2009). This study aims to assess the impact on GDP by mobile communications infrastructure investment (MCII) in SA. Other studies of this nature examining the relationship that ICT; ICT infrastructure; telecommunications infrastructure; broadband penetration rates; fixed-line telephony and internet usage has to GDP mainly revolve around panel data for a number of countries (Alleman et al., 1994; David et al., 2014; Haacker, 2010). There are very few studies that look at one market and specifically SA. Studies have also not shown explicitly the effect of mobile communication's infrastructure. Therefore, the aim is to add to the body of knowledge on the subject by assessing the impact of mobile telecommunications infrastructure on GDP, particularly in South Africa. A key question that the study wishes to answer is whether there is a positive relationship between mobile infrastructure spend and GDP.

1.3 Research Objectives and Hypothesis

The main objective this research is to examine the effect of MCII on economic growth, namely GDP, in South Africa. The specific objectives include;

i. To examine the development of mobile communications infrastructure investment in South Africa;
ii. To examine the relationship between mobile communications infrastructure investment and economic growth

To test the relationship between MCII and GDP, the researcher has formulated the hypothesis below:

H_0 - There is no relationship between mobile communications infrastructure investment and gross domestic product in South Africa

H_1 - There is a relationship between mobile communications infrastructure investment and gross domestic product in South Africa.

1.4 Justification

The researcher selected the topic based on interest and experience within the telecommunication's sector in SA. There is a growing link between mobile telecommunications and the other vertical markets with many of these telecommunications' companies entering the realms of banking, insurance and other industries. As examples, Vodacom has ventured into insurance and banking while Mobile Telephone Networks (MTN) has also entered into the entertainment industry (MTN, 2017; Vodacom, 2017).

Mobile network vendor Ericsson Australia (2010) predicts that with the internet of things (IoT) and movements towards digitalisation that there will be over 50 billion connections on mobile networks across the world by the year 2020. Mobile infrastructure will therefore play an ever-increasing role in the growth of an economy and these networks will become the centre of a vastly connected world.

The impact of mobile communications on economic growth in SA is important to understand because it provides a case for economic development through providing mobile telecommunication services. Should the relationship be a positive one, it will provide a case for an increase of focus by the government, development agencies, companies and non-governmental organisations (NGOs) on retaining and supporting this sector in the South African economy. If the relationship is inconclusive or negative then government should investigate why this is the case.

1.5 Organisation of the Study

This study will give a brief introduction in chapter one after which is a literature review in chapter two outlining the contributions of other studies; gaps in the research and the area that this study will focus on assessing. Chapter three will outline the methodology used for the study, define the data as well as the empirical model used. This section will also discuss the quantitative technique and its limitations. In chapter four, there is a discussion of the findings and lastly the conclusion, policy implications and recommendations for future research collated in chapter five.

Chapter Two
Literature Review

2.1 Introduction

The contents of this section are split into four parts, the first dealing with the development of telecommunications in South Africa (SA), where an overview of the history as well as the present day is reviewed to give some background to the study. It starts off with the roots of the telecommunications sector in SA and ends with the state of the mobile telecommunications landscape in the current day. Second is a theoretical review on why mobile telecommunications can be linked to economic growth. Here economic growth as well as mobile telecommunications infrastructure is defined using the funnel approach. The third section provides empirical evidence on how mobile telecommunications infrastructure can specifically be linked to economic growth. A review of past papers and their results is given by showing the different effects of information communications technology (ICT); telecommunications and mobile telecommunications on economic growth. Lastly, a view is given on mobile for development (M4D) in a South African context.

2.2 Development of Mobile Telecommunication in South Africa

Danesi (2014) defines information technology as an assortment of computer based media systems which include the internet, print, television and radio. Hence, it follows that mobile communication forms part of this definition. ICT in SA has its roots in postal communications: Telkom SA SOC Limited (2016) records that the Department of Postal Communications was instrumental in establishing the first telephone exchange in Port Elizabeth, on 1 May 1882, and had 20 subscribers from the business community during that same year. Public telephony was only introduced in 1898 in Kimberly (Telkom SA SOC Limited, 2016). This service was a voice calling service only and is a far cry to the current telecommunications services where both mobile and fixed-line telecommunications provide voice and data services. The first sign of a mobile cellular network in SA was in May 1986 when the South African Department of Post and Telecommunications (DPAT) introduced a public land mobile system which was an example of a second generation (2G) cellular network (Telkom SA SOC Limited, 2016). During 1991 the DPAT was split up with Telkom being spun off as a company, with the State as the sole shareholder (GCIS, 2001). At that point Telkom had approximately 3.4 million fixed-line subscribers (ITU, 2017).

The story of mobile telecommunications really started in 1993 when Vodacom was formed by a joint venture between Telkom, Vodafone and Venfin (Cairns, 2011). Later on, in 1994, Mobile Telephone Networks (MTN) launched the second mobile operator (MTN, 2016). At the end of that year there were 340 000 cellular phone customers in SA (ITU, 2017). The large growth of mobile telecommunications subscribers started in 1996 with the invention of pre-paid mobile telecommunications services. Post-paid services require fixed term contracts and a bank account so that the service provider can credit vet the ability of the customer to pay a monthly bill, whereas pre-paid services work mostly on a cash basis with no contract commitment period and pre-paid airtime vouchers being used to purchase and use telecommunications services (Sutherland, 2008). MTN (2016) noted that their pre-paid solution would allow even the unbanked to benefit from having a cell phone.

During the ten year period from 1996 to 2006 mobile subscriptions increased from just under 1 million to 39 million but in the same period fixed-line subscriptions rose from 4.3 million to only 4.8 million (ITU, 2017). Thus, the introduction of prepaid mobile services made ownership of telecommunications available to a substantial proportion of the population. Prior to the introduction of pre-paid mobile services, due to the nature of subscribing to telecommunication services, these unbanked users were unable to subscribe. During the same period, in 2001, a third mobile operator called Cell C also launched its services in South Africa (Cell C, 2017).

Mobile subscriptions are measured by the number of active subscriber identity module (SIM) cards and not the number of unique users and mobile customers have, in some instances, multiple SIM cards (Gillet, 2014; Sutherland, 2008). In 2015 the ITU (2017), notes that there was close to 88 million mobile subscriptions and 4.1 million fixed line subscriptions in SA. Statistics South Africa (2016) in their household survey, during 2016, estimated the population in SA at 55.6 million people. Because of this multiple SIM behaviour, it is not a surprise to find that the number of mobile subscriptions is higher than the population.

Telkom’s story, as a significant player in the mobile telecommunications industry, ended in 2009 when Telkom sold 15% of its share in Vodacom to the global telecommunications giant Vodafone and unbundled the remaining 35% to other existing shareholders (Mail & Guardian, 2009). However, Telkom also started up its own mobile network in 2010, the fourth entrant to a nearly saturated mobile telecommunications market in South Africa. At the time of the launch, mobile penetration (measured by the number of active SIM cards divided by the population) was at 97.9% (ITU, 2017).

Currently, there are several companies licensed to provide mobile telecommunications infrastructure in South Africa but only five that plan to provide this infrastructure on a national basis. At the end of 2016, by customer market share, Vodacom (42.1% market share) is the largest mobile communications company in South Africa with MTN (34.9% market share) being the second largest, Cell C (17.3% market share) the third, Telkom (4.5% market share) the fourth (BusinessTech, 2017). There is also a fifth entrant called Rain which only started operating its network in 2017 (Mybroadband, 2017).

For customers, the type of usage is undergoing a change from voice and text messages to data or internet usage (Dewar & Giles, 2014). This has been driven by customer adoption of over the top services (OTTs), namely social media. Stork, Esselaar, & Chair (2017) notes that mobile broadband uptake has accelerated due to smartphones becoming more affordable and capable, faster mobile networks and increase in social media use. Table 1 below illustrates that, as per Research ICT Africa’s survey in 2012, cited by Stork et al. (2017), more than 70% of respondents in SA accessed the internet via mobile phones versus only 32.4% via an internet café during the 12 months prior to the survey.

Table 1: Individual Internet Use

	15+ that use the internet			Where the internet was first used?		Where did you use the internet in the last 12 months?		Facebook Penetration Q1 2016
	2008	2012	Diff.	Computer	Mobile Phone	Mobile phone	Internet Café	
South Africa	15%	33.70%	18.70%	65.10%	34.90%	70.60%	32.40%	22.60%
Botswana	5.80%	29%	23.20%	70.60%	29.40%	64.10%	58.30%	29.20%
Kenya	15%	26.30%	11.30%	68.90%	31.10%	77.80%	72.40%	10.80%
Nigeria		18.40%		45.20%	54.80%	74.90%	45.10%	NA
Namibia	8.80%	16.20%	7.40%	50.10%	49.90%	87.30%	22.50%	19.10%
Cameroon	13%	14.10%	1.10%	82.10%	17.90%	29.70%	80%	5.80%
Ghana	5.60%	12.70%	7.10%	70.50%	29.50%	61.20%	84.70%	10.40%
Uganda	2.40%	7.90%	5.50%	28.20%	71.80%	81.30%	74%	4.50%
Rwanda	2%	6%	4.00%	70.80%	29.20%	70.90%	50.20%	4.20%
Tanzania	2.20%	3.50%	1.30%	45.80%	54.20%	74.70%	62.80%	5.30%
Ethiopia	0.70%	2.70%	2.00%	33.30%	66.70%	80.90%	42.20%	3.80%

Source: (Stork et al., 2017)

As is clear from Table 1 above, this trend of accessing the internet via a mobile phone rather than another means is similar for other African countries, namely Namibia, Nigeria, Botswana, Rwanda, Tanzania and Ethiopia. There is also a relatively high penetration of the social media platform Facebook in South Africa at 22.6% for quarter one of 2016.

Another trend which has caused a shift toward mobile internet usage has been the mobile telecommunications impact on other industries. This impact ranges from simple enabling factors to industry transformation in some instances. Examples of vertical industry enabling factors include mobile-commerce banking applications of large commercial banks; mobile video streaming services by television companies; educational applications by schools; health monitoring and diagnosis applications by health institutions and e-commerce applications by traditional retailers (Bezerra et al., 2015; Wired & J.P. Morgan, 2017). These enabling factors to industry have also lead to increases in usage of internet access via a mobile phone because they require an internet connection to be useful.

