# The Role of the Common Innovation Infrastructure in Economic Transition.

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## Abstract

Knowledge, innovation, and the pursuit of economic growth are concepts that the economists and policy makers around the world continue to investigate. As policy makers strive to improve the welfare of their nations, research suggests that perhaps innovation is the key that will unlock the gates of prosperity.

Frameworks have been developed on how countries should build innovation capacity such as the study done by Furman, Porter and Stern (2002). These frameworks have been used to test developed nations such as Australia, Denmark and the United States as well as developing nations such as Taiwan and South Korea. Their findings suggest that certain strategies were more effective at fostering innovation in developed countries than in developing countries, highlighting that the effects of policy innovation are not homogeneous.

This report investigated the innovation strategies that countries use to encourage innovation in order to induce economic transition. The findings suggest that there is an existence of the common innovation infrastructure in countries that are transitioning from efficiency-driven to innovation-driven development. These countries are using the common innovation infrastructure to encourage innovation. However, some countries are more effective at encouraging innovation than others. Measures that work for one country may not necessarily work for others.

***Keywords***

Encouraging Innovation, endogenous growth, common innovation infrastructure.

Gordon Institute of Business Science
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## Declaration

I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research.

Mpho B. Mutsila

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## List of Abbreviations

| | |
|---|---|
| GCR | Global Competitiveness Report |
| GDP | Gross Domestic Product |
| IP | Intellectual Property |
| NIC | National Innovation Capacity |
| OECD | Organisation for Economic Co-operation and Development |
| R&D | Research and Development |
| WEF | World Economic Forum |

# 1. Chapter One

## 1.1 Introduction

High levels of unemployment and deteriorating social conditions are a major concern of policy makers around the world (Schwab, 2012). This is evident from the increase in social protests that have plagued many countries since the advent of the Arab Spring in 2011. Most recently, devastating protests have occurred in South Africa, Marikana in 2012, and Brazil, 2013. Citizens around the world are distressed about the political, working and economic conditions in their countries. The result of society's frustrations is the riots that often destabilise the economies of the countries concerned. Policy makers have the challenge of taking strategic decisions in order to stabilise economic growth and adopt sustainable policies that will ensure the welfare of their citizens (Schwab, 2012). The improved welfare must be a consequence of job creation; increased per capita income; access to education and knowledge, in order for it to be sustainable.

## 1.2 Research Problem

Since the advent of the Great Recession of 2007, many economies have been faced with no or low economic growth (IMF, 2013). For some countries, the causes of these low growth rates are cyclical and are expected to increase when the vibrancy of the global economy returns (IMF, 2013). However for the less fortunate economies, the causes of declined growth rates are structural in nature.

In economics, structural problems refer to changes that are permanent or long-term and that cannot be off-set by global trends (Eberhardt & Teal, 2012). In other words, when global economic growth increases, the individual growth rates of these economies may not follow a similar trend. Symptoms of structural problems are persistent high unemployment rates and low output rates (Easterly, 2002).

Short-term monetary and fiscal policy measures are not sufficient to address the systemic nature of structural problems (IMF, 2013). These policy measures are ideally suited to cyclical problems that an economy may experience. In order to address low growth due to structural factors, perhaps an endogenous approach to growth is most ideal. According to economic growth theory, a country's economic growth may occur from exogenous or endogenous factors. The former is growth that is caused by external factors (Colander, 2012). The latter (endogenous growth) is economic growth that results from stimulus that is derived from agents within a country's economy, i.e. economic policy (Colander, 2012).

The endogenous growth theory, postulates that in order to stimulate economic growth, economies should implement policy measures that will enhance human capital, technological progress, and an increase in the knowledge base (Rizavi, Khan & Mustafa, 2010). These three factors are the source of long-term economic growth and thus economic development (Rizavi, Rizvi & Naqvi, 2011). Asian economies, such as Singapore, South Korea and Taiwan, have successfully adopted the principles of endogenous growth, the result of which has been improved growth, development and national competitiveness (Hu & Mathews, 2005).

Over the past decade, large emerging economies such as Brazil, Russia, India, China and South Africa have experienced high growth rates and have attracted global businesses and investors (Schwab, 2012). However, the BRICS have experienced declining growth since 2011 (Schwab, 2012). “The BRICs were last decade’s team” and investors are now searching for other emerging economies as sources of growth (Forbes, 2012, p.1).

Countries such as Chile, Estonia, Croatia and Argentina have leap-frogged their counterparts and could potentially become the new sources of growth (Economist, 2013a). These countries are changing structurally in an attempt to not only achieve sustainable growth, but also development and national competitiveness (Schwab, 2013).

The World Economic Forum, through the Global Competitiveness Report, encourages countries to increase national competitiveness by means of innovation in order to achieve sustained economic transformation (Schwab, 2013). Furman, Porter and Stern (2002) developed a framework on how countries can build national innovation capacity. Through their framework they establish the conditions that are necessary to foster innovation. However the framework does not account for the different development stages that characterise the global economy (Hu & Mathews, 2005). A similar study was replicated on East Asian countries and some of the findings differed from those of the previous study. Hu & Mathews (2005) found that certain strategies were more effective at fostering innovation in developing countries than in East Asian countries. This suggests that strategies used by the United States may not necessarily work for Nigeria. There is therefore no context specific framework on the strategies that countries could use in order to transition to the next level of development.

This report investigates the innovation strategies that countries use in order to encourage innovation and influence economic transition. The aim is to develop context appropriate policies that developing countries can use to encourage innovation.

## 1.3 Motivation

Economic growth has been a subject of interest for centuries. Many have proposed various drivers of growth and theorised how this growth can be achieved. It is of great interest, the reason why some countries have over the past few decades managed to transform themselves, i.e. economic miracles, and why others are still lagging far behind (Easterly, 2002). From a macroeconomic perspective, there must be strategies to sustained economic growth that can be applied by countries attempting to alter national prosperity.

Innovation, as a driver of economic transition, has recently become an area of focus (Swann, 2009). This is particularly due to the effects of globalisation and the availability information on global competitiveness. Companies, and by extension countries, need newer ways and more efficient ways to compete. A country's products, services and processes must be attractive enough to the rest of the world in order to stimulate demand and consequently growth (Aghion & Howitt, 2005). This requires constant innovation. Perhaps this maybe how the world's economic powerhouses have achieved their status.

The advances in science and technology and the wide availability of information as a result of the internet have helped bridge the gap between the rich and the poor (Economist, 2013b). Investing in innovative practices has improved the welfare of many countries, such as Estonia (Economist, 2013b). Literature suggests several drivers of a country's innovation capacity (Swann, 2009; Hu & Mathews, 2005; Furman et al, 2002). The questions that arise are how effective have these suggested drivers been for countries that are said to be improving their innovativeness. Insight on how countries are encouraging innovation can provide pearls of wisdom for countries that are seeking to improve the welfare of their citizens.

## 1.4 Context

Annually, the WEF publishes a report that ranks countries according to national competitiveness. The report is called the Global Competitiveness Report and it evaluates the competitiveness and consequently, the economic development of 144 economies. The aim of the report is to identify the drivers of prosperity and productivity for each nation. According to Schwab (2012), economic productivity and prosperity are driven by resources, efficiency or innovation.

The rationale of improving national innovation capacity in order to achieve economic growth is most relevant for efficiency-driven economies for which the next stage of development is innovation-driven (Schwab, 2012). Building innovation capacity has the potential of creating new industries, businesses and jobs (World Bank, 2010).

An efficiency-driven economy is one that has created efficient production processes and superior products through the use of existing technologies, amongst other things (Schwab, 2012). In order to advance further, the natural next step for these economies would be to compete on the basis of new and unique products and services, i.e. innovation-driven (Schwab, 2012). However, what is of interest is how this transition from efficiency to innovation-driven occurs. The GCR classifies countries that are in-between the efficiency and innovation stages as “transition from stage 2 to stage 3”. These countries are of interest because they are in the process of transformation. Similar to solving a mathematical problem, observing the process makes it easier to identify mistakes and effective solutions on how the transition occurred.  Like magic tricks, when only the beginning and the end is seen, it is hard to comprehend how the change transpired.

## 1.5 Scope

Historically economic development was known to be driven primarily by several factors, i.e. savings, investment in physical capital, size of labour force, quality of human capital, institutions, technological progress and demand (both domestic and foreign) (Colander, 2010). However, modern sources of growth are believed to result primarily from technological progress. In a report by Deloitte about global business trends in 2013 and beyond, innovation was cited as one of five important factors that is driving emerging market growth (Roa, Kalish & McLain, 2013). This view is derived from the work of economist, Robert Solow, who argued that long run economic growth is only achievable through technological progress (Easterly, 2002).

It holds then that if technological progress, and by extension innovation, is a source of higher economic growth rates, then developing economies can use borrowed technology from advanced economies in order to stimulate growth (Hayami & Godo, 2005). Rather than investing only in physical capital, developing countries should invest in education, research and development, entrepreneurship and other factors that would increase the capacity to innovate (Hayami & Godo, 2005).

Multinational companies from developed and emerging markets are seeking new growth miracles in which to invest and those that encourage innovation are an enticing option (Roa, Kalish & McLain, 2013).

Economic development and technological progress are broad subjects and this study will not attempt to cover these topics. The scope of this study will therefore focus on the role of innovation in economic transition.

## 1.6 Research Objectives

The purpose of this research is to investigate the innovation strategies used by efficiency-driven economies that are transitioning to innovation driven economies. A better understanding of these strategies will provide policy makers and economic advisors with improved insight into which innovation strategies are best suited for their economies. The objectives of this study are to firstly to determine if the endogenous growth function is applicable to the sample. The second objective is to establish which innovation strategies are most effective for the sample. The strategies will be assessed based on the Common Innovation Infrastructure developed by Furman et al (2002). The Common Innovation infrastructure is discussed at length in Chapter Two.

## 1.7 Report Structure

This report is structured in the following manner. Chapter Two is the literature review which aims to establish a theoretical framework for the research objectives. Chapter Three is a presentation of the research hypothesis which forms the basis of the statistical tests. Chapter Four is a detailed account of the methodology used to conduct the research. Chapter Five presents the results of the hypothesis tests that were conducted and Chapter Six is an analysis of those findings in comparison with the literature. Chapter Seven provides a brief synopsis of the findings and recommendations.

# 2. Chapter Two

## 2.1 Introduction

One of the driving forces behind national competitiveness is economic growth (Buera & Kaboski, 2012). Generally, economic growth is defined as the increase in the amount of goods and services a country produces from existing resources and production processes (Colander, 2010). In order to build a framework for improving competitiveness through economic growth, it is necessary to examine some of the conditions that enable growth. This literature review looks at how economic growth can be stimulated by innovation. In order to do so, the literature review assesses why growth rates differ across countries by chronicling the evolution of economic growth theories. The review then provides a link between economic growth and innovation through the theory of endogenous growth. Endogenous growth theory is an appropriate model to explain the sources of modern economic growth and innovation is at the heart of this theory (Hayami & Godo, 2005). The conceptual framework of National Innovation Capacity is then examined in order to identify the drivers of innovation. The literature review pays particular attention to the common innovation infrastructure and how its components relate to each other in order to encourage innovation. The aim of this study is to evaluate the innovation eco-systems of countries that are transitioning from efficiency-driven development to innovation-driven development. With this in mind, the literature review will substantiate the potential impact that policy has on innovation capacity and ultimately, economic growth.

## 2.2 Why Growth Rates Differ

Recent studies on the divergent economic growth rates of countries around the world have identified technological change or technological sophistication as the primary cause (Whitfield, 2012; Garicano & Rossi-Hansberg, 2012; Castellacci, 2004). The belief is that knowledge and the accumulation of technology are instrumental in reducing the gap between rich and poor countries (Whitfield, 2012). A look at how the theories on economic growth have evolved, provides insight into the thinking behind modern economic growth.

### 2.2.1 The evolution of economic growth theory

The pursuit of a higher economic growth path has been and still is the goal for policy makers around the world (Cavusoglu & Tebaldi, 2006). The reason is that economic growth "is not just about growth of aggregate output" (Kuznets, citied in Acemoglu, 2012, p. 546). Rather, as Acemoglu (2012) points out, it is about how an economy can potentially transform the structure of its sectors, demographics, society and institutions.

Eberhardt and Teal (2012), also highlight that the importance of economic growth is the impact it has on the process of structural change. When new industries emerge as countries shift from agricultural to industrial to service sectors, it is said that structural change has occurred (Hayami & Godo, 2005). Economic growth thus creates an opportunity for economic development.

Whitfield (2012) defines sustainable economic development, as a process in which an economy experiences structural changes in its production patterns and an improvement in living standards. Economic development is an important area in economic literature because the process of development not only distinguishes rich countries from poor ones but also has a bearing on the country's living standards (Whitfield, 2012; Cavusoglu & Tebaldi, 2006).

The disparity that currently exists between rich and poor countries seems to be increasing in most regions (Acemoglu, 2012). At the same time, income inequality within countries such as Japan, South Korea and China has dramatically reduced over the years (Acemoglu, 2012). The GDP per capita, used to measure economic growth, for these countries has dramatically increased over the years, creating more dollar millionaires than ever before (Sharma, 2012). The question that arises is how these countries transformed their economies and achieved what eludes the majority of countries around the world. The clues to this question may be found in the evolution of economic growth theory.

### 2.2.2 Classical Growth Theory

Classical economic growth theory was popularised by the work of economists such Adam Smith, David Ricardo and Robert Malthus (Jones, 1998). They found that economic growth and development was the result of the utilisation of land, labour and the accumulation of capital (Cavusoglu & Tebaldi, 2006). Adam Smith believed that economic growth, and therefore the wealth of nations, was driven by the division and specialisation of the labour-force. The more advanced in skills a country is, the more sophisticated the inventions from that country would be. Therefore countries that invest in education and training are more likely to have a superior work-force which ultimately improves the wealth of the nation.

David Ricardo viewed comparative advantage as a source of economic growth. The theory of comparative advantage forms the basis of the reasons and benefits of international trade (Deardorff, 2005). The theory of comparative advantage states that countries should specialise in producing products for which they have the lowest opportunity cost relative to a trade partner. The idea behind this theory is that countries must invest in industries in which they have comparative advantage created by the current or available factors of production (Bombardini, Kurz, & Morrow, 2012). In the Ricardian model, patterns of specialisation and competitiveness are determined by differences in a country's productivity (Bombardini et al, 2012). Many (Naughton, 2007; Prasad & Rajan, 2006; Zheng, Bigsten & Hu, 2009) argue that this is how China achieved its amazing economic growth. China was, and to some extent still is, endowed with cheap labour. As a result they invested in industries that could utilise their relatively cheap resources (Prasad & Rajan, 2006). China is now regarded as the manufacturing capital of the world. They made optimal use of their comparative advantage.

The major criticism of the classical economists' view on economic growth and development is that it disregards the significance of technology and technological progress (Cavusoglu & Tebaldi, 2006). Technological progress entails the increased rate of technological change that an economy experiences (Colander, 2010). It results in the improvement of technologies and the creation of new goods, which in turn increases productivity (Kruger, 2008). Productivity is improved because existing products are produced at a lower cost. The creation of new products as a result of technological progress leads to higher product quality which improves the welfare of society (Kruger, 2008).

### 2.2.3 Neoclassical Growth Theory

In order to address the inadequacies of the classical growth theory, Robert Solow developed a model that would explain the variables necessary for economic growth (Cavusoglu & Tebaldi, 2006). In the Solow Model, it is assumed that there is "perfect competition, homogeneous product, homogeneous capital, constant returns to scale, perfect substitutability between capital and labour, and diminishing marginal productivity of labour and capital" (Cavusoglu & Tebaldi, 2006, p. 53). Neoclassical economists believed that long run economic growth was driven by productivity, capital accumulation and technological progress (Cavusoglu & Tebaldi, 2006).

The superiority of the Solow growth model over the classical growth theory is the inclusion of technology as a determinant of growth. In his model, Solow (2010) sought to explain the reason why the invention of the steam train and the industrial revolution catapulted the western countries into higher economic growth and development. He felt that the classical growth models failed to capture the importance of technological change because economists like Ricardo and Mill "had a limited technical apparatus at their disposal" (Solow, 2010, p. 1115). Consequently they did not know how to account for technological change.

To an economist, for technology and technological change to be relevant, it needs to have an impact on the factors of production as well as aggregate output (Solow, 2010). It is for these two reasons that neoclassical economists, such as Solow, felt it necessary to account for technology and technological progress in growth models.

However, the Solow model treats technological progress as an external factor and does not explain how technological progress occurs (Cavusoglu & Tebaldi, 2006). Jones (1998) describes the treatment of technology in Solow's model as "manna from heaven, in that it descends on the economy automatically" (p. 34). To address this shortcoming, several economists (Romer, Lucas, Rabello, and others) introduced the endogenous growth model which sought to explain technological progress (Cavusoglu & Tebaldi, 2006).

### 2.2.4 Endogenous Growth Theory

The endogenous theory of economic growth postulates that economic growth is stimulated by the investment in human capital, innovation and knowledge (Madsen, Saxena & Ang, 2010). It was first introduced in the 1960s as an augmented version of the Solow model (Cavusoglu & Tebaldi, 2006). In this newer model, economists Arrow and Sheshinski tried to endogenise technological progress through the concept of learning by doing (Cavusoglu & Tebaldi, 2006). However, this model failed to yield any significant results. During the 1980s, Romer realised that simply augmenting the Solow model was inadequate. He relaxed two significant assumptions of the Solow Model. The Solow Model assumed that in an economy, there existed perfect competition and constant returns to scale. Romer realised that for an endogenised growth model, competition had to be imperfect and there had to be increasing returns to scale, in order to incentivise the generation of new ideas (innovation) (Cavusoglu & Tebaldi, 2006).