Transformational industry examples include Safaricom's M-Pesa service in Kenya; remittance services; Uber; mobile payment services; Google maps; Apple's iTunes and Netflix. M-Pesa has seen a lot of success in the Kenyan market but little success in South Africa with Vodacom choosing to shut it down in SA (Mcleod, 2016a). Nevertheless, there are other forms of mobile financial services in the form of payments and remittance services which are proving to be a success in South Africa. Flash EcoCash and Hello Paisa are two of these examples which provide remittance services via a mobile phone (Econet Wireless, 2018; Hello Paisa, 2017). These services have more of a development agenda because they make it cheaper to send money overseas via remittances to the unbanked (Econet Wireless, 2018). Uber has transformed the way in which users order, book and pay for point to point travel, via a taxicab, and while it is not a service than can be used by the poorer part of the population it does decrease the cost of transportation (Mlondiwa, 2015). Apple's iTunes application revolutionised the music industry allowing users to stream and download music onto their mobile phones (Griggs & Leopold, 2016). Netflix also transformed the video rental industry by allowing users to stream movies over the internet but also allows this to be done over a mobile phone (Wilson, 2016).

The future of mobile through the internet of things (IoT) and fifth generation (5G) technology will propel mobile networks to support a new wave of technological advances and automation of industries (Ericsson AB, 2018). The capability of 5G networks being able to provide low latency, high bandwidth connections will enable driverless cars; home automation accessible from anywhere; remote monitoring and diagnostics for individuals, government and businesses (GSA, 2015; Zhang, Xu, Wu, & Lu, 2014). There is also a continuing trend of fixed to mobile substitution where fixed-line services are being replaced by mobile services (GSA, 2015). The number of mobile subscriptions in SA have far surpassed the number fixed-line subscriptions and continue to grow.

2.3 Theoretical Review: Mobile Telecommunication Infrastructure Investment and Economic Growth

There are a quite a few measures used to gauge the size, growth and health of an economy but gross domestic product (GDP) is the most common and widely used measure. It has become the yardstick for calculating the size of an economy or economic growth. Callen (2017) states that GDP is one of the most common measures of national and global economies used by newspapers, television news, reports by governments, the business community and central banks to describe economic growth.

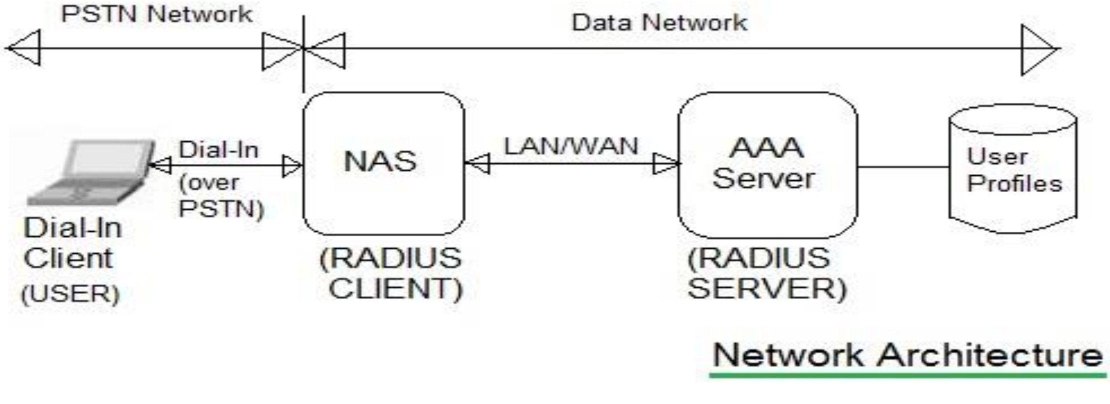
For a definition of GDP, the OECD (2016) notes that gross domestic product is made up of final consumption expenditure, gross capital formation and exports less imports. If we break down the words in the definition then gross implies that there is no depreciation and domestic means it is only those institutions which operate within the country (OECD, 2016). This definition highlights that GDP is a measure of the new economic activity within a country. Furthermore, GDP does not measure the expenditure on unpaid work (volunteerism) and black market activities because these are difficult to measure (Callen, 2017). GDP just as a number on its own will not give you any indication of how well or how badly and economy is performing and therefore, for it to have meaning, one must compare between countries and even over time. Knowing whether an economy is expanding or contracting is of immense importance to many stakeholders including politicians, economists, businesses, academics and development practitioners alike.

One cannot analyse economic growth without analysing the different models of economic growth. The classical economic growth model examined the relationship between economic growth and the factors of production, namely capital and labour (Domar, 1946; Harrod, 1939). A simplified version of the Harrod-Domar theory is that investment leads to increases in capital accumulation which then leads to economic growth (Domar, 1946; Harrod, 1939). Solow (1962) then argued that there is a flaw in the assumptions of this model because capital and labour do not exist in fixed proportions. The Solow-Swan model was independently developed by the two economists (Sardadvar, 2011). This model states that investing in new technologies will allow production with fewer resources and thereby overcoming the steady state, however, it is criticised because it cannot explain the sources of technological change (Mukupa, Lungu, & Chibangula, 2016). These two models are exogenous because they cannot explain the sources of technological change. Further to these models, many authors have developed endogenous models including (Fisher, 1969; Mankiw, Romer, & Weil, 1992; Romer, 1990). In these instances, the models incorporate technological change as part of the economy with variables introduced to reflect technological change, hence they are endogenous.

Information communication technology (ICT) has many definitions mostly centred around products and services that will allow the retrieval, collection, storage, transmission or reception of information electronically. Ritchie & Brindley (2005) define ICT as digital technologies designed to organise, process, store, communicate and collect information. It follows that this broad definition includes infrastructure, the internet as well as end user devices. Infrastructure included in this definition would therefore also include fixed-line network infrastructure, servers, data centres and mobile network infrastructure.

The key difference between a mobile network and a fixed-line network is that mobile technology uses the air interface or radio spectrum to carry digital information while fixed-line technology uses physical cables. Figure 1 below shows a basic diagram of a fixed-line network. The dial in client (user) dials into the network over the public telephony switched network (PSTN) which is a physical cable to the user's premises. This PSTN interconnects into a data network.

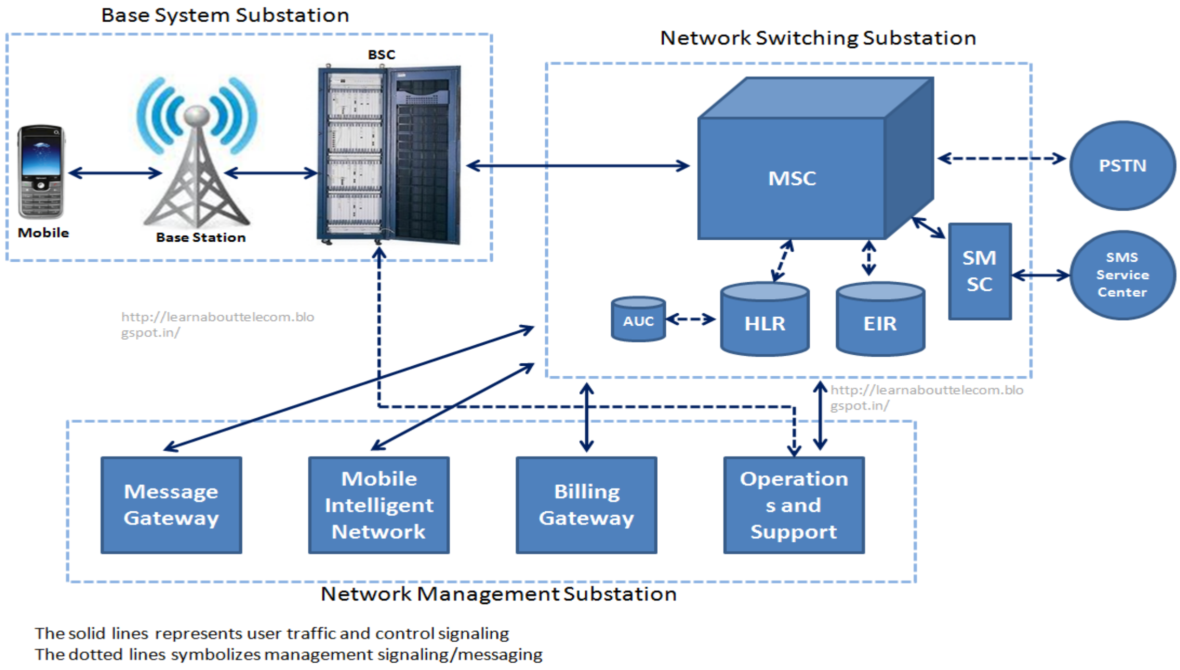
Figure 1: Fixed-line Network Infrastructure Diagram



Source: (BroadbandSoHo.Com, 2006)

From Figure 2 below, the technology employed in mobile networks includes antennae on physical towers (base stations) with connections to base station controller (BSC) which then links back to a network switching substation and network management substation (core network) that links multiple towers together. Users communicate with each other, with the network and use the internet through end user devices namely cellular telephones, modems and routers. The link from the mobile user does not use a physical cable but connects to the antenna over the air.

Figure 2: Mobile Network Infrastructure Diagram



Source:(Learnaboutbasics.com, 2013)

It has been shown that infrastructure has an effect on economic growth. Aschauer (1989) focuses on public expenditure on productivity and finds that infrastructure like severs, highways, airports and water systems have the most explanatory power in the United States. In a later study Munnel (1992) argues that a relationship exists but with private as well as public investment. The source of investment in mobile telecommunications infrastructure in SA is mostly private investment. Although the government did have a shareholding in Vodacom through Telkom, Telkom was partly privatised in 1997 and then listed on the Johannesburg stock exchange (JSE) and publicly traded in 2003 (Maltz, 2003).

The magnitude of mobile telecommunications investment in South Africa is large: ICASA (2016) estimates that telecommunications investment was over R16 billion, in 2015 alone, and 68% of this total investment was comprised of mobile telecommunications investment. This expenditure adds to GDP directly but mobile telecommunications may also have spill over effects on other parts of the economy.