In the first generation model of endogenous growth, Romer contended that the generation and use of ideas was not competitive (Jones, 1998). To illustrate this, Jones (1998) argues that both Toyota and GM are able to take advantage of the just-in-time technique. This is because once an idea exists; it is available for simultaneous use by all who have knowledge of that idea (Jones, 1998). Perfect competition only exists for the skills necessary to implement those ideas (Jones, 1998).

The purpose of the endogenous growth theory was to understand the factors that contribute to the technological progress that was proposed in the Solow Model (Jones, 1998). The importance of understanding these drivers is that it empowers decision makers to engage in activities that stimulate economic growth. In other words, the concept of endogenous growth provides the possibility for countries to transform the productivity levels of the economy through technological change. The fundamental difference between the neoclassical growth theory and the endogenous growth theory is the process of technological change. The former believed that technological change was "manna from heaven" while the latter believed that technological change was an instrument of policy.

## 2.3 The heart of endogenous economic growth: Technological Change

The review of the growth theories above, illustrates the view that productivity, through technological progress, is a source of growth although it may have been articulated in different ways. This is the first clue to the conundrum of how middle-income countries have successfully transitioned to high-income countries. Whitfield (2012) attributes the transition to the "upgrading of an economy's productivity" (p. 242).

According to Whitfield (2012), upgrading entails improving the efficiency of existing factors of production through the innovation of new products and the production of higher value-added products (i.e. technological progress). In the 2012-2013 Global Competitiveness Report technological progress is identified as the historical source of productivity gains for most developed economies (Schwab, 2012). This view is supported by several authors who refer to technological progress as an engine of growth (Acemoglu, Gancia, & Zilibotti, 2012 & Schwab, 2012). Technological progress not only challenges the status quo, but it also creates new possibilities with regards to products, services and industries (Schwab, 2012).

Technological progress increases an economy's capacity to create value (Whitfield, 2012). A perfect example is the industrial revolution. The industrial revolution began in the 18th century in Britain and was the most significant form of technological progress. It created productivity gains for Britain, Western Europe and the United States by mechanising manufacturing. The industrial revolution also created new industries within manufacturing that spread throughout the world (Ray, 2007). As a result, the Western world gained global dominance because it invested in the capacity to create value (Reinert, 2007).

Countries interested in engaging in technological progress through innovation need to create an enabling environment. According to the GCR the creation of this environment requires a partnership between the private and public sectors (Schwab, 2012). This partnership must result in the investment in R&D; the creation of high-quality scientific institutions; the protection of intellectual property; entrepreneurs and access to venture capital and financing (Schwab, 2012).

## 2.4 Economic Innovation: The driving force of Technological Change

Economic innovation is “the successful exploitation of new ideas” (Swann, 2009, p. 25). The process of innovation involves research and creativity, invention, design and development and the commercialisation of the inventions (Swann, 2009). Innovation drives growth through technological progress and should thus be given special attention by policy makers.

There are different types of innovations that can be categorised as either radical or incremental. An important question is which type of innovation would significantly change the growth path of large emerging market countries that have the required capacity. It is proposed that these countries need to experience productivity explosions that will cause shifts in the techno-economic paradigms that currently exist (Whitfield, 2012). These productivity explosions can be created through disruptive innovation.

The concept of disruptive innovation was first popularised by Clayton Christensen as a strategy of creating and sustaining successful growth (Christensen & Raynor, 2003). It has the potential of disrupting existing markets through the expansion and the development of new markets and providing new functionality of existing products and services (Yu & Hang, 2010). Yu & Hang (2010) describe disruptive technologies as “technologies that provide different values from mainstream technologies and are initially inferior to mainstream technologies along the dimensions of performance that are most important to mainstream customers” (p. 436). Stated differently, disruptive technologies find new uses in neglected market segments and adjust the technology to suit the needs on those segments. In the early stages of use, these disruptive technologies appeals only to the lower-end of the market. Gradually through incremental improvements, these technologies begin appealing to other market segments and therefore create new industries. Disruptive innovations provide developing countries with opportunities to create disruptive technologies that will address problems unique to emerging markets.

It is proposed by Lundvall, Joseph, Chaminade and Vang (2009) that developing countries should create inclusive innovation systems that are built to address their specific needs. These systems must have the capacity to develop disruptive technologies for them to be sustainable. However, Lundvall et al (2009) found that creating these innovation systems has historically been challenging for most developing countries because of lack of capacity to improve on existing technologies.

Brazil, Chile, China, India, and South Korea are some of the developing countries that have successfully managed to create innovation systems that have contributed to their economic development (Lundvall et al, 2009). The innovation systems in China and India have over the years improved their competitiveness through "new to the world innovations and knowledge-based assets which are difficult to copy" (Lundvall et al, 2009, p. 35).

### 2.5 National Innovation Capacity: Building an Innovation Eco-system

An innovation eco-system can be described as an environment that comprises of private and public sector agents that interact in various mechanisms to gather technical, commercial and financial inputs necessary for innovation (World Bank, 2010). Furman et al (2002), define an innovation eco-system as one that enables a country to produce and commercialise new-to-the-world technologies over the long run. More recently, Hu and Mathews (2005) further added that an innovation eco-system is one that facilitates the accelerated transmission of technologies from technologically advanced countries to less advanced countries.

Throughout this literature review, innovation has been identified as an important ingredient of economic growth and development. It improves productivity, competitiveness and the general welfare of nations. However in order for the seeds of innovation to bear fruit, the conditions in the economy, governance, education and infrastructure must be conducive (Furman et al, 2002, & World Bank, 2010). By definition, an ecosystem is a community of agents that work together within the system to bring about some desired outcome. According to the World Bank (2010), for effectiveness, an innovation eco-system requires inputs from the private and public sector. The result of this interaction between private sector and public sector should be the creation of innovation endowments such as technology centres, science parks, export zones and new cities (World Bank, 2010). These innovation endowments improve the welfare of society.

Innovation is said to be primarily the activity of the private sector and entrepreneurs but government has a significant role as well (World Bank 2010). Governments can play both a direct and indirect role. Historically, governments in developed countries have supported and invested in programs and projects that are geared towards infrastructure and technology improvements (World Bank, 2010). Countries like the United States have programs that are geared towards the development of technology for space, defence and transportation purposes (World Bank, 2010). Governments also have an indirect impact on the rate of a country's technological advancement through incentives and laws (World Bank, 2010). Furman et al (2002) define government's role as one that creates a common innovation infrastructure. In their study on national innovation capacity, Furman et al elaborate that a common innovation infrastructure is one where there is R&D tax incentives; policies aimed at promoting science and technology; the support of research and higher education; as well as a cumulative stock of technological knowledge. To be impactful, the role of government should therefore depend on the needs and capabilities specific to the country (World Bank, 2010).

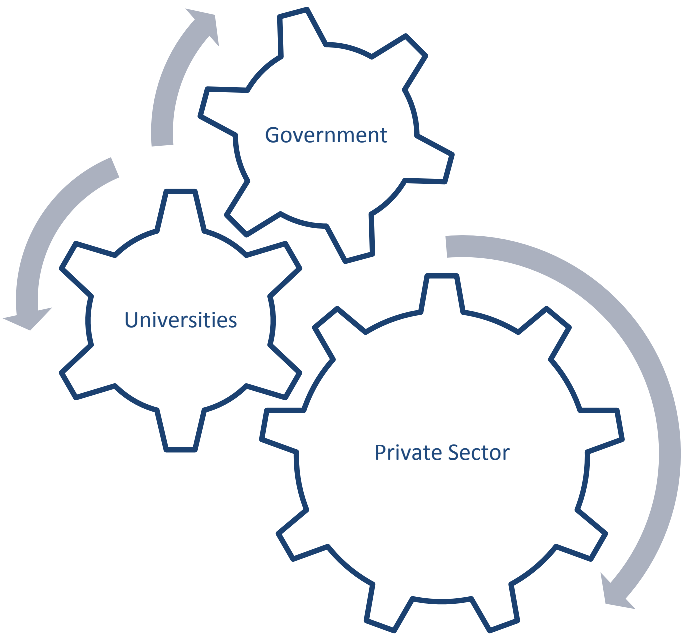


**Figure 1: Role players of an Innovation System**

As mentioned above, entrepreneurs and the private sector are significant role players in the innovation eco-system. The role of the entrepreneur is to exploit existing knowledge and technology to create new products and services which satisfy local demand (World Bank, 2010). These entrepreneurs operate within an environment that is known as the private sector. According to Furman et al (2002), the capacity of an innovation system will depend on the industries in which these entrepreneurs compete. In their study, Furman et al (2002) used the framework developed by Porter to demonstrate the drivers of an innovation eco-system.

- Innovation Inputs: These are human capital; research institutions such as universities; high quality information infrastructure; and venture capital.
- Local Context & Competition: Firms invest in innovation related activities based on the context of the environment in which they operate. Competition also encourages firms to invest in innovations that will create a competitive advantage.
- Local Demand: The existence of consumers with sophisticated demands for advanced products and services.
- Related and supporting industries: These are local suppliers and related companies that form part of an industry's value chain.

Based on Porter's framework, Furman et al (2002) developed a model that would empirically test the existence and capacity of a country's innovation system. This model was used to test the national innovation capacity of 17 OECD countries. Hu and Mathews later replicated the study to test national innovation capacity of 5 East Asian countries. A country's national innovative capacity is the ability for a nation's institutions to sustain innovation (Hu & Mathews, 2005). It entails looking at sources within a country that contribute to sustainable innovation (Hu & Mathews, 2005). The Furman et al framework was developed on three theories. The first is on endogenous growth and knowledge stock; the second is on how the interaction between firms, universities and public R&D institutions creates a national innovation system; and thirdly is Porter's ideas on national competitiveness. The National innovation capacity model tested the countries in three areas: common innovation infrastructure; the cluster-specific innovation environment; and the linkages between innovative infrastructure and cluster-specific innovation. The common innovation infrastructure refers to a country's "common pool of institutions, resource commitments, and policies that support innovation across the economy" (Furman et al, 2002, p. 905). A country's cluster specific innovation environment refers to the microeconomic environment in which firms and entrepreneurs commercialise innovations. When a country has an effective cluster environment, it magnifies the potency of the common innovation infrastructure through the linkages of quality institutions like universities, trade associations and networks (Furman et al, 2002).

The first finding from the study on the OECD countries was that the levels of inputs dedicated to innovation caused differences in national innovation capacity. Secondly, public sector policy plays a significant role in the differences in R&D productivity across countries. The third finding was that a national innovation system has an influence on the market share gained from the commercialisation of technology, i.e. national competitiveness. The results from the study conducted by Hu and Mathews (2005) "were in broad agreement with the findings" of the Furman et al (2002) study.

Given the findings of the two studies and the importance of innovation to economic growth, a closer look at how factors in the macroeconomic environment facilitate innovation is necessary.

## 2.6 The Common Innovation Capacity

The common innovation infrastructure is the soil in which the seeds of innovation are sown. It is in the interest of policy decision makers to cultivate a fertile environment in which firms and entrepreneurs can operate. It provides the macroeconomic environment for innovation. It can be divided into three categories: cumulative technological sophistication (knowledge stock); human capital and financial resources available for R&D; and resource commitments and policy choices made by government.

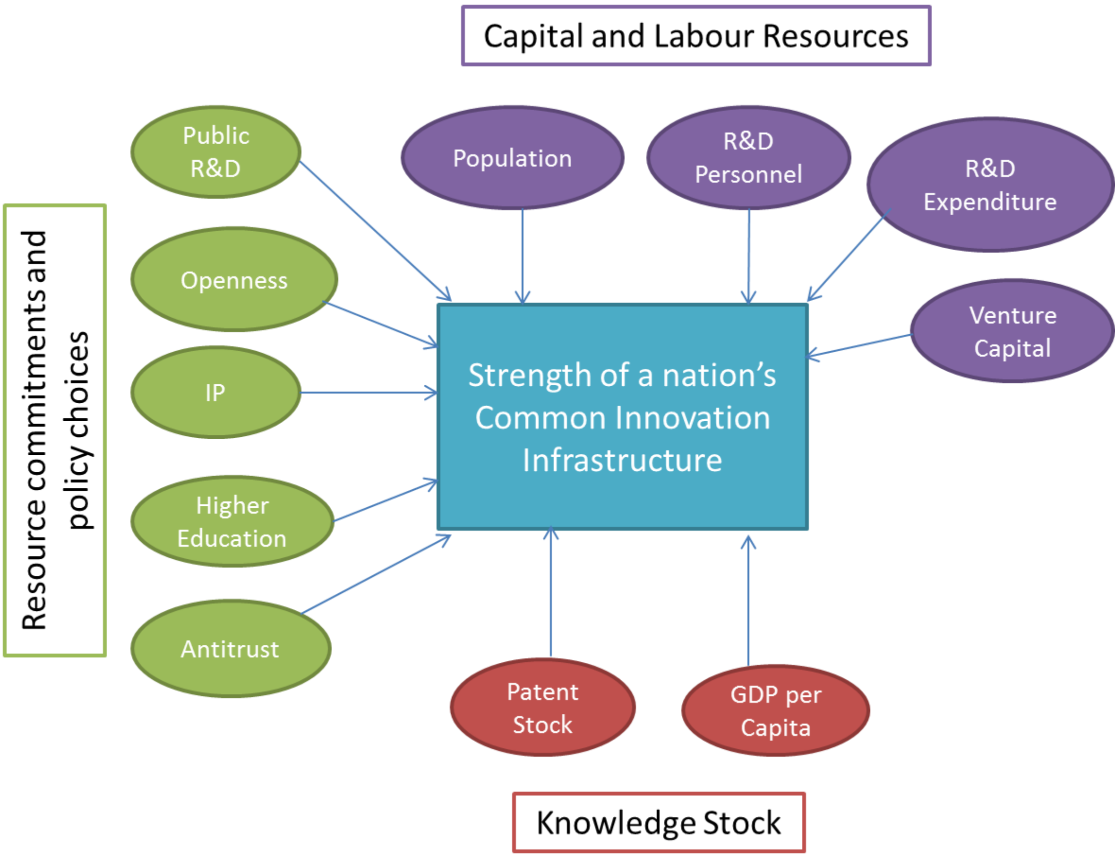


**Figure 2: Common Innovation Infrastructure- adapted from Furman et al (2002); Hu & Mathews (2005)**

### 2.6.1 Knowledge Stock –Endogenous Growth

In economics, a country's stock of knowledge is the accumulated intellectual property and inventions that economic agents generate. Knowledge stock is generated when opportunities present themselves in the market and economic agents create products, services and processes that aid in the exploitation of that knowledge (Braunerhjelm, Acs, Audretsch and Carlsson, 2010). However, one must differentiate knowledge and economically relevant knowledge. The latter is knowledge that will result in higher growth rates through commercial use (Braunerhjelm et al, 2010).

A country's investment in knowledge along with human capital has been cited as a fundamental key to growing endogenously (Braunerhjelm et al, 2010). Countries that invest in the creation and accumulation of knowledge often benefit from the spillover effects that are associated with such activities (Swann, 2009). Examples are evident from the United States, Japan and Germany where many products and services have resulted from government R&D.

In endogenous growth models, knowledge is often associated with patent stock. According to Furman et al (2002), a country's stock of knowledge comprises GDP per Capita and the accumulated stock of patents. "GDP per capita and patent stock reflects the potential and direct capacity to support knowledge accumulation" (Hu & Mathews, 2005, p.1333). Patents are a good proxy for the accumulation of economically relevant knowledge as most often patents represent inventions that are commercially viable. In addition, because of the cost and administration associated with the patenting process, it can be assumed that economic agents would only apply for patents if the benefits out-weigh the costs.

Innovation occurs when economic agents such as entrepreneurs convert a country's stock of knowledge into "economically useful firm-specific knowledge" (Braunerhjelm et al, 2010 p. 107). As a country's stock of knowledge increases, economic agents have a pool of ideas that they can exploit. Through entrepreneurship, Braunerhjelm et al (2010) argue that knowledge stock contributes to economic growth.

### 2.6.2 Capital and Labour Resources

This category of the common innovation infrastructure is made up of financial and human resources. Venture capital and R&D expenditure are important drivers of innovation (OECD, 2007). They help bridge the gap between invention or ideas and the commercialisation of those ideas. An unfortunate reality is that there are many new and innovative ideas that are financially viable, but the lack of capital means that most of these never reach the market. Countries with active venture capital systems, such as the United States, have higher innovation rates because these systems provide start-ups with the financial and non-financial resources necessary to make their innovations profitable (OECD, 2007). In addition to capital, labour plays a significant role. It has been found that countries with high numbers of R&D personnel also have higher patenting rates. There is a direct correlation between the number of researchers and scientists and the patenting rate, particularly in developed economies.

### 2.6.3 Resource commitments and Policy Choice

The government plays an important role in the category of the common innovation infrastructure. Through policy, government can encourage innovation in three ways (Swann, 2009).