Koutroumpis (2009) notes that mobile broadband networks can reach sparsely populated areas and support a wide range of applications. Therefore, modern day mobile networks provide broadband speeds and telecommunication service access to a large portion of the population. The high entry price of telecommunications over fixed-line networks has excluded this part of the population from participating in broadband services. In 2014, there were already some mobile offerings that were cheaper than a fixed-line DSL service (Vermeulen, 2014). By zooming in on mobile telecommunications, this paper aims to isolate the effect on mobile communications infrastructure investment on GDP.

2.4 Empirical Literature: Mobile Telecommunication Infrastructure Investment and Economic Growth

A study on the effect of mobile telecommunication infrastructure investment and economic growth would not be complete without first examining the role of ICT, ICT infrastructure and mobile telecommunications on economic growth. The researcher has taken this approach because mobile telecommunications infrastructure is a subset of the broader category of ICT. There have been numerous studies assessing the impact of investments in ICT infrastructure on economic growth that centered on the role of ICT in economic development.

Alleman et al. (1994) looked at mobile communication, using a macroeconomic econometric approach in the Southern African Development Community (SADC) region, to analyse the potential impact on economic growth in the region. They argue that while there are some positive relationships, there is inconclusive evidence to prove this impact within the SADC region. In their study for the period 1990 to 1996, Jorgenson & Stiroh (1999) show that investment in ICT leads to a large impact through substitution and not to third parties of the computer revolution.

To investigate whether the United States economy was a unique case for the impact of ICT and economic growth Colecchia & Schreyer (2002) undertook a study of nine organisation for economic cooperation and development (OECD) countries including Australia, Canada, Finland, France, Germany, Italy, Japan, the United Kingdom and the United States. The impact shown is between 0.2% and 0.9% depending on the period analysed (Colecchia & Schreyer, 2002). Lee, Gholami, & Tong (2005) chose to study the impact of ICT in developed as well as developing countries. This study showed that while ICT contributes to growth in developing countries, it does not contribute to economic growth in developed countries (Lee et al., 2005).

The panel study of OECD countries by Czernich, Falck, Kretschmer, & Woessmann (2011), for the period 1996 to 2007, shows that the impact on broadband infrastructure on economic growth is a positive one with an estimated an impact of between 0.9% and 1.5% percentage point growth for a 10% increase in broadband infrastructure.

Ng, Lye, & Lim (2013) also looked at the impact of broadband infrastructure but over a panel of 10 countries of the Association of Southeast Asian Nations (ASEAN) from 1998 to 2011. Their study illustrates a significant positive relationship between broadband infrastructure and economic growth across these countries (Ng et al., 2013).

The international monetary fund (IMF) working paper by Haacker (2010) examines the macroeconomic, specifically growth, impacts of ICT in low and low-middle income countries. Haacker (2010) employed a growth accounting framework with two goods where ICT was an investment good and all other products were both investment and consumption goods. The study displays that capital deepening in ICT contributes 0.3% in low-middle-income countries and 0.2% in low-income countries (Haacker, 2010) .

Vu (2011) looked at the impact of ICT from another perspective by using ICT penetration to test whether there is a causal link between ICT and economic growth across 102 countries over the period from 1996 to 2005. The research demonstrates that there is a positive link between ICT and economic growth theoretically and empirically but that the ICT penetration rate has a diminishing marginal effect on economic growth as penetration increases (Vu, 2011).

For the Australian market using data from the 1960s to 2011, Shahiduzzaman & Alam (2014) tested the cointegration and causal relationship of ICT and economic output. They find that there is a strong cointegration relationship and causality from ICT to GDP but not a strong causality from GDP to ICT (Shahiduzzaman & Alam, 2014).

More recently, Edquist & Henrekson (2017) undertook a study to measure the impact of ICT and R&D capital on value added in Sweden . They also looked at whether there is a difference between hardware investment and software investment. The findings of their study show that a 10% increase in ICT capital leads to a 1.7% increase in value added and that software investment has a significant effect on value added whereas hardware investment does not (Edquist & Henrekson, 2017).

Telecommunications infrastructure and economic growth in central and eastern Europe (CEE) was investigated by Madden & Savage (1998) which incorporated 27 countries with transitional economies, in the CEE region over the period 1990 to 1995. The study finds that there is a positive relationship between aggregate investment and growth (Madden & Savage, 1998).

Lam & Shiu (2010) performed a study of the impact of telecommunications on economic growth over 105 countries in a panel study between 1980 and 2006. Their paper used telecommunications density and found a positive bidirectional result (Lam & Shiu, 2010). A different approach was taken by Pradhan, Arvin, Norman, & Bele (2014) where they tested development of telecommunications infrastructure, economic growth and four other macroeconomic variables in the G-20 countries. Pradhan et al. (2014) showed that there is a difference between the long run and short run results with the long run having a bi-directional Granger-causality between the development of telecommunications infrastructure and economic growth as opposed to the short run which is inconclusive.

David et al. (2014) performed a study on Botswana, Cape Verde, Mauritius, Nigeria, Seychelles and South Africa to test the relationship between mobile and fixed-line subscribers per 100 people (mobile and fixed-line penetration rates) and GDP. They adopted a Granger causality test using dynamic panel data to test the relationship as well as an ordinary least squares (OLS) regression using mobile and fixed-line penetration rates (David et al., 2014). The Granger test did not produce any conclusive results but the OLS shows a positive relationship (David et al., 2014).

In a research article by Koutroumpis (2009), data on 22 OECD countries were used to examine the impact on economic growth by broadband infrastructure. Once again, the production function was used but it was embedded within a microeconomic model for demand and supply of broadband infrastructure and the results prove that there is a positive impact on economic growth (Koutroumpis, 2009). A more recent study by Kumar, Kumar, & Patel (2015) employed an autoregressive distributed lag (ARDL) technique and Granger causality tests to examine the relationship between telecommunications and per worker output in small Pacific island states. Their results show that there are significant long run effects of telecommunications on output per worker (Kumar et al., 2015).

There have only been some sources which examine the effects of telecommunications on economic growth in one country. Beil, Ford, & Jackson (2005) focused on telecommunications investment and economic growth just in the United States of America (USA) and covered data over a period of 50 years from 1947 to 1996. The result proved that there is a causal relationship between economic growth and telecommunications but not vice versa (Beil et al., 2005).

Further research by Lam & Shiu (2010) examined the causal relationship between telecommunications and economic growth in China and found a causal relationship between GDP and telecommunications at the national level but a causal relationship between telecommunications and GDP only exists in the more affluential eastern province. Kaur & Malhotra (2014) undertook investigating the effect of telecommunications development, GDP and other sectoral components of GDP, in India, with the results showing that there is a long run causal effect of telecommunications development and GDP at the aggregate as well as sectoral levels.

A research paper by Atsu, Agyei, Phanuel Darbi, & Adjei-Mensah (2014) aimed at looking at the long run impact of telecommunications investment on economic growth in Ghana. The method employed is a cointegration model using the total production function (TPF) with variables for data from 1976 to 2007 and the variables used to estimate telecommunications investment was revenue of the mobile telecommunications operators (Atsu et al., 2014). The results produce a positive but insignificant impact of telecommunications on economic growth (Atsu et al., 2014).

The ARDL method is also used by Oyeniran & Onikosi-Alliyu (2016) and tests for the relationship between telecoms infrastructure and economic growth in Nigeria. Results of the study show that there is a positive relationship between telecommunications infrastructure and economic growth but that foreign direct investment (FDI) proved to be more effective than local government investment (Oyeniran & Onikosi-Alliyu, 2016).

2.5 Mobile for Development (M4D)

Literature over the past couple of years has moved from a focus on ICT for development or ICT4D to centre on mobile for development or M4D. The narrative of M4D focuses on bridging the digital divide via mobile phones. Discussions on how mobile technology can be used to provide access to the internet, and therefore provide information and other services to various communities' range over several sectors and communities. This research will explore some of these sectors and communities below.

2.5.1 Agriculture (mAgri)

mAgri is the use of mobile phones to provide agricultural services to farmers. According to Simpson & Calitz (2014) mobile phones can be used for extension services provided by agricultural associations. These extension services include information about the market, farming techniques, research, products, best practices as well as agricultural conditions. Simpson & Calitz (2014) further found that 70% of the respondents use mobile phones and propose that these agricultural associations have an opportunity to provide extension services to these commercial farmers. By doing so, even small scale commercial farmers would be kept up to date with all the relevant information including market prices in real time.

2.5.2 Healthcare (mHealth)

South Africa currently has the highest incidence of human immunodeficiency virus (HIV) in the world. According to UNAIDS (2018) the proportion of people living with HIV in SA is 19% of the worldwide figure with 15% of new infections and 11% of AIDS related deaths on the globe also coming from SA. This requires innovative low-cost initiatives to provide healthcare services to masses of people. Odine, Dean, & Florida (2015) undertook a study on the services available and use of those services within South Africa. They found that the short message service (SMS) was used because of the high prices of mobile internet in SA. Services that they found include Project Masiluleke which provides HIV support and awareness through text messages; MAMA - a programme which provides healthcare information to mothers; e.Mobile TV – a "free to air" mobile television channel which provides healthcare services and information; SMSpill – a prescription bottle which reminds patients when to take medication via the use of a mobile phone chip; Text to Change – an SMS healthcare information service and text4baby which also provides healthcare information to mothers (Odine et al., 2015). They also found that this healthcare information being disseminated is being widely used (Odine et al., 2015).

2.5.3 Mobile Money

The GSMA (2018b) notes that mobile money could enable more financial inclusion, economic growth and economic empowerment and thereby transform the financial lives of underserved people. In South Africa, there have been some success stories as well as failures regarding mobile money. Both Vodacom and MTN closed down their mobile money operations in SA, besides having successes in other markets, but there are other market players like Hello Mobile which have seen success with their mobile money operations (Mcleod, 2016b). Another mobile money service which has been doing well is Zoona and although it doesn't operate in South Africa, it is a South African company which has processes more than $1 billion in transactions (Jackson, 2016).