Government can influence a firm's R&D activities through the use of subsidies in two ways. According to the Pignou approach, government can provide general subsidies or specific subsidies (Swann, 2009). General subsidies take the form of tax breaks on any

R&D expenditure. Specific subsidies, on the other hand, are targeted at incentivising areas of R&D which the government is keen to encourage. Specific R&D subsidies are more complex and costly to administer but they are more effective. Critics of the Pignou approach argue that this approach does not necessarily result in additional R&D activity (OECD, 2007). In addition, they question the efficiency of these subsidies in creating extra social benefits (Swann, 2009). The abuse of tax subsidies was also cited as an argument against the effectiveness of tax subsidies in genuinely stimulating R&D (OECD, 2007). An example of tax abuse would be the risk of companies claiming tax credits on activities that they would not have classified as R&D activities (OECD, 2007).

Competition policy and the protection of international property rights are instrumental in encouraging innovation activity (OECD, 2007). If firms and entrepreneurs are confident that their inventions, products and services have IP protection, there is a higher probability that they will engage in innovative activities. In addition, a regulatory environment that stimulates completion amongst firms and discourages monopolistic behaviour fosters innovation (OECD, 2007). Therefore a combination of these two policy measures that government has at its disposal has a significant impact of the rate of innovation within a country (Swann, 2009). However, there is an adverse to these two measures. Although IP protection is ideal for innovators, the high costs and administration associated with patenting ideas may discourage firms that do not have the financial and non-financial resources necessary to complete the patenting process (Swann, 2009). IP protection also slows down the process of technology diffusion as it places a price on the spill-over effects of the invention (Swann, 2009). The consequence is that it distorts competition.

Governments can directly participate in R&D activities that may not be explored by the private sector. This usually happens when the activities are "socially valuable but privately unprofitable" (Swann, 2009, p. 269). Examples of such expenditure can take the form of research laboratories, innovation hubs, funding of university research, supporting of collaborations between industry and universities and funding engineering and technology programmes (Swann, 2009).

"One-third to two-thirds of national income growth in advanced economies was ultimately accounted for by the growth of formal education" (Hayami & Godo, 2005, p.176). This reflects the importance of investing in education. Through the education system, human capital is created, which in turn, creates the knowledge necessary for innovative activities (Hayami & Godo, 2005). Thus the percentage of government expenditure dedicated to higher education has the potential to promote innovation and ultimately economic growth.

## 2.7 Summary

The review of literature demonstrates that there is a link between a country's common innovation infrastructure, innovation and economic growth.


**Figure 3: The relationship between the common innovation infrastructure, innovation and growth**

The common innovation infrastructure represents a myriad resources and policy instruments that are available to a country's economic agents. It is made up of a country's knowledge stock, financial and human capital as well as policy choices. The combination and interaction of these components is said to have a significant impact on a country's capacity to innovate (Furman et al, 2002). Through economic agents such as entrepreneurs, the innovation of new products, services and processes spurs new ventures and industries. These activities lead to productivity gains and economic growth. Through innovation policy, decision makers are able to improve the welfare of their citizens by encouraging innovation and ultimately economic growth.

The aim of this study is to investigate the innovation strategies that countries use in order to encourage innovation and influence economic transition. In order to do so, the common innovation infrastructure component of the model used in the studies by Furman et al and Hu and Mathews will be reproduced.

# 3. Chapter Three: Research Hypothesis

## 3.1 Introduction

According to the literature review above, the engine of economic growth is technological progress, which is driven by the existence of an innovation eco-system. The purpose of this research is to assess the Common Innovation Infrastructure of the 14 countries that are experiencing an economic transition. The Common Innovation Infrastructure is a component of a country's national innovation capacity (NIC) which is a framework developed by Furman, Porter and Stern (2002) .The research will compare the investment and policy choices of a sample of 14 countries. The aim is to assess the correlation between innovation and economic growth; capital and labour resources; as well as R&D policy.

## 3.2 Research Hypothesis

**Hypothesis 1:** The null hypothesis states that there exists no relationship between a country's level of innovation (represented by the number of international patents) and economic growth (represented by GDP per capita).

$$H_0{:}b_2 = b_3 = b_4 = 0 \text{ and } H_1{:}\ b_2 \neq b_3 \neq b_4 \neq 0$$

**Hypothesis 2:** The null hypothesis states that there is no relationship between a country's level of innovation and the quality of capital and labour resources.

$$H_0{:}b_2 = b_3 = b_4 = b_5 = 0 \text{ and } H_1{:}\ b_2 \neq b_3 \neq b_4 \neq b_5 \neq 0$$

**Hypothesis 3:** The null hypothesis states that there exists a relationship between innovation (represented by number of international patents in a given year), and a country's resource commitments and policy choices.

$$H_0{:}b_2 = b_3 = b_4 = b_5 = b_6\ 0 \text{ and } H_1{:}\ b_2 \neq b_3 \neq b_4 \neq b_5 \neq b_6 \neq 0$$

# 4. Chapter 4: Research Methodology

## 4.1 Introduction

The method of research that was used for this study was quantitative. A causal quantitative research methodology provides the opportunity to explore the possible relationship between two or more phenomena (Leedy & Ormrod, 2010). This study aims to investigate the impact of the common innovation infrastructure on innovation.

## 4.2 Research Design

The design of how research will be completed is important as it facilitates the collection of evidence necessary to answer the research problem. According to (Polonsky & Waller 2011), the purpose of a research design is to ensure that the evidence collected enables the research to answer the research question as unambiguously as possible. Research design is therefore the logical structure of enquiry. In order for quantitative research to be meaningful, there is a criterion which should be met (Polonsky & Waller 2011). Firstly, this research was designed in a manner that described characteristics of a population. Secondly, it sought to determine the answers to how the common innovation infrastructure impacts innovation. Thirdly, this study was based on a previous understanding of the nature of the research problem (Furman et al, 2002; Hu & Mathews, 2005).

The focus of this research was to assess how 14 countries are encouraging innovation by looking specifically at the policy and investment decisions made over a fifteen year period. The design was similar to that used in studies by Furman et al (2002) and Hu & Mathews (2005) on National Innovation Capacity. For the purposes of this research, an assessment of the Common Innovation Infrastructure was conducted. The data was obtained from the same sources as the Furman et al (2002) and the Hu and Mathews (2005) studies, where some exceptions are noted. In both studies, some data was sourced from the OECD and the Asian Development Bank databases. The explanatory variables that determine the relationship have been identified and are listed in Table 1.

This research was designed with the objective of assessing how 14 countries, including the BRICS countries, are encouraging innovation. According to Saunders and Lewis (2012), an explanatory study attempts to explain the relationship between variables by assessing the responses of the said variables in different situations. In order to assess the relationship between the chosen variables, a historical panel data analysis was conducted (Rowbotham, 2011).

In order to answer the research questions, the researcher examined impact of the independent of variables on the dependent variable. This required a longitudinal study as it was necessary to assess how variables that form part of the study's framework have changed over a period of time (Saunders and Lewis, 2012).

According to Rowbotham (2011), there are three methods one can use to analyse panel data. There is the pooled ordinary least squares regression method which uses a combination of time series and cross sectional data (Vogt, 2005). This method pools all the observations together and neglects the time series and cross sectional aspects of the data. The problem with this method is that for this study, it will not distinguish between the various countries in the sample. It therefore ignores the individuality that may exist between countries (Rowbotham, 2011). The second method one can use to analyse panel data is the fixed effects method. Unlike the pooled OLS method, the fixed effects method allows for heterogeneity as each country has its own intercept value. Although the intercepts are different, they are time invariant, i.e. fixed over time. The third method is the random effects method which allows for variations in both country and time (Rowbotham, 2011).

This study used the fixed-effects method to analyse the impact of the common innovation infrastructure on a country's level of innovation. This method has been found to be successful in studies that use panel data (Rowbotham, 2011; Hu & Mathews, 2005; Furman et al, 2002).

The common innovation infrastructure was adopted from the studies of Furman et al (2002) and Hu and Mathews (2005). The common innovation infrastructure is a component of the National Innovation Capacity which they defined as:

$$L\,A_{j,t} = \delta YEAR^{YEAR}{}_{t} + \delta COUNTRY^{C}{}_{j} + \delta INFLX^{INF}{}_{j,t} + \delta CLUSL\,Y^{CLUS}{}_{j,t}$$

$$+\delta LINKL^{ZLINKj,t} + \lambda\, LH^{A}{}_{j,t} + \varphi L\,A_{j,t} + \varepsilon_{j,t}$$

In an attempt to assess the impact of the common innovation infrastructure on innovation activity a simpler model, similar to the one by Rowbotham (2011), was defined:

$$y_{it} = \alpha_{it} + \beta x_{it} + \varepsilon_{it}$$

where *i* (*i* = 1, …*n*) is the countries and *t* (*t* =1….T) is the periods. The innovation function (patent stock) is measured by the dependent variable y; β is the parameter of interest; and ε is the residual. The design matrix (x) is as follows:

*x* = [GDP/Cap, Pop, R&D Personnel, R&D Expenditure, Openness, IP, ED Share, Antitrust, Venture Capital]

This model was found appropriate as similar studies by Owen (2005) and Mohamad (2008) used it to test the performance of exports subject to a number of variables over a certain period of time. This study is similar as it tested innovation performance subject to a number of variables over a certain period of time. Table 1 provides a brief description of each variable in the model and from which database it was obtained.

### Table 1: Data Definition & Sources

| Variable | Full Variable Name | Definition and Measure | Source | Furman et al (2002) Source |
|---|---|---|---|---|
| **GDP per capita** | GDP per capita | Gross domestic product in thousands of PPP-adjusted 2005 US$ | World Bank | World Bank |
| **Patent stock** | Stock of international patents | Cumulative patents from 1996 to 2010 | USPTO | CHI US patent database |
| **POP** | Population | Population (millions of people) | Countries' official statistics | OECD science and technology indicators |
| **R&D Personnel** | Aggregate employed S&T personnel | Full-time equivalent scientists and engineers in all sectors | World Bank | OECD science and technology indicators |
| **R&D expenditure** | Aggregate R&D expenditure | R&D expenditures in all sectors in millions of PPP-adjusted 1997 US$ | World Bank | OECD science and technology indicators |

| Variable | Full Variable Name | Definition and Measure | Source | Furman et al (2002) Source |
|---|---|---|---|---|
| **Openness** | Openness to international trade and investment | Average survey response by executives on a 1–10 scale regarding relative openness of economy to international trade and investment | IMD world competitiveness report | IMD world competitiveness report |
| **IP** | Strength of protection for IP | Average survey response by executives on a 1–10 scale regarding relative strength of IP | IMD world competitiveness report | IMD world competitiveness report |
| **ED share** | Share of GDP spent on higher education | Public spending on secondary and tertiary education divided by GDP | World Bank | World Bank |
| **Antitrust** | Stringency of antitrust Policies | Average survey response by executives on a 1–10 scale regarding relative strength of national antitrust policies | IMD world competitiveness report | IMD world competitiveness report |
| **Venture Capital** | Strength of venture capital markets | Average survey response by executives on a 1–10 scale regarding relative strength of venture capital availability | IMD world competitiveness report | IMD world competitiveness report |

## 4.3 Unit of analysis

The unit of analysis for this study is countries that have experienced economic growth and development as a result of increased innovation activities. Countries that exhibit such characteristics are monitored by the WEF in the annual Global Competitiveness Report. These countries are identified in the report as those that are in the transition from Stage 2 to Stage 3 of economic development (Schwab, 2012).

## 4.4 Population

The population for this study is the countries that are in the transition from Stage 2 (efficiency-driven) to Stage 3 (innovation-driven) economies according to the 2012-2013 Global Competitiveness Report. The reason for the choice of this population is because the focus of this research is to assess how efficiency-driven economies like South Africa can transition to innovation-driven economies like Singapore. This focus narrows the population to the 21 countries that are currently transitioning from efficiency to innovation-driven economies.

## 4.5 Approach

The research approach used to conduct any study has a significant impact on the potency and accuracy of the findings (Saunders & Lewis, 2012). It is therefore important to outline the method that will be used to collect the data as it will assist the researcher and audience of the research to evaluate the quality of the data, findings and conclusions (Saunders & Lewis, 2012).

Whether a researcher conducts a study using primary data or secondary data will depend on the quality and usefulness of available data. Primary data collection requires that the researcher collect data directly from the selected sample, the data is "collected specifically for the research project being undertaken" (Saunders & Lewis, 2012, p. 84). Secondary data involves the use of data that has been collected by other researchers and institutions for other purposes (Saunders & Lewis, 2012). Secondary data may be qualitative, quantitative, raw, or compiled data (Saunders & Lewis, 2012). According to Saunders & Lewis (2012), there are a range of methods available for the purposes of collecting qualitative and quantitative data. It can be collected through questionnaires, semi-structured and unstructured interviews.

For the purposes of this study, secondary data was collected from the various databases that are listed in Table1. This information is freely and readily available from the internet. Two descriptive studies, which are described below, were conducted. Firstly, a correlational study was conducted. This form of descriptive research provides the researcher with an opportunity to study the statistical relationship between two or more variables (Leedy & Ormrod, 2010). In the correlational study the objective is to test whether a relationship exists between GDP and the proxy variables of innovation. Secondly, a developmental study was conducted. Once the relationship between the chosen variables was identified, the researcher observed the developmental trend of the variables over a period of time. The aim of the developmental study was to observe the movement of GDP per capita and the other proxy variables of innovation over 15 years. This step was necessary to assess whether the encouragement of innovation had a sustainable impact on economic growth.

A combination of descriptive and inferential statistics was used to analyse the data.

## 4.6 Sampling Method

A sampling method is not applicable to this study as the population of 21 countries will be tested. In addition, 3 efficiency-driven economies were added to the sample. The reason for this addition was to assess how these three countries were performing in relation to the rest of the sample. However, due to data limitations which are discussed below, the sample size decreased from 21 to 14.

## 4.7 Potential limitations of the methodology

The definitions and measures of the various variables may differ across countries. This limitation is overcome by using proxies for the variables from a central database as the measurement of variables are standardised. Because this research uses both cross-sectional and time-series variations, additional limitations can be noted. Firstly, due to cross-sectional variation, the estimates used in the regression model may cause problems of “unobserved heterogeneity” because of the comparisons made across countries (Furman et al, 2002). Secondly, due to time-series variations, idiosyncratic conditions may occur within a country because of shifts in fundamentals (Furman et al, 2002). To address these limitations, dummy variables are included to control for time and country differences.

Missing data poses an additional limitation to the study. It was observed during the data collection process that for certain countries there were a number of variables missing during various years under the period of observation. Some of the limitations caused by missing data include the reduction of the sample size; the reduction of the power of the study to test hypotheses; and introduction bias (Davis, 2010). All these limitations may reduce the reliability and validity of the findings (Davis, 2010).

There are several methods available to the researcher to help address the limitations associated with missing data. This study uses a data imputation method to replace the missing data. Data imputation requires the replacement of missing values with reasonable values (Davis, 2010). The researcher chose to use an imputation method rather than deletion because the latter may cause a biased sample (Davis, 2010). Mean imputation, hot deck imputation, single imputation and multiple imputations are all various imputation methods that are available to the researcher. According to Davis (2010), mean imputation involves calculating the average of the dataset and replacing it for the missing value. While hot deck imputation requires replacing the missing data with estimates based on similar and complete data sets (Davis, 2010). Single imputation is self-explanatory and is ideal when the number of missing values is small (Davis, 2010). The most effective technique of missing data is multiple imputation which is a process of filling in "the missing data with plausible values, [analysing] the completed data set, and [repeating] the process multiple times" (Reiter, 2007, p. 664).

## 4.8 Reliability and Validity

The reliability refers to the consistency of the instrument used in the study to generate a certain result when what is being measure has not changed (Leedy &Ormrod, 2010). Validity of an instrument is how well the instrument measures what it is intended to measure (Leedy &Ormrod, 2010). These two concepts reflect the possibility that there exists an error in the measurements (Leedy &Ormrod, 2010). For this study, the secondary data was obtained for reliable databases such as the World Bank. These databases have been used by many reputable institutions around the world and are deemed appropriate sources of information (Furman et al, 2002; Hu & Mathews, 2005).

# 5. Chapter 5: Research Results

## 5.1 Data Cleaning

During the data cleaning process a mean imputation method was used to account for missing data. This was done by calculating the average growth rate of the time series and using that growth rate to calculate the missing data. This method proved effective for countries that had few missing data points in between various years during the selected period (Davis, 2010). However, for countries that had large chunks of missing data either at the beginning or at the end of the sample period, this method proved to be difficult. In situations like these, using the average growth rate creates the risk of calculating figures that are significantly different from their true values. This could cause bias results during data analysis (Gujarati, 2005). As a result of large chunks of missing data that could not be reliably calculated, ten countries were removed from the sample. The sample size was reduced from 24 countries to 14 and the sample period was reduced from 1990-2012 to 1996-2010.

## 5.2 Description of Research sample

The sample selected for this study was derived from countries that are transitioning from Stage 2 – Stage 3 development according to the World Economic Forum's Global Competitiveness Report 2011-2012. These are countries whose development is advancing from efficiency-driven to innovation-driven development. Countries in the former stage are those that have developed efficient production processes and have technological readiness, while the latter are countries that are competing based on new and unique products and processes (Schwab, 2012). The stage of development into which countries fall is based on the level of GDP/capita and the extent to which they are factor driven, i.e. exporting more than 70 percent of mineral resources (Schwab, 2012). Countries that are "transitioning" are those that fall between these stages of development. In addition to these countries, China, India and South Africa were added to the sample I order to analyse their performance in comparison to their BRICS counterparts that fall with in this category.

The sample consists of 11 countries that are classified as transitioning from Stage 2 to Stage 3 of development as well as India, China, and South Africa. Annual observations of ten variables for each country were observed for the period 1996 to 2010. The variables were selected based on the three hypotheses that this study has tested. The data of 210 observation points across the sample is presented in Appendix A.

An overview of the sample data is provided using descriptive statistics and hypothesis testing with the objective of identifying the relationships between the selected variables.

## 5.3 Descriptive Results

### 5.3.1 The relationship between innovation and economic growth (endogenous growth)

Table 2 is a correlation matrix of the variables that form part of the ideas production function. The results presented in this equation reveal that there is a negative relationship between the rate of international patenting and a country's economic growth rate. The table also shows that the rate of patenting increases as the population growth rate as well as the growth in R&D personnel increases. From the table there seems to be an inverse relationship between economic growth, population growth and the growth of R&D personnel in the selected sample.

**Table 2: Innovation, Economic Growth, R&D Personnel and Population Correlation Matrix**

| | Patenting Rate | Economic Growth Rate | Population Growth Rate | R&D Personnel |
|---|---|---|---|---|
| Patenting Rate | **1.000000** | -0.224151 | 0.620225 | 0.627261 |
| Economic Growth Rate | -0.224151 | **1.000000** | -0.776409 | -0.594619 |
| Population Growth Rate | 0.620225 | -0.776409 | **1.000000** | 0.887020 |
| R&D Personnel | 0.627261 | -0.594619 | 0.887020 | **1.000000** |

Table 3 below provides the correlation figures of economic growth and innovation for the individual countries in the sample. This table excludes the correlations between the population growth rates, R&D personnel and innovation. The correlations of these variables are found to support literature based on the fixed effects panel model. However the correlation between economic growth and innovation is inconsistent with literature. An investigation into how these two variables relate for each individual county is presented by Table 3. At a country level, the correlation between innovation and economic growth varies. Half of the sampled countries display an inverse relationship while the other half has a relationship consistent with literature.

**Table 3: Innovation and Economic Growth Correlation Matrix**

| | *Economic Growth A-H* | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Argentina** | **Brazil** | **Chile** | **China** | **Croatia** | **Estonia** | **Hungary** |
| **Patent Stock** | -0.08 | 0.55 | -0.11 | 0.69 | -0.63 | -0.64 | -0.57 |

| | *Economic Growth I-T* | | | | | | |
|---|---|---|---|---|---|---|---|
| | **India** | **Malaysia** | **Mexico** | **Poland** | **Russia** | **South Africa** | **Turkey** |
| **Patent Stock** | 0.58 | 0.06 | -0.36 | -0.17 | 0.31 | 0.42 | 0.11 |

A direct positive, yet moderate correlation is evident in countries such as Brazil, China and India. While Russia and South Africa exhibit slightly weak correlation between economic growth and the cumulative patent stock. This means that in varying degrees, an increase in economic growth can be associated with an increase in the stock of patents. Croatia, Estonia and Hungary show moderate weak relationships between patent stock and economic growth, while the rest of the sample have weak relationships between the variables.

### 5.3.2 The relationship between innovation and capital and labour resources

Table 4 is a correlation matrix that shows the relationship between innovation and R&D Expenditure, R&D personnel, Venture Capital and Population respectively. The strength and direction of the relationships varies. All variables in the matrix have a positive relationship with innovation. The relationship between innovation and the independent variables ranges from weak positive (venture capital) to moderate positive (R&D personnel, R&D Expenditure and Population). Table 4 also provides the correlation between the independent variables. The relationship between some of these variables with each other is interesting as there is evidence of a number of strong relationships, e.g. the population size and the pool of R&D personnel.

**Table 4: Labour and Capital Resources Correlation Matrix**

| | PATENT STOCK | R&D EXPENDITURE | R&D PERSONNEL | VENTURE CAPITAL | POPULATION |
|---|---|---|---|---|---|
| PATENT STOCK | **1.000000** | 0.409331 | 0.520359 | 0.163225 | 0.408020 |
| R&D EXPENDITURE | 0.409331 | **1.000000** | 0.603244 | 0.115735 | 0.320360 |
| R&D PERSONNEL | 0.520359 | 0.603244 | **1.000000** | 0.149053 | 0.687251 |
| VENTURE CAPITAL | 0.163225 | 0.115735 | 0.149053 | **1.000000** | -0.038290 |
| POPULATION | 0.408020 | 0.320360 | 0.687251 | -0.038290 | **1.000000** |

Table 5 presents the correlation coefficients between patent stock and elements of capital and labour resources for all the countries in the sample.

**Table 5: Labour and Capital Resources Correlation Matrix (Country-level)**

| *Patent Stock A-H* | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Argentina** | **Brazil** | **Chile** | **China** | **Croatia** | **Estonia** | **Hungary** |
| **R&D Expenditure** | 0.94 | 0.84 | 0.95 | 0.96 | -0.48 | 0.91 | 0.13 |
| **R&D Personnel** | 0.89 | 0.94 | 0.71 | 0.93 | 0.50 | 0.76 | -0.33 |
| **Venture Capital** | 0.52 | 0.54 | -0.13 | 0.25 | -0.35 | 0.04 | 0.33 |

| *Patent Stock I-T* | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **India** | **Malaysia** | **Mexico** | **Poland** | **Russia** | **South Africa** | **Turkey** |
| **R&D Expenditure** | 0.85 | 0.89 | 0.34 | 0.60 | 0.54 | -0.62 | 0.44 |
| **R&D Personnel** | 0.93 | 0.74 | 0.94 | -0.04 | -0.88 | -0.14 | 0.83 |
| **Venture Capital** | -0.85 | -0.34 | 0.87 | -0.49 | 0.49 | -0.53 | -0.69 |

For seven countries in the sample, i.e. Argentina, Brazil, Chile, China, Estonia, India and Malaysia, there is a high positive relationship between patent stock and R&D Expenditure. The correlation coefficients for these countries range between 0.85-0.96. For Poland and Russia there exists a moderate positive relationship between patent stock and R&D expenditure. While Turkey, Mexico and India experienced a weak positive relationship between patent stock and R&D expenditure during the period. Croatia and South Africa were the only two countries in the sample to display a negative relationship between patent stock and R&D expenditure over the period. The correlation coefficients for Croatia and South Africa were -0.48 and -0.62 respectively.

From the sample, 9 of the countries showed moderate to high positive correlation between patent stock and R&D personnel. These countries include Argentina, Brazil, Chile, China, Croatia, Estonia, India, Mexico and Turkey. South Africa and Poland exhibited similar patterns as the aggregate variables, i.e. weak negative relationship between patent stock and R&D personnel. While Hungary had a slightly weak negative relationship, Turkey had a strong negative relationship between patent stock and R&D personnel.

The results indicate that 50 percent of the sample exhibits a moderate to strong negative relationship between availability of venture capital and a country's stock of patents. Countries such as Argentina, Chile, India and Hungary exhibit moderate correlations between venture capital activities and patent stock. The data for the rest of the sample indicate that there is low to no correlation between these variables.

### 5.3.3 The relationship between innovation and resource commitment and policy

The scatterplot matrix below presents the relationships that are tested in Hypothesis 3. Figure 4 is a graphical representation of the relationship between innovation and resource commitments and policy choices for the sample. The scatterplots fitted with a linear regression line show the strength and direction for each relationship. Visual inspection of this matrix generally reveals trends that are supported by literature. All variables with the exception of ED share have weak to moderate positive relationships with innovation. The correlation between the share of GDP spent on education and innovation is very weak and negative, as shown in Figure 4.

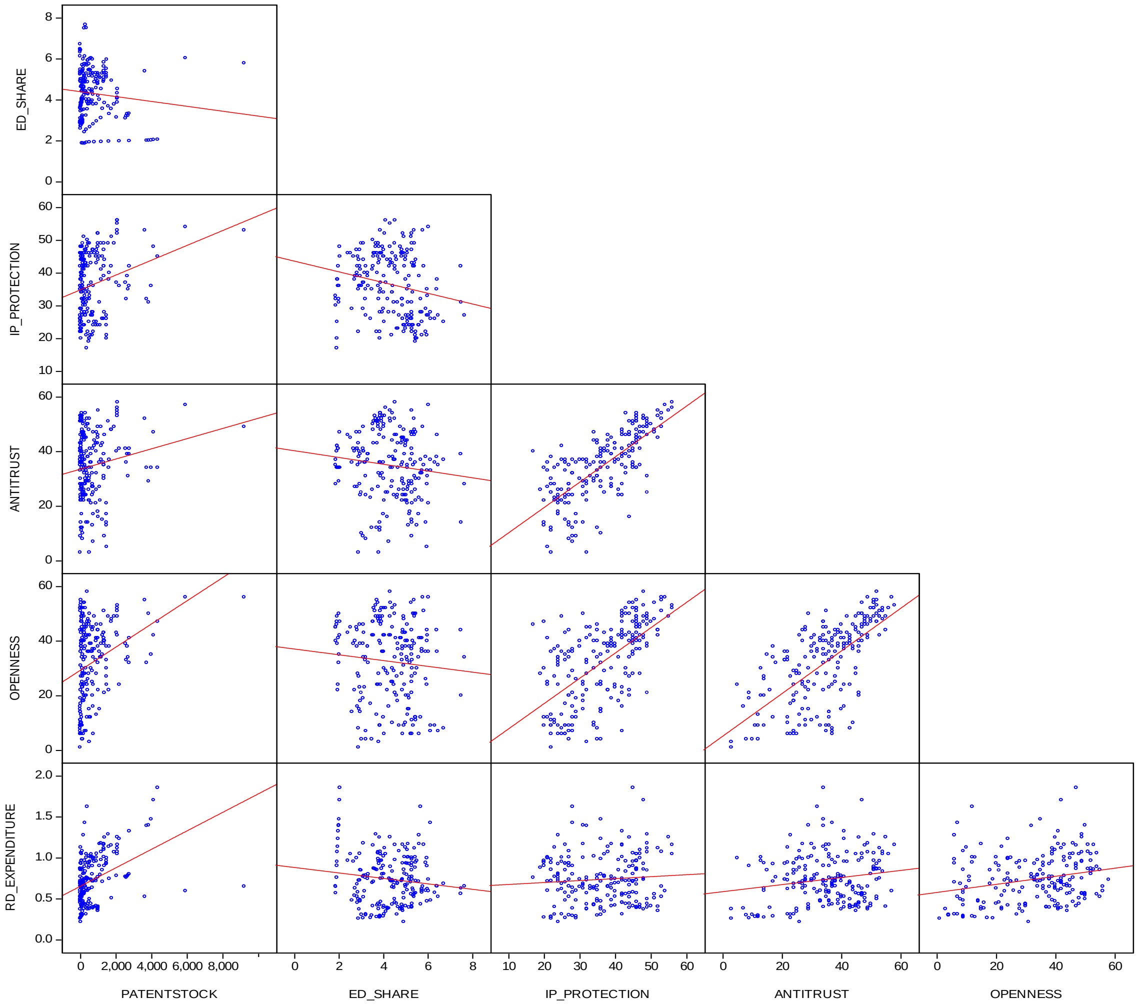


Figure 4: Resource Commitments and Policy Choice Scatterplot Matrix

Table 6 presents the correlation coefficients between patent stock and elements of capital and labour resources for all the countries in the sample.

**Table 6: Resource Commitments and Policy Choice Correlation Matrix**

| *Patent Stock A-H* | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Argentina** | **Brazil** | **Chile** | **China** | **Croatia** | **Estonia** | **Hungary** |
| **ED Share** | 0.82 | 0.44 | 0.56 | 0.96 | 0.94 | 0.03 | -0.18 |
| **Openness** | 0.60 | 0.50 | 0.38 | -0.14 | 0.45 | 0.14 | 0.66 |
| **IP Protection** | 0.63 | 0.65 | 0.62 | 0.63 | -0.22 | 0.51 | 0.88 |
| **Antitrust** | 0.47 | 0.48 | -0.02 | 0.03 | 0.11 | -0.04 | 0.97 |

| *Patent Stock I-T* | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **India** | **Malaysia** | **Mexico** | **Poland** | **Russia** | **South Africa** | **Turkey** |
| **ED Share** | -0.34 | -0.21 | 0.73 | -0.19 | 0.96 | -0.79 | 0.94 |
| **Openness** | -0.76 | -0.19 | 0.82 | -0.88 | 0.63 | 0.52 | 0.49 |
| **IP Protection** | -0.66 | -0.10 | 0.93 | -0.38 | 0.67 | 0.98 | 0.44 |
| **Antitrust** | 0.54 | -0.32 | 0.96 | -0.79 | 0.84 | 0.98 | 0.73 |

Like the correlations mentioned above, the relationship between patent stock and the share of GDP spent on higher education by the public sector varies across the countries. Argentina, China, Mexico, Russia and Turkey have strong positive correlations between these variables. This means that in these countries, as public spending on education increases, so will the stock of patents increase. However the data also shows that in Hungary, Malaysia, India and South Africa, an inverse relationship exists. For these countries government's investment in higher education reduces the stock of patents that country has. South Africa shows the strongest negative correlation within the sample.

Mexico is the only country in the sample that shows the existence of a strong positive relationship between the country's openness to investment and trade and the cumulative stock of patents. The rest of the sample shows that the correlation varies across countries. The majority of countries display a moderate positive relationship between openness and patent stock. Unlike Mexico, Poland's data strongly indicated that as international trade and investments increases, the cumulative stock of patents decreases.

On average, across the sample, there exists a moderately positive relationship between intellectual property protection and the country's stock of capital. Only Croatia, India, Malaysia and Poland displayed a negative relationship between these variables.

Data for Hungary, Mexico and South Africa indicate that in these countries, there is a strong positive relationship between the stringency of antitrust policy and the cumulative stock of patents. Weak correlations between these variables exist for Chile, China, Croatia, and Estonia indicating that antitrust policies have little to no effect on the stock of patents in these countries. The remainder of the countries display a moderate relationship between antitrust policies and stock of patents.

### 5.3.4 Summary of findings

Hypothesis 1-3 were tested on two levels. The relationships within these three hypotheses were tested at an aggregate sample level and on an individual country level. After preliminary analysis, the relationships between most variables seem to be in agreement with literature. However there are some exceptions. Firstly, the relationship between economic growth and innovation is negative at an aggregate level and for 50 percent of the countries in the sample. This would lead to the conclusion that economic growth would have a negative impact on a country's international patenting rate and vice versa, as the correlation coefficients do not show causality. Secondly, a preliminary analysis on the relationship between the share of government expenditure on higher education and innovation contradicts the finding of literature. As with economic growth, the data on both aggregate and country level says that the relationship is negative.

For the rest of the variables, the data confirms literature but the country level data reveals stronger relationships. On average, there is a moderate positive relationship between the patent stock and the variables in the common innovation infrastructure.

The preliminary analysis of the correlations between these variables provides an indication of the appropriateness of the models chosen to test the hypotheses. Based on the correlation coefficients of hypothesis 1-2, the preliminary analysis indicates that the models used may be appropriate to explain the relationships that are being tested.

## 5.4 Hypothesis Test

The hypothesis tests were done in EViews 7 using a fixed effects model. The following procedure was followed in all three of the hypothesis tests:

a. A non-directional sample t-test is the method used for all the hypothesis tests. This is based on deductive reasoning (a priori) derived from the literature review.
b. All tests are performed at a 5% level of significance; i.e. 95% confidence level. In accordance with similar studies by Furman et al (2002) and Hu and Mathews (2004).
c. The overall F significance statistic was used to reject or not to reject the null hypothesis in the multiple regression models.
d. Assumptions (adopted from Gujarati (2006)):
   i. The regression models designed are linear and correctly specified.
   ii. The error terms have mean values of zero – this assumption was proved correct for the models used for the hypothesis testing by examining the residual histograms found in Appendix B.
   iii. There is constant homoscedasticity. This means that a systematic pattern between the residual term and the dependent variable does not exist.
   iv. There is no autocorrelation between the error terms for Hypothesis 1 and Hypothesis 3. There is evidence of negative autocorrelation in the model for Hypothesis 2. The Durbin-Watson D test was used to test for autocorrelation. The computed d-values for Hypothesis 1 and Hypothesis 3 are 1.48 and 1.44 respectively. A d-value that is closer to 2 is an indication that there is no autocorrelation (Gujarati, 2006). The computed d-value for Hypothesis 2 is 0.33 which is closer to 0 and is an indication that there may be negative autocorrelation between the error terms (Gujarati, 2006). Autocorrelation compromises the results of the regression because the estimated results may underestimate the true value of the population (Weiers, 2008). As a result, a transformation of the regression was required (Gujarati, 2006).
   v. There is stationarity based on the Dickey-Fuller test (Gujarati, 2006).

e. The Power of the hypothesis tests, i.e. the probability of rejecting a false null hypothesis, was determined from the EViews output. (Weiers, 2011). This will verify the probability of a Type II Error. A Type II Error occurs when the null hypothesis is not rejected when it is false (Weiers, 2011).

f. The following statistical measures are analysed: $R^2$ / adjusted $R^2$, p-value and the F-value.

g. The EView output is found in Appendix C.

### 5.4.1 Hypothesis 1

The null hypothesis states that there exists no relationship between a country's level of innovation (represented by the number of international patents) and economic growth (represented by GDP per capita).

$$H_0: b_2 = b_3 = b_4 = 0 \text{ and } H_1: b_2 \neq b_3 \neq b_4 \neq 0$$

In order to test this relationship, fixed effects regression was run. The following linear regression model was defined and inputted into EViews for each country in the sample:

$$\text{Ln Patent Stock} = b_1 + b_2 \log \text{GDP/Capita} + b_3 \log \text{R\&D Personnel} + b_4 \text{Log Population}$$

Fixed Effects Regression Results

$$\text{Ln Patent Stock} = -4.4579 - 0.7304X_1 + 0.0793X_2 + 0.1523X_3$$[1]

p = (0.8355) (0.0342) (0.6981) (0.8996)

Adjusted $R^2$ = 0.9280

Overall F-value = 0.0000

[1] $X_1$ = Economic Growth; $X_2$ = R&D Personnel; $X_3$ = Population.