2.5.4 Digital Identity

One of the programmes being run by the GSMA (2018a) focuses on using mobile technology as a unique identifier for underserved individuals. World Bank Group (2018) estimates that there are more than 1 billion people who are unable to prove their identity and the view is that without being able to prove their identity that they are unable to access financial services, social benefits, healthcare, education, political and legal rights, gender equality and migration. This also creates issues for governments because these people cannot access the services that they provide because they don't have an identity (World Bank Group, 2018).

2.5.5 Smart Cities

Deloitte has a definition on smart cities which encompasses at a high level what is meant by a smart city. Dubbeldeman & Ward (2015) from Deloitte define that smart cities provide a high quality of life and management of natural resources by investment in three areas: namely social and human capital; ordinary infrastructure and technology. Since mobile phone penetration is high in most countries, these now provide a sensor network that can be used for certain applications of smart cities (World Bank Group, 2018). It is also argued by that mobile operators are best placed to implement smart cities because of their reach, scalability and economies of scale (GSMA, 2017b). It is for these reasons that mobile technology will be the most ubiquitous access medium to implement smart city capabilities.

2.5.6 Criticism of M4D

It is not just a pretty picture that has been painted. Han (2012) argues that the price of mobile telephony in South Africa is expensive and causes a barrier to mobile phones being used for development purposes. It is because of this high cost of ownership of mobile phones and mobile internet that mobile networks have a role to play if M4D is to become a reality (Han, 2012). It is also argued that owning a mobile phone can lead to one being a victim of theft and that the instead of preventing HIV, that mobile phones might lead to an increase in HIV because sexual predators use chat rooms to find their victims (Han, 2012).

2.6 Conclusion

Most of the relevant research above utilised the production function with some sort of modification. The most popular statistical techniques in more recent years seems to be the ARDL method, Granger causality tests and tests for cointegration. Studies vary in their results with some showing no causality effect but with a majority showing that there is a long run effect as well as bi-directional causality. A number of these studies have also focused on regional or panel data across multiple countries with very few focusing on individual countries. From the literature, there has also been focus on the link between ICT, telecommunication density and telecommunications investment and GDP. This study proposes that there is a gap in the literature because there have not been any studies on the impact of mobile telecommunications infrastructure on economic growth and very few studies which focus on one country. Lastly, M4D shows that there could be an impact of mobile telecommunications on development within South Africa, but unaffordable prices of mobile internet access and mobile phones may be a barrier.

Chapter Three
Research Methodology

3.1 Introduction

This chapter discusses data source, analytical model and limitations of the analytical model. The statistical method used to assess the variables was the Autoregressive Distributed Lags (ARDL) method. Step one involved testing for stationarity of the variables with the Augmented Dickey Fuller and Phillips-Perron tests and also to satisfy a condition of the ARDL approach which states that the variables cannot be integrated of order *I(2)* (Pesaran, Shin, & Smith, 2001). In step two, the variables were checked for cointegration, using a bounds test for a long run relationship. Lastly, if the variables were not cointegrated then the relationship could be studied using a vector autoregressive (VAR) model. If they were cointegrated then a vector error corrective model (VECM) regression is estimated with the first difference of the variables and the first lag of the residuals for the short run effects; and the first differenced dependent variable on the first difference of the regressors. To conclude the chapter, some of the limitations of the approach were also explored.

3.2 Data and Research Design

3.2.1 Data Sources

The research was performed using secondary time series data from the World Development Indicators (WDI) World Bank Group (2017c) and the GSMA (Global System for Mobile Association) Intelligence GSMA (2017a) databases. The WDI contains information on telecommunications investment, labour, capital and GDP. The only relevant information to this study, within the GSMA database, was telecommunication investment figures. Data from Ovum (2017) was also considered but was not used in the study.

3.2.2 Data Period

Data availability remained a major factor in choosing the data period. Mobile telecommunications investment data was only available for the period 1994 to 2016. All other inputs into the study were available for longer periods of time but also available for the period chosen. Since mobile telecommunication's networks in South Africa (SA) only started operations in 1993, and assuming that, these operators would only have reported on their investments a year later, the period chosen would be able to analyse the effect of mobile communications infrastructure investment (MCII) from the beginning of mobile telecommunications networks in South Africa.

3.2.3 Rationale for Data Source

The dataset was selected because of credibility and accuracy. World Bank Group (2017c) states that their database presents the most current and correct global development data, compiled from officially recognised worldwide sources. The WDI data set was also compared to other databases including GSMA (2017a) and Ovum (2017). It was found that GSMA (2017a) had many missing data points and where all data points were available, namely in 2013 and 2014, they were approximately equal to that of World Bank Group (2017c). For all other data points, the GSMA (2017a) data was significantly lower than World Bank Group (2017c). With regard to Ovum (2017), the investment data was only available from 2008 to 2016 and the values for 2008 to 2010 were lower than those of World Bank Group (2017c) whereas from 2011 to 2014, the numbers were higher. The similar trends point to a possibility of the use of different average exchange rates. The data in World Bank Group (2017c) source quoted that the information encompassed total communications investment but by running a query on the World Bank Group (2017a) database , the detail of the data was also analysed to find what sources of data were used. Through this exercise, the researcher discovered that the data collected was from mobile operators records for the period 1994 to 2014. For the last two data points for mobile infrastructure investment, namely 2015 and 2016, the figures in the GSMA (2017a) database were used because it contained information on capital expenditure for all the mobile operators in SA.

3.2.4 Nature of the Study

The nature of the study is quantitative using secondary data. The aim was to perform an econometric statistical analysis to draw inferences on whether a relationship existed between mobile infrastructure investment and economic growth. The population of the study includes mobile operators (namely Cell C, Telkom, MTN and Vodacom) within South Africa and the statistical tests were performed in the opensource statistical software RStudio Version 1.1.383.

3.3 Analytical Framework

The neoclassical growth model was used and it explains growth by various factors including labour, capital and technological progress (Atsu et al., 2014; Jorgenson & Stiroh, 1999;

Oyeniran & Onikosi-Alliyu, 2016; Shahiduzzaman & Alam, 2014). This model would be represented by the equation:

$$Y(t) = A(t)f[K(t), L(t)] \tag{1}$$

Where *Y(t)* denoted output, *A(t)* is represents technological advancement, *K(t)* meant sources of capital and *L(t)* represented sources of labour.

To incorporate telecommunications infrastructure investment into the equation telecommunications capital expenditure was used as a source of capital, separated from other forms of capital. By taking the natural logarithm on both sides of the equation the following formula is derived which was consistent with the approach taken by Shahiduzzaman & Alam (2014):

$$\ln GDP_t = \beta + \alpha_1 \ln K_{MIt} + \alpha_2 \ln K_{0t} + \alpha_3 \ln L_t + \alpha_4 \ln U_t + \varepsilon_t \tag{2}$$

Where K_{MI} represented the capital from mobile communications infrastructure investment;K_0 denoted the total infrastructure capital excluding mobile communications infrastructure investment; L stood for labour; α_1, α_2, α_3, α_4 represented the elasticities of the outputs of the production function and β and a_t denoted the constant and the error terms, respectively. A control variable for unemployment was also used for the unemployment rate (*U*). Lastly GDP meant gross domestic product.

As a proxy for K_{MI} the data for telecommunications infrastructure with private investment was employed, secondly the proxy for K_0, used in the model, was gross capital formation, L was measured by the proxy of the total labour force. The proxies for K_{MI}, K_0 and GDP were measured in United States Dollars (USD) and were given at the exchange rate at the time of recording (current USD) (World Bank Group, 2017c). The labour force was measured in number of people in the labour force. The proxy for unemployment was the unemployment rate measured as a percentage of the total labour force (World Bank Group, 2017c).

As per the WDI, the World Bank Group (2017c) variables were named and defined as follows:

Table 2: Definitions of Variables

Variable	Description	Definition
GDP	Gross Domestic Product (current US$)	Value added was defined as the gross output of producers less the value of intermediate goods and services consumed in production before fixed capital production. Therefore, GDP represented the sum of value added by all producers.
K_{MI}	Investment in telecoms with private participation (current US$)	The investments in telecommunications projects which had reached financial closure and includes private participation.
K_0	Gross capital formation (current US$)	Private and public investment in fixed assets, changes in inventories and net acquisition of valuables.
L	Labour force, total	Included all people over 15 years of age who were employed, unemployed and looking for work as well as first-time job-seekers. They supplied labour to produce goods.
U	Unemployment, total (% of total labour force) (modelled ILO estimate)	Individuals without work but seeking work, without work but could work or part of the labour force.

Source: (World Bank Group, 2017c)

3.4 Estimation Approach

3.4.1 Stationarity Tests (Tests for Unit Roots)

Unit root tests were conducted to determine whether these series were stationary, since most time series are non-stationary or likely to display a trend (Atsu et al., 2014; Kaur & Malhotra, 2014). The augmented Dicky-Fuller (ADF) and Phillips-Perron (PP) tests were used to test for unit roots, as employed by (Atsu et al., 2014; Beil et al., 2005; Kaur & Malhotra, 2014).

ADF and PP tests were both used to also determine the order of integration of each series. The ADF test used the following expression:

$$\Delta Y_t = \alpha Y_{t-1} + \sum_{i=1}^{m} \beta_i \Delta Y_{t-1} + \delta + \gamma t + \varepsilon_t \quad (3)$$

Where ΔY was the first difference of the series, *t* represented the time trend, δ a constant and *m* denoted the number of lags. If null hypothesis of $\alpha = 0$, was rejected, then the series would be stationary and referred to as *I (0)* or had a zero order of integration, If this null hypothesis was not rejected, the series was differenced again and the test for the null hypothesis would be repeated until the null hypothesis was rejected (Lee et al., 2005). The number of differences until the null hypothesis was rejected denotes the order of integration (Kaur & Malhotra, 2014).

The PP test is the other unit root test and is better suited to smaller series samples (Atsu et al., 2014). It is a generalisation of the ADF test, is autoregressive of order 1 AR(1) and uses lagged instead of differenced variables (Kaur & Malhotra, 2014). The equation used was:

$$\Delta Y_{t-1} = \alpha + \gamma Y_{t-1} + \varepsilon_t \tag{4}$$

ΔY is the difference of the series, γ is the constant time trend and Y_{t-1} was the lagged time series.