Table 7: Regression Output 1

| | Coefficients | p-value | Adjusted $R^2$ | F-significance |
|---|---|---|---|---|
| **Argentina** | | | | |
| $b_2$ | -3.6315 | 0.0924 | | |
| $b_3$ | 7.8979 | 0.0081 | 0.9514 | 0.0000 |
| $b_4$ | 3.7592 | 0.6805 | | |
| **Brazil** | | | | |
| $b_2$ | -4.5739 | 0.0001 | | |
| $b_3$ | -0.1707 | 0.7989 | 0.9885 | 0.0000 |
| $b_4$ | 20.5269 | 0.0000 | | |
| **Chile** | | | | |
| $b_2$ | -0.4047 | 0.9030 | | |
| $b_3$ | 0.4065 | 0.8579 | 0.9454 | 0.0000 |
| $b_4$ | 27.4162 | 0.0032 | | |
| **China** | | | | |
| $b_2$ | 0.9222 | 0.6288 | | |
| $b_3$ | -1.4720 | 0.1818 | 0.9854 | 0.0000 |
| $b_4$ | 48.739 | 0.0026 | | |
| **Croatia** | | | | |
| $b_2$ | 5.0344 | 0.0003 | | |
| $b_3$ | 1.9376 | 0.0538 | 0.8559 | 0.0000 |
| $b_4$ | 9.4221 | 0.5717 | | |
| **Estonia** | | | | |
| $b_2$ | 0.7226 | 0.7925 | | |
| $b_3$ | 5.4309 | 0.0249 | 0.8081 | 0.0000 |
| $b_4$ | -58.593 | 0.1592 | | |
| **Hungary** | | | | |
| $b_2$ | -1.1208 | 0.2739 | | |
| $b_3$ | 0.3659 | 0.5984 | 0.9871 | 0.0000 |
| $b_4$ | -90.0069 | 0.0013 | | |

| | Coefficients | p-value | Adjusted $R^2$ | F-significance |
|---|---|---|---|---|
| **India** | | | | |
| $b_2$ | -5.8346 | 0.0003 | | |
| $b_3$ | -0.4208 | 0.6940 | 0.9829 | 0.0000 |
| $b_4$ | 37.4050 | 0.0000 | | |
| **Malaysia** | | | | |
| $b_2$ | -4.1228 | 0.0048 | | |
| $b_3$ | -0.7828 | 0.0105 | 0.9659 | 0.0000 |
| $b_4$ | 21.1286 | 0.0000 | | |
| **Mexico** | | | | |
| $b_2$ | 5.9067 | 0.0143 | | |
| $b_3$ | 0.7274 | 0.1986 | 0.9189 | 0.0000 |
| $b_4$ | 2.4333 | 0.5394 | | |
| **Poland** | | | | |
| $b_2$ | 2.4401 | 0.0009 | | |
| $b_3$ | -1.5710 | 0.4996 | 0.9209 | 0.0000 |
| $b_4$ | -36.0689 | 0.1868 | | |
| **Russia** | | | | |
| $b_2$ | -1.4958 | 0.5014 | | |
| $b_3$ | -0.1272 | 0.9655 | 0.7868 | 0.0001 |
| $b_4$ | -68.0139 | 0.1501 | | |
| **South Africa** | | | | |
| $b_2$ | -2.6532 | 0.0011 | | |
| $b_3$ | 0.9858 | 0.0602 | 0.9750 | 0.0000 |
| $b_4$ | 8.1466 | 0.0001 | | |
| **Turkey** | | | | |
| $b_2$ | 1.7599 | 0.4414 | | |
| $b_3$ | -2.4872 | 0.0619 | 0.9349 | 0.0000 |
| $b_4$ | 33.5535 | 0.0003 | | |

Explanation of Results

Table 7 presents the regression results of the relationship between innovation and economic growth for each individual country in the sample at a 5 percent level of significance. The dependent variable in this regression is innovation and the independent variables are economic growth, R&D personnel, population. The regression coefficient, $b_2$, indicates what impact a change in economic growth would have on innovation. The results from the fixed effects regression reveal that if economic growth were to increase by 1 percent, the international patenting rate would decrease by 0.73 percent. The results also show that if the growth rates in R&D personnel and population were to increase by 10 percent, the international patenting rate would increase by 0.8 and 1.5 percent respectively. Similar results are found for Argentina, Chile and South Africa. The results for the other countries in the sample varied as seen in Table 7. The coefficient of determination, $R^2$, for the regression is 0.9280. This means that approximately 93 percent of the variations in innovation can be explained by a combination of economic growth, R&D personnel and population, ceteris paribus.

Across the sample the direction of the slopes of $b_2$ vary from positive to negative. For Estonia, this value suggests that if growth of GDP/capita were to increase by 1 percent, the international patenting rate would increase by 0.72 percent (Gujarati, 2006). The $b_2$ value for Argentina shows that if the R&D personnel growth rate increased by 1 percent, Argentina's international patenting rate would increase by 7.8 percent. This is high compared to that of the aggregate result. Russia is the only country with an adjusted coefficient of determination ($R^2$) that is less than 80 percent. The remaining countries in the sample have very high values for $R^2$, indicating the changes in economic growth, R&D personnel and population are attributable for the variations in the international patenting rate.

GDP/capita is the only statistically significant estimator of Patent Stock as it has a p-value that is less the 0.05, the significance level. R&D Personnel and Population have p-values greater than 0.05. In a multiple regression model, the statistic that will determine if the null hypothesis is rejected is the F-value. When F-values are almost zero it means that there is greater evidence against the null hypothesis (Gujarati, 2006).The F-value of the aggregate regression is 0.000 which means that the null hypothesis should be rejected. Endogenous growth does exist. There is a statistical relationship between innovation and economic growth, R&D activity and population. The statistical significance of the estimators across the countries varies. However the F-values for each country indicate that the regression is statistically significant and the null hypothesis is therefore rejected.

### 5.4.2 Hypothesis 2

The null hypothesis states that there is no relationship between a country's level of innovation and the quality of capital and labour resources.

$$H_0:b_2 = b_3 = b_4 = b_5 = 0 \text{ and } H_1: b_2 \neq b_3 \neq b_4 \neq b_5 \neq 0$$

In order to test this relationship, an ordinary least squares (OLS) regression was run. The following linear regression model was defined and inputted into Excel for each country in the sample:

$$\text{Patent stock} = b_1 + b_2 \text{ R\&D Expenditure} + b_3 \text{ R\&D Personnel} + b_4 \text{ Venture Capital} + b_5 \text{ Population}$$

Fixed Effects Regression Results

$$\text{Patents} = -2877.199 + 82.15X_2 + 0.001X_3 + 21.87X_4 + 0.00001X_5$$[2]

$$p = (0.0004) \quad (0.8569) \quad (0.0056) \quad (0.0016) \quad (0.0001)$$

$$R^2 = 0.6013$$

Overall F-value = 0.0000

Explanation of Results

The model used to determine the relationship between a country's innovation and its capital and labour resources is deemed to be statistically significant at a 5 percent level. Capital and labour resources explain approximately 60 percent of the variations of innovation.

Table 8 presents the estimation results of the relationship between the level of innovation and the capital and labour resources for each individual country in the sample at a 5 percent level of significance The adjusted coefficient of determination suggests that this regression model is good as changes in capital and labour resources explain 82 percent to 99 percent of the variations in a country's level of innovation across the sample with the exception of Croatia. In Croatia's regression, labour and capital resources explain only 63 percent of variations in innovation; however this model is still a good fit. The majority of the countries have an adjusted $R^2$ value greater

[2] $X_2$= R&D Expenditure; $X_3$= R&D Personnel; $X_4$= Venture Capital $X_5$= Population.

than 90 percent. Further evidence of the appropriateness of the model is given by significance test for the overall regression equation, F-value (Weiers, 2008).

### Table 8: Regression Output 2

| | Partial Regression Coefficients | p-value | Adjusted $R^2$ | F-significance |
|---|---|---|---|---|
| **Argentina** | | | | |
| $b_2$ | 25041.71 | 0.1828 | | |
| $b_3$ | 0.13 | 0.5312 | 0.8377 | 0.0001 |
| $b_4$ | 18.30 | 0.6846 | | |
| $b_5$ | -0.0006 | 0.5013 | | |
| **Brazil** | | | | |
| $b_2$ | -427.14 | 0.1061 | | |
| $b_3$ | 0.002 | 0.2860 | 0.9819 | 0.0000 |
| $b_4$ | 6.562 | 0.0362 | | |
| $b_5$ | 0.00006 | 0.0002 | | |
| **Chile** | | | | |
| $b_2$ | 6851.63 | 0.0003 | | |
| $b_3$ | -0.05 | 0.2575 | 0.9694 | 0.0000 |
| $b_4$ | -5.43 | 0.0753 | | |
| $b_5$ | -0.00006 | 0.4789 | | |
| **China** | | | | |
| $b_2$ | -3892.97 | 0.1847 | | |
| $b_3$ | 0.002 | 0.0196 | 0.9391 | 0.0000 |
| $b_4$ | 31.58 | 0.1297 | | |
| $b_5$ | 0.00004 | 0.0304 | | |
| **Croatia** | | | | |
| $b_2$ | -694.45 | 0.0065 | | |
| $b_3$ | 0.026 | 0.1410 | 0.6270 | 0.006 |
| $b_4$ | -4.39 | 0.2506 | | |
| $b_5$ | -0.001 | 0.1660 | | |
| **Estonia** | | | | |
| $b_2$ | 502.97 | 0.0006 | | |
| $b_3$ | -0.03 | 0.4743 | 0.8807 | 0.0000 |
| $b_4$ | 0.42 | 0.8604 | | |
| $b_5$ | 0.003 | 0.0337 | | |
| **Hungary** | | | | |
| $b_2$ | -706.17 | 0.0710 | | |
| $b_3$ | 0.08 | 0.0012 | 0.9624 | 0.0000 |
| $b_4$ | 5.71 | 0.0789 | | |
| $b_5$ | -0.002 | 0.0079 | | |

| | Partial Regression Coefficients | p-value | Adjusted $R^2$ | F-significance |
|---|---|---|---|---|
| **India** | | | | |
| $b_2$ | 1982.77 | 0.4270 | | |
| $b_3$ | 0.01 | 0.0012 | 0.9802 | 0.0000 |
| $b_4$ | 6.08 | 0.4852 | | |
| $b_5$ | 0.000008 | 0.0042 | | |
| **Malaysia** | | | | |
| $b_2$ | -676.76 | 0.0005 | | |
| $b_3$ | -0.003 | 0.0533 | 0.9929 | 0.0000 |
| $b_4$ | -1.98 | 0.0399 | | |
| $b_5$ | 0.0002 | 0.0000 | | |
| **Mexico** | | | | |
| $b_2$ | 331.36 | 0.6433 | | |
| $b_3$ | 0.004 | 0.1700 | 0.9533 | 0.0000 |
| $b_4$ | 4.88 | 0.5298 | | |
| $b_5$ | 0.00004 | 0.0032 | | |
| **Poland** | | | | |
| $b_2$ | 477.79 | 0.0404 | | |
| $b_3$ | -0.0023 | 0.6317 | 0.8390 | 0.0001 |
| $b_4$ | -0.2828 | 0.8361 | | |
| $b_5$ | -0.0003 | 0.0010 | | |
| **Russia** | | | | |
| $b_2$ | 915.84 | 0.0109 | | |
| $b_3$ | 0.0002 | 0.7989 | 0.9775 | 0.0000 |
| $b_4$ | -14.79 | 0.0506 | | |
| $b_5$ | -0.0003 | 0.0000 | | |
| **South Africa** | | | | |
| $b_2$ | -33.83 | 0.9663 | | |
| $b_3$ | 0.04 | 0.0292 | 0.9795 | 0.0000 |
| $b_4$ | -1.07 | 0.7810 | | |
| $b_5$ | 0.00008 | 0.0171 | | |
| **Turkey** | | | | |
| $b_2$ | -194.07 | 0.0376 | | |
| $b_3$ | 0.002 | 0.1036 | 0.9511 | 0.0000 |
| $b_4$ | -0.58 | 0.3942 | | |
| $b_5$ | 0.00001 | 0.0060 | | |

The significance test for the overall multiple regression equation for each country reveals that the model fitted for Hypothesis 2 is statistically significant for all of the countries when tested at a 5 percent level. The null hypothesis is rejected across the sample, i.e. there exists a relationship between the level of innovation and the capital and labour resources. The partial regression coefficients can be tested individually to determine which variables can significantly explain changes in the dependent variable, ceteris paribus (Gujarati, 2006). Partial regression coefficients with a p-value that is less than 0.05 are statistically significant and are therefore good estimators of innovation. In other words, partial regression coefficients that have a p-value that is lower than 0.05 are the most suitable independent variables to predict the level of innovation over the 1996 – 2010 period (Weiers, 2008). Based on these results, the model used for Hypothesis 2 is appropriate.

### 5.4.3 Hypothesis 3

The null hypothesis states that there exists a relationship between innovation (represented by number of international patents in a given year), and a country's resource commitments and policy choices.

$$H_0:b_2 = b_3 = b_4 = b_5 = b_6\ 0 \text{ and } H_1: b_2 \neq b_3 \neq b_4 \neq b_5 \neq b_6 \neq 0$$

In order to test this relationship, an ordinary least squares (OLS) regression was run. The following linear regression model was defined and inputted into Excel for each country in the sample:

$$\text{Patent stock} = b_1 + b_2 \text{ ED Share} + b_3 \text{ IP Protection} + b_4 \text{ Antitrust} + b_5 \text{ Openness} + b_6 \text{ R\&D Expenditure}$$

Fixed Effects Regression Results

$$\text{Patent Stock} = -2275.14 + 265.74\ X_2 - 1.41\ X_3 + 19.07\ X_4 + 7.28\ X_5 - 1384.07\ X_6$$ [3]

p = (0.0005) (0.0098) (0.9087) (0.0790) (0.3623) (0.0011)

Adjusted $R^2 = 0.5468$

Overall F-value = 0.0000

Explanation of Results

In the aggregate model used to test Hypothesis 3, the partial regression coefficient indicate that there exists a negative relationship between IP protection and R&D expenditure and innovation. The coefficients also show a positive relationship between education share, antitrust and openness with innovation. This contradicts the correlation coefficients provided by the descriptive statistics. In the descriptive statistics, only a negative relationship existed between innovation and government spending on education. The adjusted coefficient of determination (adjusted $R^2$) of 55 percent gives evidence for the appropriateness of this model in explaining the relationship between the variables. The overall significance of the model when tested at a 5 percent level gives evidence to reject the null hypothesis, i.e. there is a relationship between innovation and a country's resource commitments and policy choices.

[3] $X_2$= ED Share; $X_3$= IP Protection; $X_4$= Antitrust; $X_5$= Openness; $X_6$=R&D Expenditure.

### Table 9: Regression Output 3

| | Partial Regression Coefficients | p-value | Adjusted $R^2$ | F-significance |
|---|---|---|---|---|
| **Argentina** | | | | |
| $b_2$ | 580.55 | 0.6013 | | |
| $b_3$ | 12.71 | 0.9410 | | |
| $b_4$ | -153.44 | 0.3334 | 0.8318 | 0.0004 |
| $b_5$ | 47.10 | 0.5105 | | |
| $b_6$ | 27361.31 | 0.0370 | | |
| **Brazil** | | | | |
| $b_2$ | 258.00 | 0.1831 | | |
| $b_3$ | 10.11 | 0.5543 | | |
| $b_4$ | 33.73 | 0.1865 | 0.7538 | 0.0021 |
| $b_5$ | -23.98 | 0.2642 | | |
| $b_6$ | 2130.62 | 0.0022 | | |
| **Chile** | | | | |
| $b_2$ | -28.87 | 0.7689 | | |
| $b_3$ | 2.60 | 0.6946 | | |
| $b_4$ | 1.13 | 0.8521 | 0.9219 | 0.0000 |
| $b_5$ | 9.60 | 0.0527 | | |
| $b_6$ | 6141.10 | 0.0008 | | |
| **China** | | | | |
| $b_2$ | 18468.42 | 0.2607 | | |
| $b_3$ | 17.98 | 0.5017 | | |
| $b_4$ | -43.96 | 0.1088 | 0.9202 | 0.0000 |
| $b_5$ | 3.39 | 0.8369 | | |
| $b_6$ | 1004.09 | 0.7133 | | |
| **Croatia** | | | | |
| $b_2$ | 389.34 | 0.0000 | | |
| $b_3$ | 9.78 | 0.1611 | | |
| $b_4$ | 5.12 | 0.5143 | 0.9337 | 0.0000 |
| $b_5$ | 8.00 | 0.0258 | | |
| $b_6$ | -87.75 | 0.4089 | | |

| | Partial Regression Coefficients | p-value | Adjusted $R^2$ | F-significance |
|---|---|---|---|---|
| **Estonia** | | | | |
| $b_2$ | 20.64 | 0.3812 | | |
| $b_3$ | 9.90 | 0.1864 | | |
| $b_4$ | 3.30 | 0.2980 | 0.9003 | 0.0000 |
| $b_5$ | 7.37 | 0.2256 | | |
| $b_6$ | 317.58 | 0.0000 | | |
| **Hungary** | | | | |
| $b_2$ | -530.68 | 0.0170 | | |
| $b_3$ | -27.19 | 0.0751 | | |
| $b_4$ | 5.14 | 0.4794 | 0.8248 | 0.0004 |
| $b_5$ | 0.16 | 0.9714 | | |
| $b_6$ | 2449.86 | 0.0000 | | |
| **India** | | | | |
| $b_2$ | -624.94 | 0.0499 | | |
| $b_3$ | 19.04 | 0.7559 | | |
| $b_4$ | 45.24 | 0.0983 | 0.9019 | 0.0000 |
| $b_5$ | -90.91 | 0.0361 | | |
| $b_6$ | 13105.84 | 0.0063 | | |
| **Malaysia** | | | | |
| $b_2$ | -71.41 | 0.0841 | | |
| $b_3$ | 4.26 | 0.6403 | | |
| $b_4$ | -4.60 | 0.6247 | 0.7841 | 0.0012 |
| $b_5$ | 2.39 | 0.7924 | | |
| $b_6$ | 1058.64 | 0.0001 | | |
| **Mexico** | | | | |
| $b_2$ | 218.51 | 0.2707 | | |
| $b_3$ | -4.27 | 0.8242 | | |
| $b_4$ | 23.93 | 0.0280 | 0.8945 | 0.0000 |
| $b_5$ | 7.54 | 0.4838 | | |
| $b_6$ | -1624.08 | 0.3314 | | |

| | Partial Regression Coefficients | p-value | Adjusted $R^2$ | F-significance |
|---|---|---|---|---|
| **Poland** | | | | |
| $b_2$ | -66.01 | 0.0505 | | |
| $b_3$ | 1.77 | 0.6396 | | |
| $b_4$ | -12.37 | 0.0171 | 0.5707 | 0.0215 |
| $b_5$ | -4.20 | 0.2685 | | |
| $b_6$ | -1655.33 | 0.0109 | | |
| **Russia** | | | | |
| $b_2$ | 1008.25 | 0.0008 | | |
| $b_3$ | -30.95 | 0.3924 | | |
| $b_4$ | 17.58 | 0.7393 | 0.8982 | 0.0000 |
| $b_5$ | 20.09 | 0.4427 | | |
| $b_6$ | -842.93 | 0.3252 | | |
| **South Africa** | | | | |
| $b_2$ | -323.28 | 0.0000 | | |
| $b_3$ | -5.66 | 0.1198 | | |
| $b_4$ | -5.91 | 0.0384 | 0.9962 | 0.0000 |
| $b_5$ | 2.54 | 0.3488 | | |
| $b_6$ | 2715.76 | 0.0000 | | |
| **Turkey** | | | | |
| $b_2$ | 66.64 | 0.2752 | | |
| $b_3$ | 0.87 | 0.7152 | | |
| $b_4$ | -1.78 | 0.4548 | 0.8137 | 0.0006 |
| $b_5$ | 2.20 | 0.0325 | | |
| $b_6$ | 227.04 | 0.0613 | | |

The results of the partial regression coefficients and the significance of the estimators are mixed. Estonia was the only country with estimators that were all positive. However they were not all significant. R&D Expenditure was the only statistically significant estimator for Estonia. The model produced high adjusted $R^2$ for most countries but Poland's adjusted $R^2$ was only 57 percent. As with the aggregate model, not all estimated coefficients conform to a priori expectations. Similarly to the aggregate model, the null hypothesis can be rejected for each country. There is a relationship between a country's resource commitments and policy choices and a country's level of innovation.

### 5.4.4 Summary of findings

Three fixed effect regression models were fitted to the panel data that was collected for 14 countries that are transitioning from efficiency-driven economies to innovation-driven economies. These models were designed to test the relationships that were defined by the three hypotheses. It was found that in Hypothesis 1 there is a relationship between innovation and economic growth, R&D personnel and population. According to the results, these three variables explain 93 percent of the variations in innovation for countries transitioning from Stage 2 to Stage 3. This is an indication that endogenous growth does exist in these countries.

The null hypothesis for Hypothesis 2 was rejected as the multiple regression model was found to be statistically significant at a 5 percent level of significance. There is therefore a relationship between the level of innovation and the quality of capital and labour resources across the sample countries. All the sample countries have a very high adjusted $R^2$ value which is further indication of the appropriateness of this model in explaining a country's level of innovation.

The model designed to test Hypothesis 3, i.e. the combined effect of resources commitments and policy choices on innovation, was found to be statistically significant. The null hypothesis was rejected and therefore there is a relationship between the independent and dependent variables.

According to Gujarati (2006), one must use the following diagnostics tools to determine the adequacy of a chosen model:

a. Adjusted $R^2$ – Is its high enough?
b. The estimated p/f values – are they statistically significant?
c. Are the signs of the estimated coefficients in line with their a priori expectations?

All models had moderate to high adjusted $R^2$ values. The majority of the estimated coefficients conformed to a priori expectations with the exception of economic growth in Hypothesis 1, and openness and R&D Expenditure in Hypothesis 3. It was found that not all the estimates for the independent variables were statistically significant. However the overall regression model was found to be statistically significant. This means that individually the estimators are not significant but collectively they were significant estimators.

# 6. Chapter 6: Discussion of Results

## 6.1 Introduction

The elusive quest for growth has led the world's decision makers to apply a "myriad of remedies" to their economies that are yet to fulfil the solutions they promise (Easterly, 2002, cover). Easterly (2002) argues that the problem is not the economics of growth but the failure of decision makers to apply economic principles to practical policy. This study set out to determine how economic growth can be achieved through encouraging innovation. The review of a body of literature revealed that a relationship does exist between economic growth and innovation through a nation's innovation infrastructure. The literature also showed the importance of building a country's innovation capacity and the impact it has on growth. In an attempt to explore the assertions made by literature, secondary data was collected and regressions were run to test the hypotheses that were derived from the literature review. The results from the regressions were presented in Chapter Five and will now be discussed in this chapter.

## 6.2 Hypothesis 1 - The relationship between innovation and knowledge stock (Endogenous Growth)

Innovation is an engine of economic growth as it improves productivity and provides the capacity to create value (Acemoglu, Gancia, & Zilibotti, 2012 & Schwab, 2012). Literature identifies innovation as the driving force behind the economic performance and transformation of many industrialised countries (Whitfield, 2012). Investment in innovation capacity is how the Western world gained global dominance (Reinert, 2007). Literature postulates that there is a direct or positive relationship between innovation and economic growth (Swann, 2009).

The results obtained from the panel study with fixed effects found that innovation (represented by the patent stock) had a significant effect on the sample of economies transitioning from Stage 2 to Stage 3 of development. The regression that was run for Hypothesis 1 evaluated the ideas production function that was suggested by Romer (1990), Jones (1998) and Hu and Mathews (2005). The null hypothesis stated that there was no relationship between innovation and economic growth. From the regression results, the null hypothesis was rejected at a 5 percent level of significance. A relationship was found to exist between economic growth and innovation for the sample.

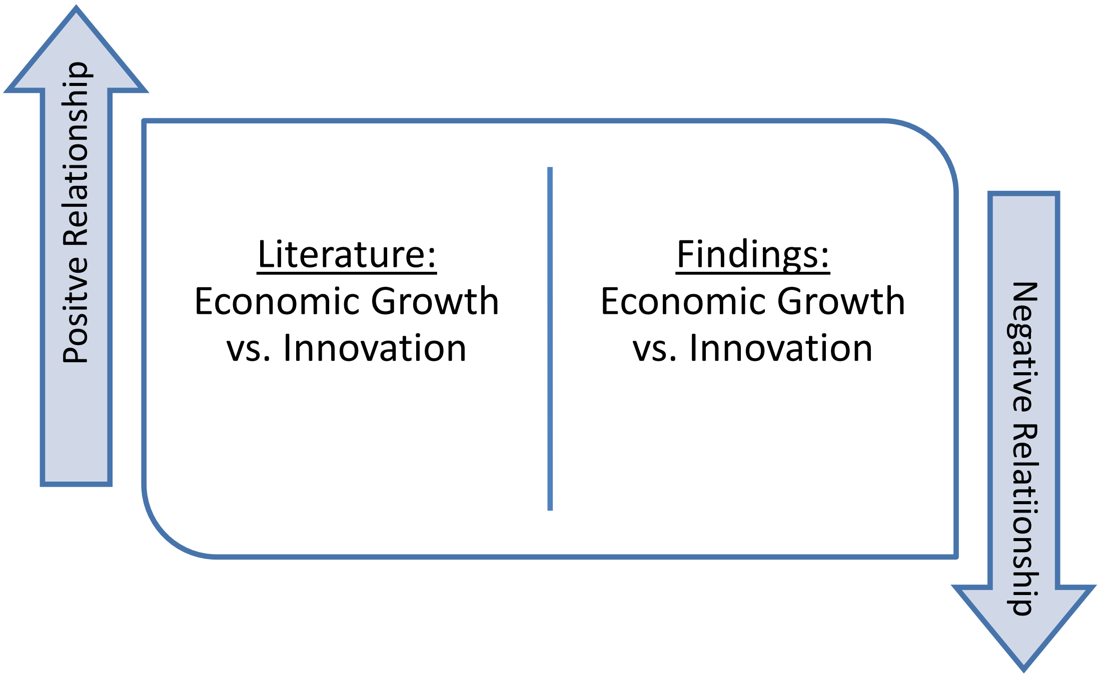


**Figure 5: Literature vs. Findings – Hypothesis 1**

The results found that patents increase with the growth rate of R&D Personnel but decreased with the growth rate of GDP/capita. The findings on the relationship between GDP/capita and the rate of international patenting contradict the findings presented by Furman et al (2002) and Hu and Mathews (2005). An interpretation of the results says that a 10 percent increase in GDP/capita yields a 7.3 percent decrease in the international patenting rate, and a 10 percent increase in R&D Personnel results in a 0.73 percent increase in international patenting rate. Hu and Mathews (2005) found that a 10 percent rise in GDP/capita was accompanied by a 37.8 percent rise in international patents for East Asian countries. While Furman et al (2002) found that a 10 percent increase in GDP/capita was associated with a 10 percent rise in the international patenting rate for OECD countries.

Although a relationship does exist between economic growth and innovation, the relationship is negative which is not supported by literature. The implication is that the endogenous growth model does not seem to apply in countries that are transitioning from Stage 2 to Stage 3 of development.

However, an analysis at an individual country level reveals that the relationship varies across the countries. For all the countries in the sample, the idea production function is statistically significant. However, in some countries a statistically significant positive relationship exists between innovation and economic growth while in others it does not.

Only Croatia, Mexico and Poland had results that were statistically significant and supported a relationship that is consistent with literature. In these countries endogenous growth seems to exist.

The results from Brazil, India and South Africa are consistent with the results from the fixed effects regression model, i.e. endogenous growth is not applicable. This finding is inconsistent with a priori expectations.

An interesting point to note about Brazil, India and South Africa is that in the past they were regarded as having the highest growth rates amongst the emerging market economies (Schwab, 2012). The results suggest that the economic growth of these countries cannot be attributed to the theory of endogenous growth. These three countries form part of the BRICS, along with China and Russia. The results of the relationship between innovation and economic growth for the latter two countries were not statistically significant and were therefore excluded from the comparison below. For the sake of interest though, the results from China revealed that endogenous growth was applicable while Russia’s results agreed with those of Brazil, India and South Africa.

Another point of interest is that amongst the BRICS, China had the highest competitiveness ranking in the Global Competitiveness Report (Schwab, 2012). China also out-ranked its fellow BRICS members with regards to business sophistication and innovation (Schwab, 2012). This may be the attributing factor as to why the endogenous growth theory may explain China’s economic growth.

**Table 10: Countries that display endogenous growth**

| | Coefficients | p-value | Adjusted $R^2$ | F-significance |
|---|---|---|---|---|
| **Croatia** | | | | |
| $b_2$ | 5.0344 | 0.0003 | | |
| $b_3$ | 1.9376 | 0.0538 | 0.8559 | 0.0000 |
| $b_4$ | 9.4221 | 0.5717 | | |
| **Mexico** | | | | |
| $b_2$ | 5.9067 | 0.0143 | | |
| $b_3$ | 0.7274 | 0.1986 | 0.9189 | 0.0000 |
| $b_4$ | 2.4333 | 0.1986 | | |
| **Poland** | | | | |
| $b_2$ | 2.440 | 0.0009 | | |
| $b_3$ | -1.571 | 0.4996 | 0.9209 | 0.0000 |
| $b_4$ | -36.0689 | 0.1868 | | |

The question that now arises is what makes endogenous growth applicable to some countries in the sample while it is not applicable to others. If these countries are all regarded as transitioning from Stage 2 to Stage 3 (which is based on level of innovativeness) then surely endogenous growth should be applicable to all.

Firstly, with regards to India and South Africa, these countries do not fall into the "transitioning from Stage 2 to Stage 3" category of development. As mentioned in Chapter 4, they were included in the sample in order to make a comparison with other BRICS members. Secondly, one of the limitations of the data collected is that the variable 'patents' may not fully capture a country's level of innovativeness as most latecomer countries such as those in the sample. These countries advance through the use of borrowed technologies rather than new to the world technologies, hence they will have lower patenting rates (Hu & Mathews, 2006, Hayami &Godo, 2005). Thirdly, countries that seem to exhibit characteristics of endogenous growth may be placing greater emphasis on activities that foster innovation.

**Table 11: Countries that do not display endogenous growth**

| | Coefficients | p-value | Adjusted $R^2$ | F-significance |
|---|---|---|---|---|
| **Brazil** | | | | |
| $b_2$ | -4.5739 | 0.0001 | | |
| $b_3$ | -0.1707 | 0.7989 | 0.9895 | 0.0000 |
| $b_4$ | 20.5269 | 0.0000 | | |
| **India** | | | | |
| $b_2$ | -5.8346 | 0.0003 | | |
| $b_3$ | -0.4208 | 0.6940 | 0.9829 | 0.0000 |
| $b_4$ | 37.405 | 0.0000 | | |
| **South Africa** | | | | |
| $b_2$ | -2.6532 | 0.0011 | | |
| $b_3$ | 0.9858 | 0.0602 | 0.9750 | 0.0000 |
| $b_4$ | 8.1466 | 0.0001 | | |

## 6.3 Hypothesis 2 - The relationship between innovation and capital and labour resources.

The objective of Hypothesis 2 is to highlight the importance of a country's capital and labour resources on the national innovation rate. In order to meet this objective a null hypothesis stating that there is no relationship between a country's level of innovation and the quality of capital and labour resources was defined.

An understanding of the impact of the pool of labour and capital on the rate of innovation is important for policy makers. This will enable countries to strategically channel investments into areas that will create sustainable innovation and economic growth. Countries that have an optimal mix of labour and capital resources dedicated to R&D activities have the potential to transform the nature of their economies.

Population, R&D Personnel, R&D spending, and venture capital have all been identified as significant contributors to a country's ability to innovate (Grossman, 2009; Ray, 2010; Malerba, 2007). The lack of labour, skilled R&D professionals and financial resources (R&D spending and venture capital) inhibits the possibility of growth through innovation (Hu & Mathews, 2005). Furman et al (2002) argue that countries need skilled scientists and engineers in order to take advantage of and produce innovative products and services. However, if R&D spending accounts for a small percentage of the expenditure budget, these vital skills may go to waste as the financial resources required to engage in innovative activities will be limited. The reality for many countries is that the venture capital industry accounts for a very small percentage of GDP, less than 0.03 percent (OECD, 2013). In addition to the skills and the money needed to create innovative products and services, labour is needed to implement these ideas. Therefore the potency of this combination of factors has a direct impact on a country's innovation output.

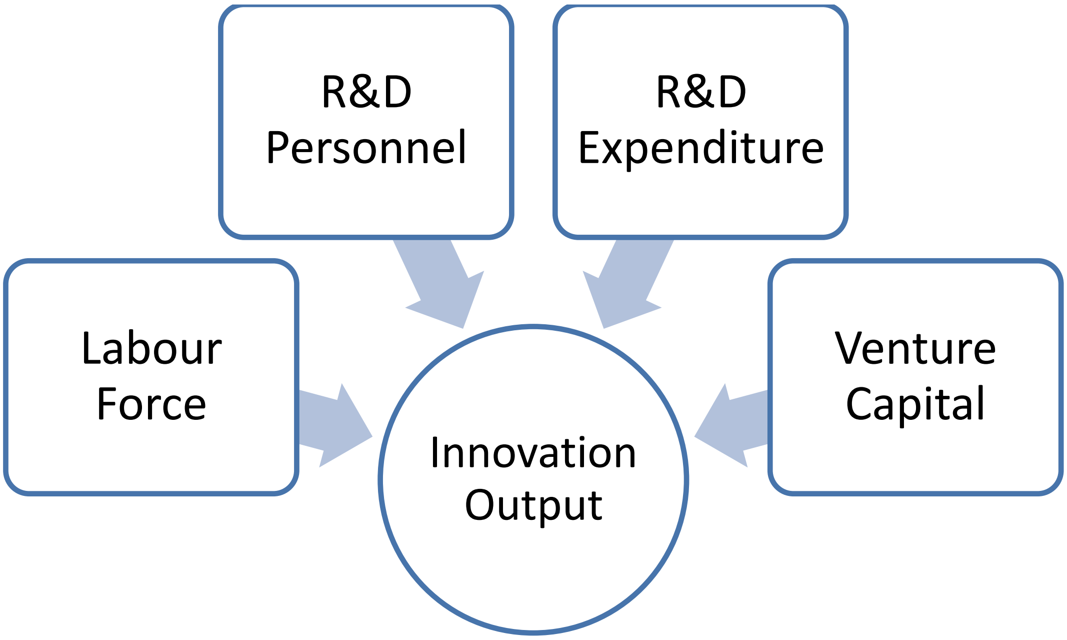


**Figure 6: Capital and Labour Resources -Hypothesis 2**

The results from Chapter Five agree with the views of previous studies. From the descriptive statistics it was found that positive relationships exist between the innovation output and R&D personnel, R&D expenditure, and venture capital. The correlation between R&D personnel and patent stock was the strongest of the three. This shows that the more skills available for R&D activities the greater the likelihood of creating innovation output. R&D expenditure as a percentage of GDP was also found to have a significant correlation with a country's innovation output. Countries which have more funds dedicated to R&D activities tend to have higher patenting rates. It was also found that venture capital and innovation output have a positive linear relationship although not as strong as the two variables mentioned above.