3.4.2 Cointegration Analysis

To test for cointegration, the autoregressive distributed lags (ARDL) bounds test was used. Shahiduzzaman and Alam (2014) note that this test is suitable for smaller samples and can be applied regardless of whether series are integrated of order *I(0)* or *I(1)*. Lee et al. (2005) states that for there to be cointegration, the order of integration of the variables on the right side of the equation must equal the order of integration of the variables on the left side of the equation. The critical values for the F-tests are the ones used by (Narayan, 2005).

The equation used in the bounds test, as derived from Shahiduzzaman & Alam (2014) is shown below:

$$\begin{aligned}\Delta \ln GDP = \beta + \textstyle\sum_{i=1}^{m} \alpha_1 \Delta \ln GDP_t + \sum_{i=1}^{m} \alpha_2 \Delta \ln K_{MIt} + \\ \textstyle\sum_{i=1}^{m} \alpha_3 \Delta \ln K_{0t} + \sum_{i=1}^{m} \alpha_4 \Delta \ln L_t + \sum_{i=1}^{m} \alpha_5 \Delta \ln U_t + \alpha_6 \ln GDP_{t-1} + \alpha_7 \ln K_{MIt-1} + \\ \alpha_8 \ln K_{0t-1} + \alpha_9 \ln L_{t-1} + \alpha_{10} \ln U_{t-1} + \varepsilon_t\end{aligned} \tag{5}$$

The hypothesis for this test was as follows:

H_0 – There is no cointegration relationship between the variables i.e.

$$H_0: \alpha_6 = \alpha_7 = \alpha_8 = \alpha_9 = \alpha_{10} = 0$$

H_1 – There is a cointegration relationship between the variables i.e.

$$H_1: \alpha_6 \neq \alpha_7 \neq \alpha_8 \neq \alpha_9 \neq \alpha_{10} \neq 0$$

In the case where there was no cointegration found then the coefficients of the short run equation could be estimated by a vector autoregressive model (VAR) on the first difference of the variables.

3.4.3 Vector Error Correction Model

In the case where the variables were cointegrated then an adjustment first needed to be made to the equations, to take into account the cointegration relationship between the variables before the Granger causality is run (Djoumessi, 2009). The VECM model adopted from Djoumessi (2009) is then represented by:

$$GDP_t = \vartheta_1 ECT_{t-1} + \sum_{i=1}^{l} \alpha_i GDP_{t-i} + \sum_{i=1}^{m} \beta_i K_{MIt-i} + \sum_{i=1}^{n} \gamma_i K_{0t-i} + \sum_{i=1}^{o} \delta_i L_{t-i} + \sum_{i=1}^{p} \varepsilon_i U_{t-i} + \theta_t \quad (6)$$

$$K_{MIt} = \vartheta_2 ECT_{t-1} + \sum_{i=1}^{q} a_i K_{MIt-i} + \sum_{i=1}^{r} b_i GDP_{t-i} + \sum_{i=1}^{s} c_i K_{0t-i} + \sum_{i=1}^{t} d_i L_{t-i} + \sum_{i=1}^{u} e_i U_{t-i} + \omega_t \quad (7)$$

In these equations $\vartheta_1 ECT_{t-1}$ and $\vartheta_2 ECT_{t-1}$ represented the error correction terms as the residuals of the cointegration equation (Lee et al., 2005). θ_t and ω_t are the residuals of the equation.

3.4.4 Granger Causality

The method used involved testing if there was a causal relationship between economic growth and MCII and then testing whether there was a causal relationship between mobile telecommunication infrastructure investment and economic growth (Atsu et al., 2014; Kumar et al., 2015; Madden & Savage, 1998; Pradhan et al., 2014; Shahiduzzaman & Alam, 2014; Shiu & Lam, 2008b). Shiu & Lam (2008b) employed a similar causality test using VAR models of the form:

$$GDP_t = \sum_{i=1}^{l} \alpha_i GDP_{t-i} + \sum_{i=1}^{m} \beta_i K_{MIt-i} + \sum_{i=1}^{n} \gamma_i K_{0t-i} + \sum_{i=1}^{o} \delta_i L_{t-i} + \sum_{i=1}^{p} \varepsilon_i U_{t-i} + \theta_t \quad (8)$$

$$K_{MIt} = \sum_{i=1}^{q} a_i K_{MIt-i} + \sum_{i=1}^{r} b_i GDP_{t-i} + \sum_{i=1}^{s} c_i K_{0t-i} + \sum_{i=1}^{t} d_i L_{t-i} + \sum_{i=1}^{u} e_i U_{t-i} + \omega_t \quad (9)$$

The null hypothesis of K_{MI} does not cause *GDP* as well as *GDP* does not cause K_{MI} were specified and rejected if the F-value exceeded the critical F-value at the chosen level (Lee et al., 2005)

3.5 Constraints and Limitations

One of the major limitations of this analysis was the small data sample of just 23 observations for each variable. This sample size was quite small and lower than studies by Oyeniran & Onikosi-Alliyu (2016) which had more than 120 observations and Atsu et al. (2014); Kaur & Malhotra (2014) both with more than 30 observations. The reason for the small sample size is the recent start of mobile communications networks in South Africa.

A further constraint in the ARDL approach is that the variables cannot be integrated of order *I(2)*, if they were, the results would be incorrect (Pesaran et al., 2001).

Lastly, the ARDL approach only allows for one long run relationship and does not allow for more than one long-run relationship, therefore this technique may be insufficient if more than one long run relationship existed (Pesaran et al., 2001).

Chapter 4

Research findings and discussion

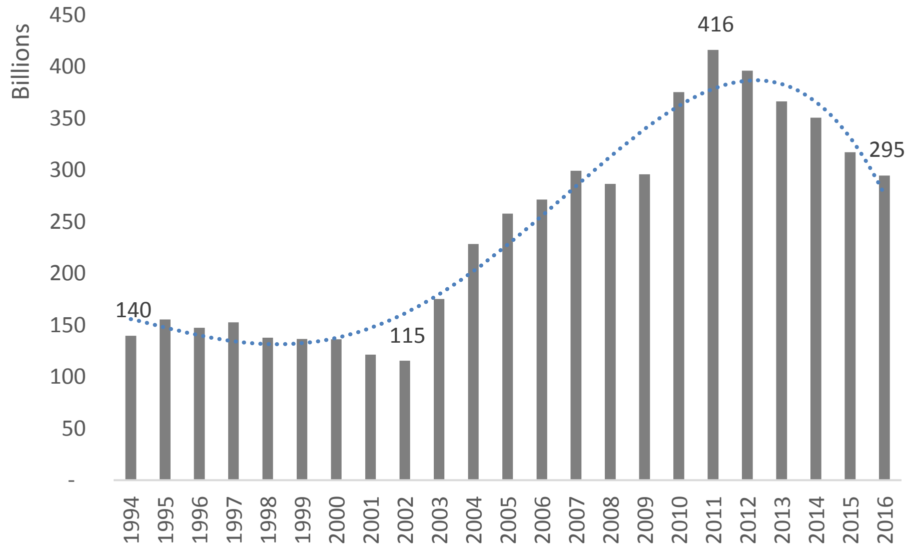
4.1 Introduction

This chapter presents the discussions of the results of the empirical analysis. It includes sections on the descriptive statistics, unit root and cointegration test, and short run regression estimates.

4.2 Development of Mobile Communications Infrastructure Investment

Figure 3 below shows mobile communications infrastructure investment (MCII) for the period 1994 to 2016:

Figure 3: Mobile Communications Infrastructure Investment USD (Current Prices)



Source: Researchers estimates from Research data, 2017

In 1994, MCII was $140 billion, it then showed a slight decline to $115 billion and increased to a peak of $416 billion in 2011. From 2011 to 2016 there had been a declining trend in this investment from $416 billion to $295 billion.

4.3 Summary Statistics

The data was summarised to examine the properties of each of the variables. The descriptive statistics of the untransformed variables used in the empirical analysis is presented in table 3. The transformed variables showed similar results.

Table 3: Summary Statistics

Statistic	***GDP***	K_{MI}	K_0	***L***	***U***
Mean	242 451 074 081	1 540 177 841	47 380 778 183	17 623 169	24.00
Median	257 772 710 833	1 727 200 000	47 211 013 791	17 485 653	24.67
Minimum	115 482 368 344	447 700 000	18 798 182 284	14 211 207	16.90
Maximum	416 418 862 156	2 387 000 000	82 121 717 095	21 099 531	27.14
Standard Error	20 867 648 114	119 197 094	4 681 780 716	378 245	0.49
Standard Deviation	100 077 724 641	571 649 181	22 453 031 545	1 813 998	2.37
Kurtosis	-1.43	-0.55	-1.65	-0.38	2.52
Skewness	0.22	-0.68	0.13	0.03	-1.38
Count	23	23	23	23	23.00

Note: ***GDP****= Gross Domestic Product;* K_{MI} *= Mobile infrastructure investment;* K_0 *= gross capital formation;* ***L****= labour force;* ***U*** *= unemployment. Source: Researchers estimates from Research data, 2017*

There were no missing data for the data set because all the variables had 23 observations. One striking observation was that the mean and median values were very close together for variables gross domestic product (*GDP)*, gross capital formation (K_0) and labour *(L).* Bulmer (1967) provides limits to assess skewness as follows: if the skewness of a variable is less than -1 or greater than 1, then the distribution can be regarded as highly skewed; if the skewness is between -1 and -0.5 or between 0.5 and 1 then the distribution of the variable is regarded as moderately skewed; and if the skewness statistics is between -0.5 and 0.5 then the distribution is regarded as having symmetrical properties like with the normal distribution. Therefore, this phenomenon of the mean and median being close together could be explained by the skewness statistics which were positive but less than 0.5. This indicated a slight positive skewness in the distribution but could be regarded as approximately symmetric. For the variable mobile infrastructure investment (K_{MI}) the difference between the mean and the median was larger and this showed in the skewness statistic of -0.68. In this case, the statistic was greater than -1 but less than -0.5, indicating that the distribution of this variable was moderately negatively skewed. For the variable *U,* there was a large difference between the median and the mean which was also reflected in the skewness statistic of -1.38. Here the statistic remained less than -1 and it was concluded that the distribution of the variable is highly negatively skewed.