Table 12: Hypothesis 2 correlation matrix

| | PATENT STOCK | RD EXPENDITURE | RD PERSONNEL | VENTURE CAPITAL |
|---|---|---|---|---|
| PATENT STOCK | **1.000000** | 0.409331 | 0.520359 | 0.163225 |
| RD EXPENDITURE | 0.409331 | **1.000000** | 0.603244 | 0.115735 |
| RD PERSONNEL | 0.520359 | 0.603244 | **1.000000** | 0.149053 |
| VENTURE CAPITAL | 0.163225 | 0.115735 | 0.149053 | **1.000000** |

As with the findings of the descriptive statistics, the results from the regression that tested Hypothesis 2 are in agreement with literature. R&D Expenditure, R&D Personnel, venture capital and population are found to be statistically significant in explaining variations in innovation output. When one of these independent variables increases, the level of innovation output will also increase, ceteris paribus. However this relationship does not hold for each country in the sample.

The results from the hypothesis tests varied across the individual countries. For some countries there was a positive relationship amongst innovation output and the three variables and for some countries the relationships were mixed. The strength of these relationships also varies across the countries in the sample.

For four countries in the sample (Argentina, India, Mexico, & Russia), there exists a direct relationship between innovation, R&D Expenditure, R&D Personnel, Venture Capital and Population. Table 13 presents each country's cumulative stock of patents and average economic growth rates from 1996 -2010. From the table it can be seen that Argentina, India, Mexico and Russia have among the highest stock of patents in the sample.

In Estonia the results suggest that R&D Expenditure and Venture Capital were the drivers of innovation. While in Chile, R&D Expenditure was the main driver of innovation. Venture capital and R&D personnel were the main drivers of innovation in Brazil, China, and Hungary. In Croatia, South Africa and Turkey; R&D Personnel seemed to be the only drivers of innovation.

It would appear that in countries where there was a direct relationship between innovation and two or more of the independent variables they had the highest cumulative stock of patents. The exception was Estonia which had the lowest number of patents. This finding would support the argument that on average the combined effect of capital and labour resources dedicated to R&D activities will increase a country's innovation output (Hu & Mathews, 2005; Furman et al, 2002).

Table 13: Summary of Patent Stock, Growth, Expenditure and Personnel

| Country | Patent Stock | Economic Growth | R&D Expenditure | R&D Personnel | R&D Personnel as a Percentage of Population |
|---|---|---|---|---|---|
| Estonia | 75 | 5% | 89% | 4567 | 0.34% |
| Turkey | 79 | 3% | 58% | 42942 | 0.07% |
| Croatia | 124 | 3% | 88% | 9728 | 0.22% |
| Poland | 139 | 4% | 62% | 78496 | 0.20% |
| Chile | 231 | 3% | 30% | 10070 | 0.06% |
| Malaysia | 388 | 3% | 60% | 16235 | 0.07% |
| Hungary | 508 | 3% | 90% | 24156 | 0.24% |
| Mexico | 650 | 2% | 39% | 58775 | 0.05% |
| Brazil | 849 | 2% | 96% | 169449 | 0.09% |
| Argentina | 1011 | 2% | 47% | 44576 | 0.12% |
| South Africa | 1033 | 2% | 80% | 25302 | 0.06% |
| India | 1397 | 5% | 73% | 365799 | 0.03% |
| Russia | 1406 | 4% | 111% | 956961 | 0.66% |
| China | 2003 | 9% | 114% | 1319148 | 0.10% |

## 6.4 Hypothesis 3 – The relationship between innovation and resource commitment and policy

Hypothesis 3 tests the impact of government policy on innovative activities and thus innovation output. The object is to illustrate that government policy has a significant effect on a country's innovation capacity (World Bank, 2012). Although government does not directly participate in innovative activities, it can create an enabling environment (Swann, 2009).

Policy is a potent instrument that is available to a country's decision makers. It is often used to channel national debate. It can be used to focus national resources in order to meet objectives. Policy that is focussed on creating capacity is usually the most effective. Innovation Policy is no different.

Through the effects of innovation policy, economic agents are incentivised to increase a nation's patent stock and take advantage of spillover R&D from other nations (Diao, Roe & Yeldan, 1999). This stimulates growth and social welfare (Diao et al, 1999).

However other studies argue that this effect is dominant if the policy is targeted towards projects that would otherwise be unprofitable for economic agents to undertake (Wallsten, 2000). This is on the premise that economic agents are profit-maximising and would have therefore engaged in any R&D activity that produced profits.

Policies focussed on openness to international trade and investment; strengthening IP protection; and minimising anti-competitive behaviour have a bearing on the level of innovation. In developing countries openness improves innovation. Schneider (2004) found that high technology imports are significant in explaining local innovation for both developing and developed countries. In the same study it was found that in developing countries, the innovation rate is significantly affected by IP protection policies.

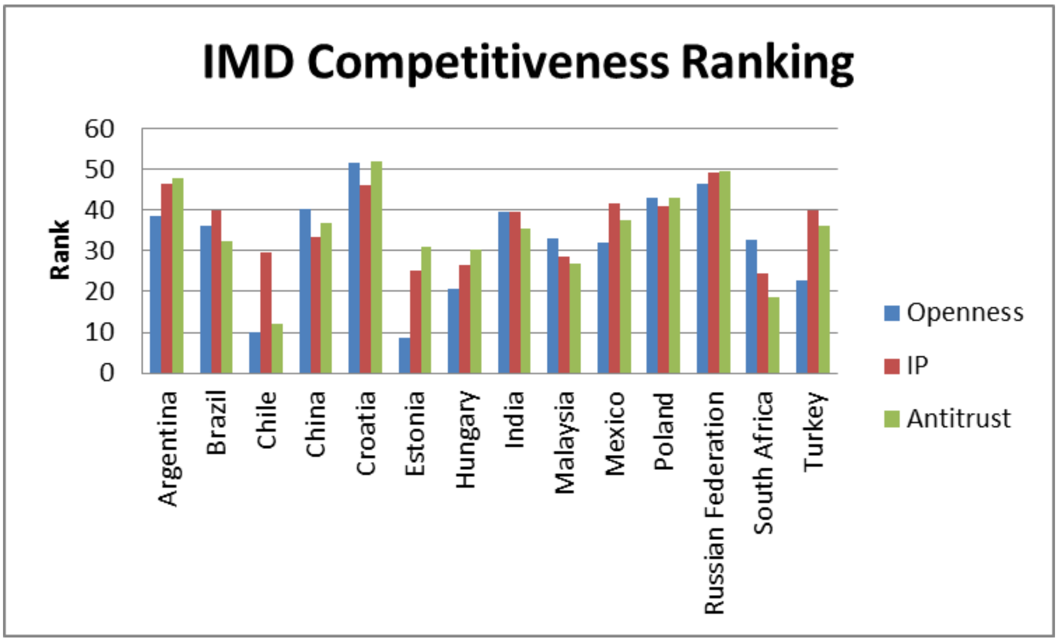


Figure 7: IMD Competitiveness Ranking

The results obtained from the panel study with fixed effects found that innovation a country's resource and policy choices had a statistically significant effect on innovation. From the regression results, the null hypothesis was rejected at a 5 percent level of significance. A relationship was found to exist between resource commitment, policy and innovation for the sample.  From the fixed effects regression two variables are found to violate a priori expectations. Openness and public R&D expenditure have an inverse relationship with innovation. These results can be interpreted as the more open to international trade a country is, the less likely it is to innovate. Logically this finding might hold true. A country might opt to import new and innovative products rather that invent their own (Schneider, 2004; Diao et al, 1999). In actual fact this is reality for many developing countries as they do not have the resources and capabilities necessary to create new to the world technologies.

Figure 9 presents the average ranking of the sample in the IMD Competitiveness Report. The countries are ranked based on the survey responses by executives on openness, the rigour of antitrust policies and IP protection. Chile, Estonia and Hungary are ranked highest in terms of openness to trade and investment. In contrast Brazil, India and Poland have amongst the weakest rankings and an inverse relationship between openness and innovation.

Mexico, along with Chile, Estonia and Hungary, has a strong relationship between openness and innovation. This suggests that in these countries openness to trade and investment stimulates innovation. This finding should hold for other countries as well because this relationship has been proved to exist in many prior studies (Schneider, 2004).

South Africa and Brazil are the only two countries where public R&D expenditure and innovation have a statistically significant positive relationship. Poland, on the other hand, has negative statistically significant relationship between public R&D and innovation.

Consistent with literature, antitrust and the share of GDP spent on education are found to have positive impacts on innovation. Countries in which the results are similar to those of the fixed effects regression are Croatia, Russia and Turkey.

### 6.5 Summary of findings

The objective of Chapter 6 was to discuss the results that were obtained from three hypothesis tests that were defined in this study. The first hypothesis tested the relationship between a country's knowledge stock and economic growth. The second hypothesis looked at the effects of capital and labour resources dedicated to R&D activities on innovation. The third hypothesis tested the relationship between a country's resource commitments, policy and innovation. Knowledge stock; capital and labour resources; and resource and policy choices are also known as the common innovation infrastructure. Studies have been conducted and it was found that this common innovation infrastructure has a significant impact on the level of innovation for 17 OECD and 5 East Asian countries (Furman et al, 2002; Hu & Mathews, 2005).

These hypotheses were tested on an aggregate level and individual country level. All three null hypotheses were rejected and a relationship was found to exist between innovation and the common innovation infrastructure on both levels. As with previous studies, the common innovation infrastructure does influence innovation for countries transitioning from efficiency-driven to innovation-driven economies.

A country level analysis found that although these relationships hold, the direction and magnitude varies across the countries. Some countries are more effective at encouraging innovation than others. Measures that work for one country may not necessarily work for others.

The objective of this research was to assess how countries are achieving economic growth through innovation. This objective was achieved as the effects that a country's common innovation infrastructure has on innovation have been identified for emerging markets.

# 7. Chapter 7: Conclusion and Recommendations

## 7.1 Introduction

In this chapter, the major findings of how countries are encouraging innovation are discussed. A discussion on the implications of the findings is also provided. In addition, this chapter provides recommendations to stakeholders based on the findings and recommendations for future research.

## 7.2 Summary of key findings

Firstly, not all countries that are classified as transitioning from efficiency to innovation driven economies display characteristics of endogenous growth. On an aggregate, economic growth and innovation have an inverse relationship, i.e. innovation is not contributing to economic growth. Only China, Croatia, Estonia, Mexico, Poland and Turkey showed endogeniety in their economic growth. For these countries the results tell a story of growth through the accumulation of knowledge and ultimately innovation. Unlike the findings by Furman et al (2002) and Hu and Mathews (2005), the endogenous growth model does not apply to countries that are transitioning from efficiency-driven to innovation-driven development. However investing in human capital has a significant effect on increasing the innovation output rate on both aggregate and country levels.

Secondly, labour and capital resources are significant contributors to variations in innovation output. However, labour resources dedicated to R&D activities have a minimal effect on innovation output. This signals the inefficiency of R&D Personnel and Population at influencing innovation for countries in this stage of development. This also suggests that venture capital and R&D expenditure have greater influence on innovation output than labour resources. However, for South Africa, Malaysia, Brazil, Turkey and China the negative relationship between R&D Expenditure and innovation suggests that expenditure may be aimed at other activities such as industrial upgrading and export production rather than on innovation (Schneider, 2005). Given that countries in the sample were once or still are efficiency-driven, this finding is plausible as resources in this stage of development are pronominally dedicated to improving production techniques.

Thirdly, an interesting and significant finding was the relationship between IP protection and innovation. Innovation output for countries in this stage of development is negatively impacted by IP protection. Like with latecomer countries studied by Hu & Mathews (2005), policies that encourage intellectual property rights discourage innovation. Whereas in developed countries, IP protection has a greater impact on innovation (Encaoua, Guellec & Martinez, (2006);Furman et al, 2002). Another significant finding was that Public R&D Expenditure negatively affected innovation output on aggregate. This would suggest that perhaps if Public R&D expenditure was targeted towards strategic projects then the relationship would be reversed. This finding is also supported by previous studies. The effects of IP protection and Public R&D did however vary across countries.

Openness to trade; competition policy and government spending on higher education account for positive variations in innovation output.

There is an existence of the common innovation infrastructure for the countries that are transitioning from efficiency-driven to innovation-driven economies. These countries are using the common innovation infrastructure to encourage innovation. However, some countries are more effective at encouraging innovation than others. Measures that work for one country may not necessarily work for others.

### 7.3 Implications

Literature and theory has provided a prescription on how countries should induce growth by encouraging innovation. It prescribes a list of remedies that will assist in alleviating the socio-economic ills that face many nations. Figure 8 is an illustration of which strategies are best suited for each stage of innovation.

From the fixed effect panel model, it can be concluded that, at an aggregate level, the common innovation infrastructure encourages innovation and by extension, economic growth. The results also indicate that government policy has a significant effect on an environment conducive to innovation, especially during the early stages of innovation development. Similar effects were found for OECD and East Asian countries. This implies that low levels of innovation and economic growth at a macro level seem to be a choice. Perhaps if decision makers were to channel more resources to activities that encourage innovation then that may translate into greater welfare for society.

However, the findings of this study also suggest that perhaps one size does not fit all. Homogenous remedies may not necessarily have the same desired effects. Rather countries need to first understand the context in which they exist, i.e. in which stage of innovation and development they are in (Lall, 2003). They need to assess their available resources and capabilities. An understanding of context and endowments will assist in devising strategies on how to best channel and exploit resources in order to achieve a desired effect.

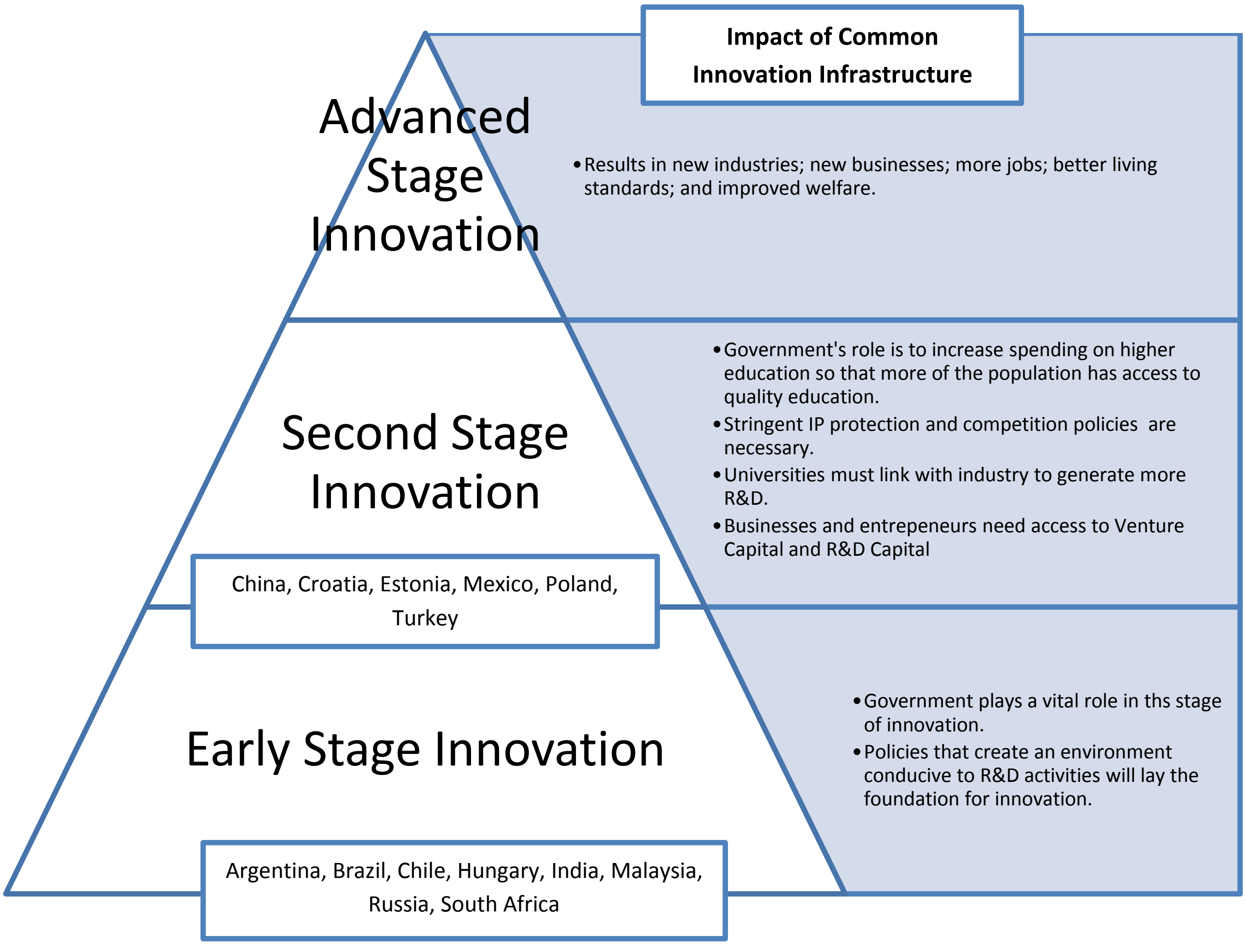


**Figure 8: Innovation Hierarchy**

### 7.4 Recommendations

Rather than take the full prescription of remedies, decision makers need to select a combination of remedies that is most appropriate for their economies. This implies that decision makers need to gain a comprehensive understanding of the remedies and even deeper understanding of national capabilities.