When looking at the standard deviations of the means of each of the variables, it can be noted that three of the variables had very large standard deviations, namely *GDP,* K_{MI} *and* K_0. The interpretation of this was a wide dispersion of the variables around the mean. Furthermore, the standard errors of these variables were also quite large, which indicated a wide dispersion of the distribution for these variables. The standard deviation and the standard error of the other two variables were low and therefore indicated that the dispersion of the distribution of the variables was narrow.

Kurtosis is a measure of the weight of the tails of a distribution. Westfal (2014) records that kurtosis of a distribution could be leptokurtic, mesokurtic, or platykurtic. These types of distributions describe the types of tails of the distribution and kurtosis with a leptokurtic one having wide tails and a positive kurtosis; a platykurtic distribution having narrow tails and a negative kurtosis; and a mesokurtic distribution (e.g. normal distribution) with a kurtosis of zero (Westfal, 2014). When considering the kurtosis of the variables *GDP*, K_{MI}, K_0, *L*, they could be described as having mesokurtic distributions, their kurtosis statistics were all less than zero. Variable *U* could be described as platykurtic since the kurtosis statistic was positive. Finally, to fit a linear regression to the data, transformations of the variables were necessary. As per the Cobb-Douglas production function, this transformation involved taking the natural logarithm of each of the variables. The research analysed the correlation between these transformed variables and table 4 below shows the correlations between each variable in a matrix.

Table 4: Correlation Matrix: First Difference of the Natural Logarithm of the Variables

Variable	*ln(GDP)*	*ln(KMI)*	*ln(K0)*	*ln(L)*	*ln(U)*
ln(GDP)	1.00				
ln(KMI)	0.36	1.00			
ln(K0)	0.99	0.32	1.00		
ln(L)	0.75	0.66	0.74	1.00	
ln(U)	0.09	0.73	0.03	0.54	1.00

Note: ***GDP****= Gross Domestic Product;* K_{MI} *= Mobile infrastructure investment;* K_0 *= gross capital formation;* ***L****= labour force;* ***U*** *= unemployment. Source: Researchers estimates from Research data, 2017*

The correlation matrix in table 4 above shows a low negative correlation between mobile K_{MI} and *GDP* as well as *U* and *GDP*. *GDP* and K_0 as well as *GDP* and *L* showed high correlations between the variables. There are also low correlations between the variables K_{MI}, K_0, *L* and *U*.

These observations of the data were not of a concern but they did point to a need to test the data for normality.

4.4 Test for Normality

To test the data for normality, the study employed the Shapiro-Wilk W test. TIBCO Software Inc. (2017) notes that this is the preferred test for normality due to the power of the test. Table 5 below shows the results of the Shapiro-Wilk W test for each variable.

Table 5: Shapiro Wilk W Test Results

Variable	W-value	p-value
GDP	0.90	0.02
K_{MI}	0.92	0.06
K_0	0.88	0.01
L	0.99	0.98

*Note: **GDP**= Gross Domestic Product; $\boldsymbol{K_{MI}}$ = Mobile infrastructure investment; $\boldsymbol{K_0}$ = gross capital formation; **L**= labour force; **U** = unemployment. Source: Researchers estimates from Research data, 2017*

At a 5% significance level, p-values lower than 5% result in the null hypothesis, that data comes from populations that are normally distributed, being rejected. Conversely, p-values greater than 5% will fail to reject the null hypothesis. For the variables gross domestic product, gross capital formation and unemployment, the researcher rejected the null hypothesis and concluded that there was not enough evidence to show that the variables were normally distributed. Regarding variables labour and mobile infrastructure investment, the results could not reject the null hypothesis and concluded that there was strong evidence that the data was normally distributed. However, the tests that were done on the data did not require the data to be normally distributed. Normality of the data would make the results more robust.

4.5 Tests for Unit Roots

Two tests were done to test for stationarity, namely the Augmented Dickey-Fuller (ADF) test ADF and Phillips-Perron (PP) tests. These tests also gave an indication of the order of integration or the number of times a series must be differenced to make it a stationary one. The lag length was selected using the AIC criterion. Table 6 below shows a summary of the tests and order of integration of each of the transformed variable:

Table 6: Unit Root Results

	Augmented Dickey Fuller Test					Phillips-Perron Test			
	Levels			First Difference		Levels		First Difference	
Variable	**Test Statistic**	**Lag Length**	**Critical Value (5%)**	**Test Statistic**	**Critical Value (5%)**	**Test Statistic**	**Critical Value (5%)**	**Test Statistic**	**Critical Value (5%)**
Ln(GDP)	0.496	1	-1.95	-2.685**	-1.95	-1.076	-3.004	-2.861*	-3.011
Ln(K_0)	0.296	1	-1.95	-2.329**	-1.95	-1.078	-3.004	-2.741*	-3.011
Ln(K_{MI})	0.781	1	-1.95	-2.710**	-1.95	-2.105	-3.004	-3.851**	-3.011
Ln(U)	1.397	1	-1.95	-2.814**	-1.95	-1.995	-3.004	-5.565**	-3.011
Ln(L)	2.369	1	-1.95	-1.905*	-1.95	-1.043	-3.004	-3.547**	-3.011

*Note: **GDP**= Gross Domestic Product; K_{MI} = Mobile infrastructure investment; K_0 = gross capital formation; **L**= labour force; **U** = unemployment. Source: Researchers estimates from Research data, 2017. *Significant @10% level. **Significant @ 5% level*

From the results shown in Table 6 above, the order of integration of all the variables was order *I(1)*, at least at the 5% significance level in one of the tests. The ARDL bounds test for cointegration requires that variables are integrated of order *I(0)* or *I(1)* (Pesaran et al., 2001). As per the literature, the researcher could employ the ARDL bounds test, since both unit root tests converged on their results.

4.5 Test for Cointegration

The order of integration of the variables were all *I (1)*, therefore it followed that a bounds test using an ARDL model with the variables in the levels could be conducted. This test checked whether there existed a cointegration relationship between the variables. The lag length from the ADF test for unit roots was used. The output of the test is shown below:

Table 7: Bounds Cointegration Results

	Test	Bounds Test
Critical Value	**F-stat**	**1.34**
	5%	3.48
Upper Bounds *I (1)*	2.50%	3.9
	1%	4.44
	5%	2.26
Lower Bounds *I (0)*	2.50%	2.62
	1%	3.07

Source: Researchers estimates from Research data, 2017. Lag length = 1.

Since the F-statistic of the bounds test was less than the critical value at the 5% level, the researcher accepted the null hypothesis that there was no cointegration relationship between the variables and concluded that no long-run relationship existed. Frimpong & Oteng-Abayie

(2006) note that if the F-statistic is less than the lower bound then null hypothesis should be accepted; if the F-statistic is greater than the upper bound then the null hypothesis should be rejected and if the F-statistic is in between the upper and the lower bound then the test is inconclusive. The cointegration result was also confirmed because there was low correlation between the dependent variables, as observed in the correlation matrix in table 4 above.

4.6 Tests for Causality

Since the data did not show a long run relationship of cointegration, there was no need to run a vector error corrective model (VECM) model and a Granger causality test was run with the first differences of the natural logarithm of the variables. The causal relationship between the variables was tested:

Table 8: Causality Results

	Causality	F-statistic	p-value	Sig,			Causality	F-statistic	p-value	Sig.
1	$d1K_{MI}$ -> d1GDP	0.0306	0.8631			11	d1L -> $d1K_0$	3.6259	0.073	10%
2	$d1K_0$ -> d1GDP	0.004	0.9501			12	d1U -> $d1K_0$	0.9864	0.3338	
3	d1L -> d1GDP	3.4796	0.0785	10%		13	d1GDP -> d1L	0.0181	0.8946	
4	d1U -> d1GDP	0.3208	0.5781			14	$d1K_{MI}$ -> d1L	0.0789	0.782	
5	d1GDP -> $d1K_{MI}$	3.8839	0.0643	10%		15	$d1K_0$ -> d1L	0.0097	0.9227	
6	d1K0 -> $d1K_{MI}$	2.7562	0.1142			16	d1U -> d1L	0.1171	0.7361	
7	d1L -> $d1K_{MI}$	5.7661	0.0274	5%		17	d1GDP -> d1U	3.444	0.0799	10%
8	d1U -> $d1K_{MI}$	5.6811	0.0284	5%		18	$d1K_{MI}$ -> d1U	1.2275	0.2825	
9	d1GDP -> $d1K_0$	0.7546	0.3965			19	$d1K_0$ -> d1U	3.5692	0.0751	10%
10	$d1K_{MI}$ -> $d1K_0$	0.003	0.9573			20	d1L -> d1U	3.0203	0.0993	10%

*Note: **GDP**= Gross Domestic Product; **K_{MI}** = Mobile infrastructure investment; **K_0** = gross capital formation; **L**= labour force; **U** = unemployment. Source: Researchers estimates from Research data, 2017. Lag length = 1.*

The test showed that weak Granger causality existed between labour force and gross domestic product *(L -> GDP)*; gross domestic product and mobile infrastructure investment (*GDP -> K_{MI})*); labour force and gross capital formation (*L -> K_0*); gross domestic product and unemployment (*GDP -> U),* gross capital formation and unemployment (*K_0* -> U) and labour force and unemployment (*L -> U).* It also showed that there was a strong Granger causality between labour force and mobile infrastructure investment (*L -> K_{MI}*) and unemployment and mobile infrastructure investment (*U -> K_{MI}*).

In the United States of America (USA), Beil et al. (2005) found a similar relationship between GDP and telecommunications investment and noted there is a causal relationship between GDP and telecommunications investment but no causal relationship between telecommunications investment and GDP. From the results of Atsu et al. (2014) the causality test showed that telecommunications investment does Granger cause GDP but that GDP does not Granger cause telecommunications investment in Ghana. Oyeniran & Onikosi-Alliyu (2016) did not perform a Granger causality test but estimated the coefficients of the long run and short run models using the ARDL approach in Nigeria.

Although (Kaur & Malhotra, 2014; Shiu & Lam, 2008b) did not examine the causal relationship between telecommunications investment and GDP, they did examine the relationship between teledensity and economic growth. Shiu & Lam (2008b) found, that in China, a causal relationship between GDP and teledensity but no causal relationship between teledensity and GDP while Kaur & Malhotra (2014) found the opposite of these results in India i.e. a causal relationship between teledensity and GDP but no causal relationship between GDP and teledensity.

For the panel studies reviewed, Pradhan et al. (2014) found a bidirectional causality between telecommunications infrastructure and economic growth in G-20 countries. Lam & Shiu (2010) examined countries by region and income level and found unidirectional causal relationships between real GDP and teledensity in Africa, Americas, upper-middle income, lower-middle income and low-income countries. A unidirectional causality is found between teledensity and real GDP for Asia and Oceania and a bidirectional relationship is found between teledensity and GDP in Europe and high-income countries (Lam & Shiu, 2010). Using the whole data set showed no causality (Lam & Shiu, 2010).

In another panel study by David et al. (2014) with the top five countries per region, namely Europe, Asia and Pacific, Americas, Arab States, CIS and Africa finds no causal relationship between mobile telecommunications subscriptions and GDP as well as fixed-line telecommunications subscriptions and GDP.

Shiu & Lam (2008a) conducted a study across 105 countries to examine the causal effect of telecommunications development on economic growth. They find a bidirectional relationship between real GDP and teledensity in Europe and high income countries whereas the relationship was unidirectional (from real GDP to teledensity) for less developed countries (Shiu & Lam, 2008a).

From the literature, some of the papers examined above showed a bi-directional causality and some only unidirectional causality. Therefore, the results within the papers are contradictory with each other.

4.7 Regression Estimates

The coefficients of the short run model were estimated with a VAR (2) using AIC as the lag selection criteria and taking the first differences of the variables, since all the variables are *I(1)* and not cointegrated. The results of the regression are shown in table 9 below:

Table 9: Short Run VAR (2) Model for d1Ln(*GDP*)

Independent Variable: d1.Ln*(GDP)*				
Dependent Variable	***Coefficient***	***t Stat***	***P-value***	
Intercept	0.4310	3.22	0.012	**
Trend	-0.0133	-2.20	0.059	*
d1.Ln(*GDP*).l1	-1.0404	-1.28	0.236	
d1.Ln(K_{MI}).l1	0.0316	0.23	0.827	
d1.Ln(K_0).l1	0.8453	1.33	0.219	
d1.Ln(*L*).l1	-4.9457	-2.30	0.050	*
d1.Ln(*U*).l1	-0.2075	-0.33	0.751	
d1.Ln(*GDP*).l2	-0.8884	-1.08	0.311	
d1.Ln(K_{MI}).l2	-0.1510	-1.40	0.199	
d1.Ln(K_0).l2	0.0679	0.10	0.922	
d1.Ln(*L*).l2	-4.9642	-1.97	0.085	*
d1.Ln(*U*).l2	-1.0159	-1.76	0.117	
R^2	0.72			
Adjusted R^2	0.32			
F-Stat	1.8			

Note: ***GDP****= Gross Domestic Product;* $\boldsymbol{K_{MI}}$ *= Mobile infrastructure investment;* $\boldsymbol{K_0}$ *= gross capital formation;*
L*= labour force;* ***U*** *= unemployment. Source: Researchers estimates from Research data, 2017.*
**Significant @10% level*
***Significant @ 5% level*
Lag length = 1

From the short run model, it was found that the only significant variables were d1(*L*).l1, the first lag of the first difference of the natural logarithm of labour force, and d1(*L*).l2, the second lag of the first difference of the natural logarithm of labour force, both at the 10% level. The model was not a good fit with an adjusted R^2 of 0.32 and an F-stat which is not significant at even the 10% level. This could be due to the small sample size. The autocorrelation plot of each variable in appendix 3 showed no autocorrelation. Mobile communications infrastructure investment did show a positive relationship with gross domestic product for the first lag but a negative relationship for the second lag. The rest of the VAR models are shown in appendix 1.

4.8 Conclusion

The properties of the data were examined including summary statistics as well as tests for normality. This analysis did not show any abnormality with the data. Analysis of the development of mobile capital investment showed increases until 2011 after which there had been a decline until 2016. Variables were then transformed by taking the natural logarithm of the each of the observations in the dataset.

Results of the statistical analysis show that the variables were not cointegrated. On examining the Granger causality between economic growth and mobile telecommunications investment it was found that there was weak Granger causality from gross domestic product (*GDP)* to mobile infrastructure investment (K_{MI}) but no Granger causality from K_{MI} to GDP, consistent with the findings of Beil et al. (2005) for USA in the literature.

By fitting a VAR (2) model to the first difference of the variables, a bad model fit was detected. Coefficients for the first and second lags of mobile telecommunications investment and economic growth (GDP) were observed but this relationship was not significant. This result was in-line with the result of the Granger causality test which showed a 10% significance of the Granger causality between labour and GDP

Chapter 5
Conclusions and Recommendations

5.1 Introduction

In this final chapter, a summary and conclusions of the paper will be given. The summary will include the literature that was reviewed, the methodology employed and the results that were obtained. The conclusion will encompass the deductions that were drawn from the results that were obtained and how this relates to development. The second part of this chapter will deal with policy recommendations and the third part will conclude with some recommendations for future research.

5.2 Summary and Conclusions

This study aimed to show whether there was a relationship between mobile telecommunications investment and economic growth in South Africa (SA). The hypothesis that was tested aimed to show that the impact of mobile telecommunications on economic growth was a positive one.

From the review of literature, it was observed that significant investments had been made in mobile networks in SA (World Bank Group, 2017c). These investments might have partly contributed to the high mobile penetration rates in South Africa. Theoretically, mobile infrastructure is a subset of ICT infrastructure and can be linked to economic growth through various models of economic growth including the classical growth theory, Harrod-Domar theory, Solow-Swan model and endogenous models developed by (Fisher, 1969; Mankiw et al., 1992; Romer, 1990). By examining the literature on ICT and mobile as sources of economic growth, it is found that studies by (Colecchia & Schreyer, 2002; Jorgenson & Stiroh, 1999; Lee et al., 2005; Ng et al., 2013) find a link between ICT infrastructure and economic growth while studies by (Atsu et al., 2014; Madden & Savage, 1998; Oyeniran & Onikosi-Alliyu, 2016; Pradhan et al., 2014) find relationships between mobile infrastructure and economic growth.

A review on mobile for development (M4D) illustrates the many applications of mobile communications in enabling development. The cases reviewed were, agriculture, healthcare, mobile money, digital identity and smart cities. In agriculture, the provision of extension services happens over mobile technology. Cellular networks enable the delivery of healthcare services and information. Mobile money enables access to banking and financial services through cellular phones. The mapping of a rural population by giving a digital identity to individuals using their phone to link them to a unique identity is a possibility and mobile networks are the perfect medium to use to provide networking capabilities for smart cities. M4D does not come without it's criticism and Han (2012) argues that the high cost of internet access in South Africa could be limiting factor in realising development via mobile networks.

In order to address the research questions, the study employed secondary data that was gathered from the World Bank Group (2017c) and GSMA (2017a) databases for the period 1995 to 2016. Gross domestic product (*GDP*), mobile infrastructure investment (K_{MI}) were the independent and dependent variables respectively. Other dependent variables included control variables of gross capital formation (K_0), labour force (L) and the unemployment rate (U). The data of GDP, mobile capital expenditure and gross capital formation were both used at current prices. The researcher used the neoclassical growth theory as a model of economic growth and applied the autoregressive distributed lags (ARDL) approach as a statistical method. The study examined the descriptive statistics of the variables to explore the properties of the variables and the researcher found that all but one variable (L) was normally distributed.

The development of mobile infrastructure investment in South Africa was analysed through the trends of the data. This trend showed a slight decline until 2002 after which there was a sharp increase until 2011 and it has been in a decline since then to 2016. To apply the neoclassical growth model, the researcher transformed the data by taking the natural logarithm of the observations of each variable.

To use the ARDL approach, the data was tested for unit roots and to ensure that they were not integrated of order *I (2)*. The ARDL approach cannot be used if the data is integrated of order *I (2)* (Pesaran et al., 2001). It was found that all the variables were integrated of order *I (1)*. The research approach then tested for the existence of a cointegration relationship. From the results, no cointegration was found between the variables and therefore a long run relationship could not be modelled.

Granger causality was tested and found that a weak Granger causality existed between *GDP* to K_{MI} but there was no Granger causality between K_{MI} and *GDP*. This concludes that there was a relationship between economic growth and mobile communications infrastructure investments (MCII) but that economic growth Granger causes MCII and not the other way around. The short run coefficients were estimated using a VAR model with the first difference of the natural logarithm of the variables. This was done because the variables were integrated of order *I (1)* and no evidence of cointegration was found. No relationship between MCII and economic growth was found. The result concurred with the results of Granger causality test but also showed that the relationship between mobile telecommunications investment and economic growth is not a positive one.

In conclusion, the findings indicate that for the data used in this paper that there was no relationship from mobile telecommunications infrastructure to economic growth in South Africa.

5.3 Policy Recommendations

Due to there being no relationship from mobile infrastructure investment to economic growth, the researcher proposes that government focus on investigations into why there isn't a relationship between the two variables and then implement policies based on the findings of these investigations:

5.3.1 Government should investigate the reasons why mobile infrastructure investment has not lead to economic development. As argued by Han (2012) this could be due to the high cost of mobile internet access. If it is found that this is the reason why mobile infrastructure has not lead to economic growth then government should implement policies to reduce the cost of mobile internet access.

5.3.2 The pervasiveness and adoption of mobile technology solutions in each industry and the reasons for and against adoption of mobile technology solutions should be investigated.

5.3.3 Understanding the use of mobile technology by businesses and individuals would be of interest to the government to propose policies that will increase usage of mobile technology. For individuals, use should also be investigated between different population groups with probable classifications by income level, age, gender and race.