Figure 9 is an implementation plan for industrial economies seeking to transition to the next phase of development. This plan assumes that countries applying this framework have technological readiness and have institutions and resources that can support the strategies suggested. These countries are also known as efficiency-driven economies (Schwab, 2012).

The first recommendation would be for decision makers to make policy choices that support the right kind of innovation (Swann, 2010). Government could invest public R&D expenditure in programs that facilitate the commercialisation of inventions and research by linking universities and research institution with entrepreneurs. This would create a system where inventors generate ideas and the entrepreneurs implement those ideas. Through the entrepreneurial activities of bringing these ideas to market new industries will be created and by extension, so will employment. A conducive business environment can also be created that gives entrepreneurs that are participating in these programs tax breaks and protection for a certain period of time. Governments could also increase its funding of higher education, particularly in the areas of science and technologies. This creates a pipeline of the human capital necessary to fuel an innovation eco-system.

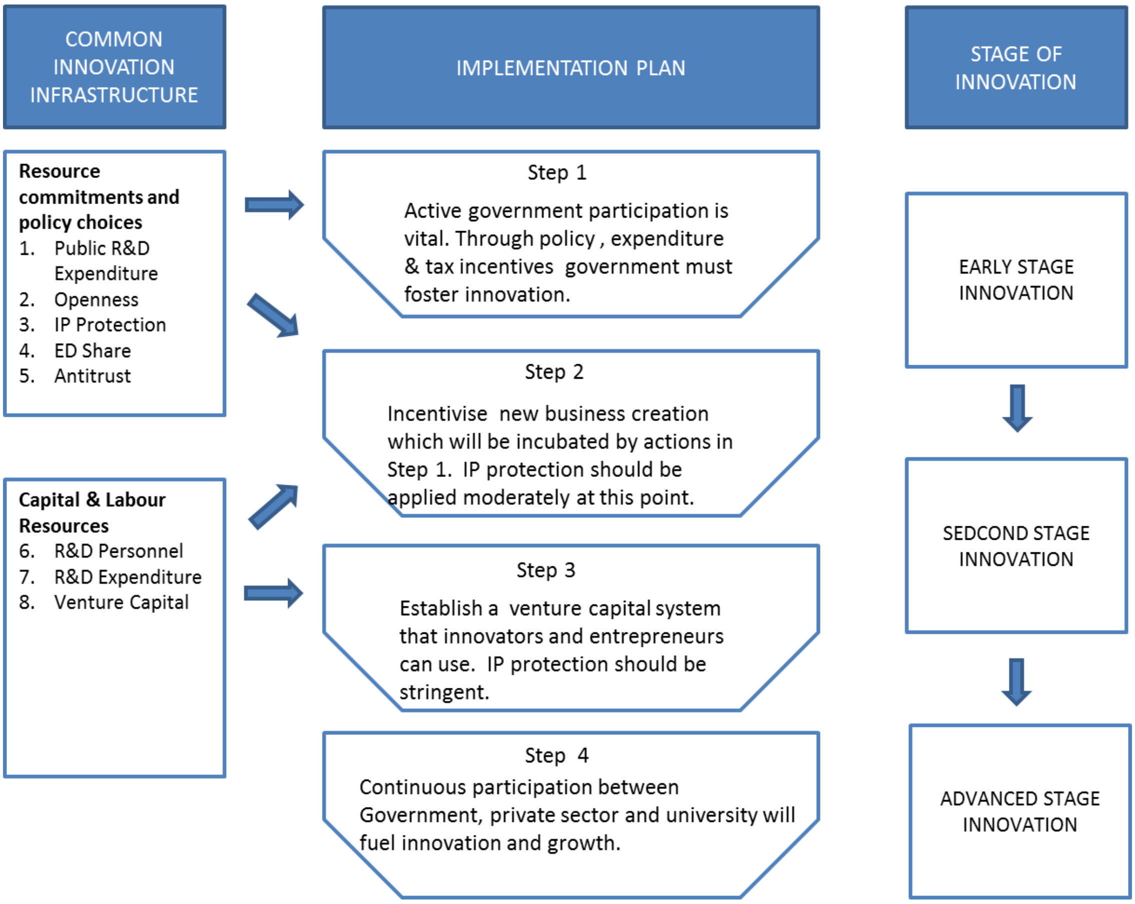


Figure 9: Innovation Strategy Implementation Plan

The second recommendation is with regards to financial capital. In order for entrepreneurs to commercialise the inventions that they source from universities and research institutions, they require scarce financial resources. Venture capital is a funding method that has been largely untapped in the emerging market. There is a case for building and promoting a venture capital system that entrepreneurs can tap into.

### 7.5 Limitation of Study

Firstly, the sample selected was limited to a few countries due to the availability of data. Secondly, the time period selected was not extensive enough to adequately assess the effect of policy choices on innovation. Common practice with studies such as this is to use time periods that span thirty to fifty years. Thirdly, the findings cannot be inferred on regions such as Africa as the sample does not share similar characteristics as most countries in Africa. Lastly, due to the quantitative nature of the data and the study, a deeper understanding into the complexities of policy and innovation could not be established.

### 7.6 Future Research

There have been extensive studies done on the innovation capacity of various regions around the world. However little has been done the innovation capacity of the African region. Africa has become the continent of choice for investors looking to exploit opportunities from the continent's untapped markets. The evidence can be seen from the growing literature and conferences on doing business in Africa (Berman, 2013). But how can emerging markets in Africa improve national innovation capacity? What impact will institutional voids that exist in Africa have on the creation of national innovation capacity? Lastly is the use of patenting as a proxy to test for innovation ideal for Africa? Future research on these questions will contribute to a better understanding on the impact of innovation strategies in Africa. A qualitative study would provide the depth and insight necessary to answer these questions.

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# Appendix A

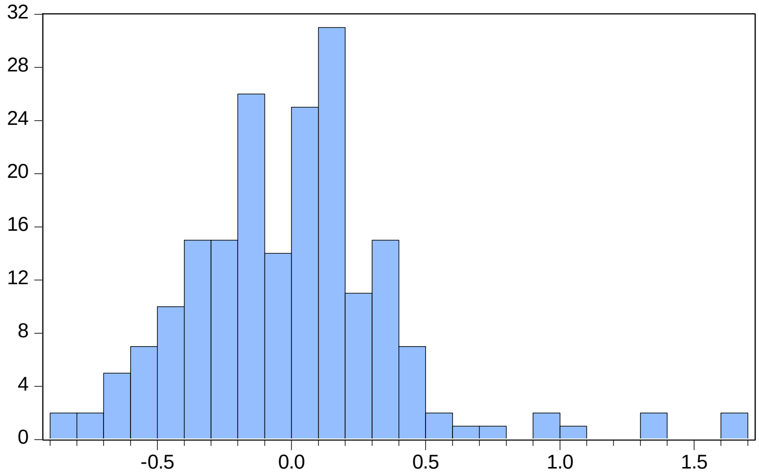
## Data Table

| | Economic Growth | Patent Stock | R&D Expenditure | R&D Personnel | ED Share | Openness | IP | Antitrust | Venture Capital |
|---|---|---|---|---|---|---|---|---|---|
| Argentina | 0.0199 | 1011 | 0.4688 | 44576 | 4.4957 | 39 | 47 | 48 | 45 |
| Brazil | 0.0183 | 849 | 0.9561 | 169449 | 4.6215 | 36 | 40 | 32 | 38 |
| Chile | 0.0279 | 231 | 0.3027 | 10070 | 3.5891 | 10 | 29 | 12 | 30 |
| China | 0.0911 | 2003 | 1.1363 | 1319148 | 1.9550 | 40 | 34 | 37 | 39 |
| Croatia | 0.0327 | 124 | 0.8844 | 9728 | 3.9195 | 52 | 46 | 52 | 50 |
| Estonia | 0.0532 | 75 | 0.8906 | 4567 | 5.5933 | 9 | 25 | 31 | 29 |
| Hungary | 0.0256 | 508 | 0.9012 | 24156 | 5.0578 | 21 | 27 | 30 | 36 |
| India | 0.0543 | 1397 | 0.7338 | 365799 | 3.5192 | 40 | 40 | 35 | 28 |
| Malaysia | 0.0260 | 388 | 0.5953 | 16235 | 5.6228 | 33 | 29 | 27 | 15 |
| Mexico | 0.0159 | 650 | 0.3851 | 58775 | 4.8192 | 32 | 42 | 38 | 46 |
| Poland | 0.0450 | 139 | 0.6194 | 78496 | 5.3303 | 43 | 41 | 43 | 34 |
| Russia | 0.0416 | 1406 | 1.1056 | 956961 | 3.4773 | 46 | 49 | 50 | 45 |
| South Africa | 0.0163 | 1033 | 0.8016 | 25302 | 5.4645 | 33 | 25 | 19 | 26 |
| Turkey | 0.0261 | 79 | 0.5758 | 42942 | 2.9101 | 23 | 40 | 36 | 43 |

# Appendix B

## Residual Histograms

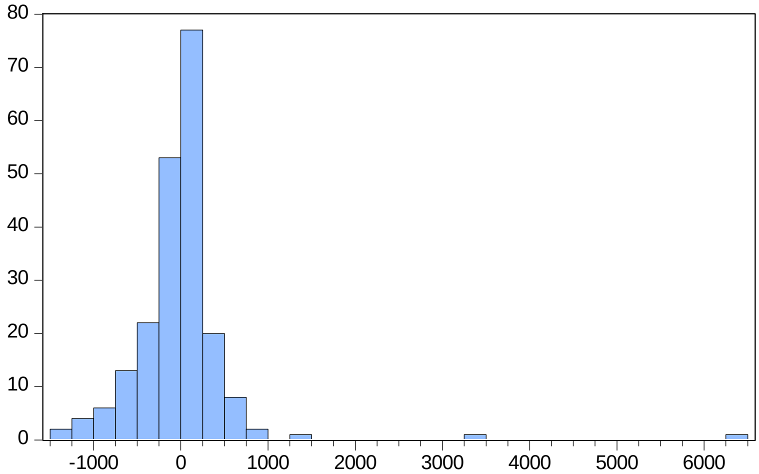
### Hypothesis 1




Series: Standardized Residuals
Sample 1996 2010
Observations 196

| | |
|---|---|
| Mean | -2.55e-17 |
| Median | 0.010055 |
| Maximum | 1.624479 |
| Minimum | -0.852896 |
| Std. Dev. | 0.392994 |
| Skewness | 1.034833 |
| Kurtosis | 6.057619 |
| Jarque-Bera | 111.3325 |
| Probability | 0.000000 |

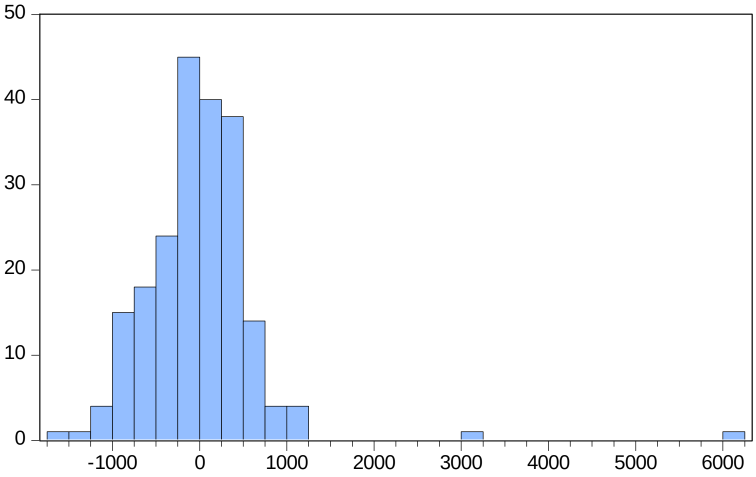
### Hypothesis 2




Series: Standardized Residuals
Sample 1996 2010
Observations 210

| | |
|---|---|
| Mean | -4.01e-14 |
| Median | 23.03516 |
| Maximum | 6420.615 |
| Minimum | -1344.162 |
| Std. Dev. | 641.1342 |
| Skewness | 5.358607 |
| Kurtosis | 53.34614 |
| Jarque-Bera | 23183.94 |
| Probability | 0.000000 |

## Hypothesis 3




| | |
|---|---|
| Series: Standardized Residuals | |
| Sample 1996 2010 | |
| Observations 210 | |
| Mean | -1.45e-13 |
| Median | -15.01547 |
| Maximum | 6165.422 |
| Minimum | -1504.808 |
| Std. Dev. | 681.5805 |
| Skewness | 3.782691 |
| Kurtosis | 34.91155 |
| Jarque-Bera | 9411.345 |
| Probability | 0.000000 |

# Appendix C

## EViews Regression Output

### Hypothesis 1:

Dependent Variable: LNPATENTSTOCK
Method: Panel Least Squares
Date: 01/11/14 Time: 03:34
Sample: 1996 2010
Periods included: 15
Cross-sections included: 14
Total panel (unbalanced) observations: 196

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -4.457892 | 21.43508 | -0.207972 | 0.8355 |
| LOGGDP_CAPITA | 0.730365 | 0.342086 | 2.135029 | 0.0342 |
| LOGRD_PERSONNEL | 0.079254 | 0.203948 | 0.388596 | 0.6981 |
| LOGPOP | 0.152344 | 1.205399 | 0.126385 | 0.8996 |

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

| | | | |
|---|---|---|---|
| R-squared | 0.939116 | Mean dependent var | 5.765390 |
| Adjusted R-squared | 0.928046 | S.D. dependent var | 1.592701 |
| S.E. of regression | 0.427229 | Akaike info criterion | 1.281166 |
| Sum squared resid | 30.11663 | Schwarz criterion | 1.799644 |
| Log likelihood | -94.55431 | Hannan-Quinn criter. | 1.491071 |
| F-statistic | 84.83568 | Durbin-Watson stat | 0.217840 |
| Prob(F-statistic) | 0.000000 | | |

**Hypothesis 2:**

Dependent Variable: PATENTSTOCK
Method: Panel Least Squares
Date: 01/14/14 Time: 00:43
Sample: 1996 2010
Periods included: 15
Cross-sections included: 14
Total panel (balanced) observations: 210

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -2877.199 | 795.5994 | -3.616392 | 0.0004 |
| RD_EXPENDITURE | 82.15013 | 454.7633 | 0.180644 | 0.8569 |
| RD_PERSONNEL | 0.001224 | 0.000437 | 2.804875 | 0.0056 |
| VENTURECAPITAL | 21.87465 | 6.806763 | 3.213664 | 0.0016 |
| POP | 1.15E-05 | 2.81E-06 | 4.085793 | 0.0001 |

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

| | | | |
|---|---|---|---|
| R-squared | 0.660404 | Mean dependent var | 747.2571 |
| Adjusted R-squared | 0.601261 | S.D. dependent var | 1100.190 |
| S.E. of regression | 694.7237 | Akaike info criterion | 16.06434 |
| Sum squared resid | 85910100 | Schwarz criterion | 16.57438 |
| Log likelihood | -1654.756 | Hannan-Quinn criter. | 16.27053 |
| F-statistic | 11.16620 | Durbin-Watson stat | 0.313263 |
| Prob(F-statistic) | 0.000000 | | |

**Hypothesis 3:**

Dependent Variable: PATENTSTOCK
Method: Panel Least Squares
Date: 01/14/14 Time: 00:53
Sample: 1996 2010
Periods included: 15
Cross-sections included: 14
Total panel (balanced) observations: 210

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -2275.140 | 645.9865 | -3.521962 | 0.0005 |
| ED_SHARE | 265.7351 | 101.8361 | 2.609440 | 0.0098 |
| IP_PROTECTION | -1.413479 | 12.30692 | -0.114852 | 0.9087 |
| ANTITRUST | 19.07354 | 10.79684 | 1.766585 | 0.0790 |
| OPENNESS | 7.282470 | 7.972889 | 0.913404 | 0.3623 |
| RD_EXPENDITURE | 1384.068 | 416.8159 | 3.320573 | 0.0011 |

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

| | | | |
|---|---|---|---|
| R-squared | 0.616205 | Mean dependent var | 747.2571 |
| Adjusted R-squared | 0.546819 | S.D. dependent var | 1100.190 |
| S.E. of regression | 740.6340 | Akaike info criterion | 16.19622 |
| Sum squared resid | 97091364 | Schwarz criterion | 16.72219 |
| Log likelihood | -1667.603 | Hannan-Quinn criter. | 16.40885 |
| F-statistic | 8.880750 | Durbin-Watson stat | 0.310229 |
| Prob(F-statistic) | 0.000000 | | |