5.3.4 Investment in technological solutions that use mobile phones should be encouraged and prioritised by government.

5.4 Avenues for Future Research

Other researchers could replicate this study by adding more control variables to examine the impact of mobile telecommunications infrastructure on economic growth. Modifications to the study could also include looking at different measures of economic growth, for example gross domestic product per capita. Another modification could include measuring the impact of cumulative mobile telecommunications investment. For South Africa, further research could delve into analysing the impact of mobile telecommunications infrastructure on different industries. The results of this study could also lead to studies regarding the adoption of mobile technology solutions in South Africa as well as the uses of mobile phones to explain the result of this paper.

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Appendices

Appendix 1: Other Fitted VAR (2) Models

Table 10: VAR (2) Model for d1Ln(K_{MI})

Regression Outputs	**Value**
R^2	0.61
Adjusted R^2	0.08
F-Stat	1.1

Independent Variable: d1Ln(K_{MI})			
Dependent Variable	***Coefficient***	***t Stat***	***P-value***
Intercept	-0.1148	-0.36	0.728
Trend	-0.0045	-0.31	0.765
d1Ln(*GDP*).l1	-1.5009	-0.78	0.461
d1Ln(K_{MI}).l1	-0.0847	-0.25	0.807
d1Ln(K_0).l1	1.4589	0.96	0.363
d1Ln(*L*).l1	5.6175	1.10	0.305
d1Ln(*U*).l1	2.4576	1.63	0.141
d1Ln(*GDP*).l2	0.1268	0.07	0.95
d1Ln(K_{MI}).l2	-0.1056	-0.41	0.692
d1Ln(K_0).l2	0.2604	0.16	0.875
d1Ln(*L*).l2	4.2827	0.71	0.498
d1Ln(*U*).l2	0.9089	0.66	0.528

*Note: **GDP**= Gross Domestic Product; **K_{MI}** = Mobile infrastructure investment; **K_0** = gross capital formation; **L**= labour force; **U** = unemployment.*
**Significant @10% level*
***Significant @ 5% level*
Source: Researchers estimates from Research data, 2017

Table 11: VAR (2) Model for d1Ln(K_0)

Regression Outputs	Value
R2	0.82
Adjusted R2	0.57
F-Stat	3.3

Independent Variable: d1Ln(K_0)				
Dependent Variable	***Coefficient***	***t Stat***	***P-value***	
Intercept	0.4851	3.96	0.004	**
Trend	-0.0170	-3.07	0.015	
d1Ln(*GDP*).l1	-0.6576	-0.88	0.403	
d1Ln(K_{MI}).l1	0.0261	0.20	0.844	
d1Ln(K_0).l1	0.7082	1.22	0.258	
d1Ln(*L*).l1	-4.1880	-2.13	0.066	*
d1Ln(*U*).l1	-0.5592	-0.97	0.362	
d1Ln(*GDP*).l2	-0.8897	-1.18	0.271	
d1Ln(K_{MI}).l2	-0.2520	-2.55	0.034	**
d1Ln(K_0).l2	-0.0662	-0.11	0.917	
d1Ln(*L*).l2	-5.1284	-2.21	0.058	*
d1Ln(*U*).l2	-1.3092	-2.47	0.039	**

*Note: **GDP**= Gross Domestic Product; K_{MI} = Mobile infrastructure investment; K_0 = gross capital formation; **L**= labour force; **U** = unemployment.*
**Significant @10% level*
***Significant @ 5% level*
Source: Researchers estimates from Research data, 2017

Table 12: VAR (2) Model for d1Ln(L)

Regression Outputs	Value
R2	0.48
Adjusted R2	-0.23
F-Stat	0.7

Independent Variable: d1Ln(L)			
Dependent Variable	***Coefficient***	***t Stat***	***P-value***
Intercept	-0.0124	-0.507	0.626
Trend	0.0009	0.854	0.418
d1Ln(GDP).l1	0.1335	0.896	0.396
d1Ln(K_{MI}).l1	0.0220	0.855	0.417
d1Ln(K_0).l1	-0.1276	-1.097	0.305
d1Ln(L).l1	0.3337	0.847	0.421
d1Ln(U).l1	0.0345	0.298	0.773
d1Ln(GDP).l2	0.1484	0.985	0.354
d1Ln(K_{MI}).l2	0.0028	0.140	0.892
d1Ln(K_0).l2	-0.0200	-0.163	0.875
d1Ln(L).l2	0.2020	0.436	0.675
d1Ln(U).l2	0.0395	0.373	0.719

Note: ***GDP****= Gross Domestic Product;* K_{MI} *= Mobile infrastructure investment;* K_0 *= gross capital formation;* ***L****= labour force;* ***U*** *= unemployment.*
**Significant @10% level*
***Significant @ 5% level*
Source: Researchers estimates from Research data, 2017

Table 13: VAR (2) Model for d1Ln(*U*)

Regression Outputs	**Value**
R2	0.75
Adjusted R2	0.41
F-Stat	2.2

Independent Variable: d1Ln(*U*)

Dependent Variable	***Coefficient***	***t Stat***	***P-value***	
Intercept	0.0123	0.319	0.758	
Trend	0.0003	0.173	0.867	
d1Ln(*GDP*).l1	-0.2211	-0.943	0.373	
d1Ln(K_{MI}).l1	0.0462	1.139	0.288	
d1Ln(K_0).l1	0.0101	0.055	0.957	*
d1Ln(*L*).l1	-0.2556	-0.412	0.691	
d1Ln(*U*).l1	0.4041	2.220	0.057	
d1Ln(*GDP*).l2	-0.0308	-0.130	0.900	
d1Ln(K_{MI}).l2	-0.0286	-0.919	0.385	
d1Ln(K_0).l2	0.0767	0.395	0.703	
d1Ln(*L*).l2	-0.4227	-0.579	0.579	
d1Ln(*U*).l2	0.1195	0.717	0.494	

*Note: **GDP**= Gross Domestic Product; K_{MI} = Mobile infrastructure investment; K_0 = gross capital formation; **L**= labour force; **U** = unemployment.*
**Significant @10% level*
***Significant @ 5% level*
Source: Researchers estimates from Research data, 2017

Appendix 2: Covariance and Correlation Matrix of the Residuals of VAR (2) Model

Table 14: Covariance Matrix of the Residuals of the VAR (2) Model

Variable	*ln(GDP)*	*ln(KMI)*	*ln(K0)*	*ln(L)*	*ln(U)*
ln(GDP)	0.013	0.006	0.010	-0.002	0.001
ln(KMI)	0.006	0.075	0.006	-0.001	-0.003
ln(K0)	0.010	0.006	0.011	-0.001	0.000
ln(L)	-0.002	-0.001	-0.001	0.000	0.000
ln(U)	0.001	-0.003	0.000	0.000	0.001

*Note: **GDP**= Gross Domestic Product; K_{MI} = Mobile infrastructure investment; K_0 = gross capital formation; **L**= labour force; **U** = unemployment. Source: Researchers estimates from Research data, 2017*

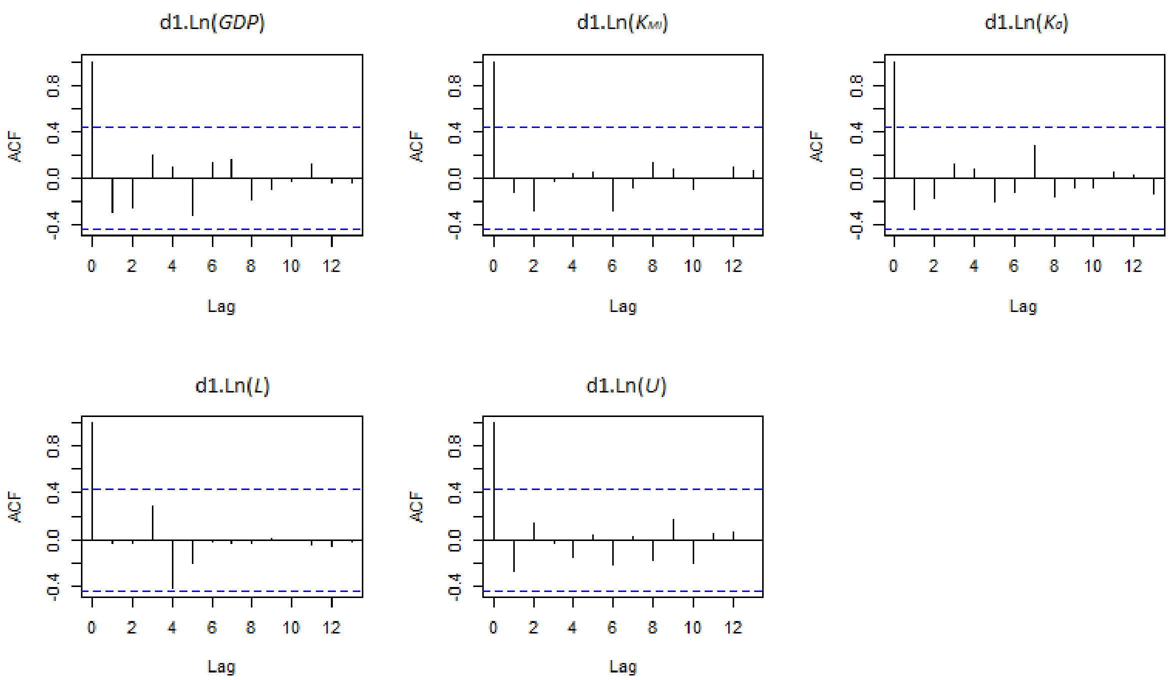
Table 15: Correlation Matrix of the Residuals of the VAR (2) Model

Variable	*ln(GDP)*	*ln(KMI)*	*ln(K0)*	*ln(L)*	*ln(U)*
ln(GDP)	1.000				
ln(KMI)	0.180	1.000			
ln(K0)	0.861	0.196	1.000		
ln(L)	-0.674	-0.240	-0.401	1.000	
ln(U)	0.175	-0.323	-0.078	-0.336	1.000

*Note: **GDP**= Gross Domestic Product; $\boldsymbol{K_{MI}}$ = Mobile infrastructure investment; $\boldsymbol{K_0}$ = gross capital formation; **L**= labour force; **U** = unemployment. Source: Researchers estimates from Research data, 2017*

Appendix 3: Autocorrelation Plots

Figure 4: Autocorrelation Plots for VAR (2) Model



Source: Researchers estimates from Research data, 2017