Growth-Maximizing Allocation of Provincial Public Capital – a KwaZulu-Natal Case Study

Key Words*:* public capital, infrasructure expenditure, economic growth, growth maximizing allocation

JEL Classification number: O1, H4

Dr. Clive Coetzee (PhD)

General Manager: Infrastructure Management and Economic Services Unit

KwaZulu-Natal Provincial Treasury

Chief Economist

clive.coetzee@kzntreasury.gov.za

033 8974538

ABSTRACT

The provision of infrastructure is one factor that influences economic growth (Canning, 1998). Adequate supply of infrastructure seems to be an important factor and vital to achieve higher productivity and growth (Calderón and Servén, 2004). Most studies have found that infrastructure positively and significantly impacts on economic growth. For example, the World Bank in their report on Infrastructure in 1994 claimed that 1% increase in infrastructure stock will increase the GDP by 1% across all countries.

In principle, public spending enhances economic growth through its external effect on the production function of private firms. This effect can be modeled by adding into the production function the aggregate flow of public spending. In this paper drawing from the theoretical framework developed by Shieh et al., (2002), I will present an endogenous growth model to empirically analyze the growth maximizing allocation of provincial public capital.

This paper will specifically attempt to address the issue of whether provincial infrastructure expenditure is at, above, or below their growth maximizing levels. The approach is based on the growth model of Barro (1990). Infrastructure capital is an input into aggregate production, but it comes at the cost of reduced investment in other types of capital. In this approach (adopted from Canning and Pedroni, 2004) there is an optimal level of provincial infrastructure expenditure which maximizes the provincial growth rate (6% pa as stated in the PGDS); if infrastructure levels are set too high they divert investment away from other capital where income growth is possibly reduced. This model implies a simple “reduced form” relationship between income per capita and infrastructure stocks per capita.

The paper focuses on the province of KwaZulu-Natal, employing a variety of econometric techniques using quarterly data from 2001 to 2012, addressing the question of the growth maximizing levels of provincial infrastructure expenditure.

1. INTRODUCTION

There has been a long-running debate on (and increasing interest in) the effects of infrastructure on regional growth and economic performance. During the 1970s and 1980s, the United States had undergone a dramatic slowdown in national productivity growth. Yet public infrastructure was seldom mentioned as a major factor in this slowdown. Mostly, the studies were focused on energy prices, social and economic regulation, and low levels of capital accumulation. Only later, with discussions of economic decline during this period, would there be associations with declining public infrastructure investment. Researchers then paid considerable attention to the possible effects of public infrastructure on state as well as national productivity.

Aschauer (in Nannan and Jianing, 2012) set the stage for subsequent discussion and much controversy by laying out the case for the importance of infrastructure to the quality of life, the environment, and private economic activity. In the second part of the paper, Aschauer focuses on the impact of infrastructure on economic activity. He cites previous studies demonstrating the positive effect of public capital stock on output, both within this country and across countries. He further notes that public capital increases the rate of return to private capital, thus stimulating private investment; at the same time it substitutes for private investment, thus discouraging private initiatives (Munnell, 1990). Aschauer estimates the production function using data averaged over the period from 1965 to 1983. His results show that state output per worker is positively and significantly related to public investment in core infrastructure, although the coefficient on the public investment variable (representing the marginal product) is extraordinarily high. More precisely, while the marginal product of private capital in his equations ranges between 9 and 12 percent, the marginal product of public capital exceeds 200 percent.

King and Levine (1994) state that few economic ideas are as intuitive as the notion that increasing investment is the best way to raise future output. This idea was the basis for the theory of "capital fundamentalism". Under this view, differences in national stocks of capital were the primary determinants of differences in levels of national product. Capital fundamentalists viewed capital accumulation as central to increasing the rate of economic growth. Evidence to support this view was based mostly on case studies of less developed countries. Correspondingly, capital fundamentalists viewed rapid capital accumulation as central to increasing the rate of economic growth. Capital fundamentalism provided a coherent foundation for giving advice on development problems: national and international policies designed to increase a nation's physical capital stock were the best way to foster economic development.

This study addresses the issue of whether provincial stocks of infrastructure are at, above, or below their growth maximizing levels. The approach is based on the growth model of Barro (1990). Infrastructure capital is an input into aggregate production, but it comes at the cost of reduced investment in other types of capital. In this approach there is an optimal level of infrastructure which maximizes the growth rate; if infrastructure levels are set too high they divert investment away from other capital to the point where income growth is reduced.

The study uses the production function approach to estimate the contribution of total provincial public capital stock to provincial economic growth. The production function is specified as:

$$Yt = Af(St, Kt, Gt) = A_t S_t^{\alpha} K_t^{\beta} G_t^{\gamma}$$

where Y_t is the real aggregate level of provincial output (GDP) at period t, K_t is the aggregate total national capital stock (general government and private) in the province (excluding aggregate provincial public capital stock), G_t is the aggregate provincial public capital stock, and S_t is the skill-adjusted aggregate provincial labour supply. This represents an additional deviation from existing work as suggested by Gupta, et al (2011): rather than using raw labour, the study constructs and uses skill-adjusted labour incorporating data on average functional literacy, age 20+, completed grade 7 or higher. Assuming Cobb-Douglas production function technology, A, α, β and γ are parameters satisfying $A > 0$, and α, β, γ ε (0, 1).

The empirical analysis adopted by this approach specifies the aggregate input-output production relationship as follows:

$$Yt = A_0 S_t^{\alpha} K_t^{\beta} G_t^{\gamma} e^{\lambda t + \varepsilon t}$$

where A_0 denotes the initial (2001) value of the scale factor and we assume year-specific intercepts λt that could reflect common exogenous technology shocks. Taking logarithms of both sides gives us:

$$lnYt = a_0 + \lambda_t + \alpha ln S_t + \beta ln K_t + \gamma ln G_t + \varepsilon_t$$

This paper makes three contributions: First, it constructs a new dataset of total provincial public capital stock. A particularly novel feature of the dataset is that the provincial public capital stock is adjusted for depreciation. This study is the first to construct such a measure of capital stock using the perpetual inventor method. Second, following the literature on the public capital-growth nexus, the study investigates the effect of total provincial public capital stock on provincial economic growth. Third, the study attempts to estimate the growth maximizing total provincial public capital stock.

2. LITERATURE OVERVIEW

Gupta, et al (2011) state that substantial research has been devoted to measuring the productivity of public capital. Many studies are based on the production function approach with the public capital stock added as an additional input factor. Some have relied on a cost or profit function in which the public capital stock is included, while others have used the VAR approach, which imposes as few restrictions as possible to address the problems raised by production function and behavioural approaches.

In the literature it is generally assumed that public capital forms an element in the macroeconomic production function and enters in two ways. First, its stock may enter the production function directly, as a third input. Second, its stock may influence multifactor productivity and thereby production in an indirect way. It depends on the functional form of the production function whether both effects can be identified. However, in most models both ways yield similar equations to be estimated, which implies that the direct and indirect impact of public capital can often not be disentangled in empirical work (De Haan, et al, 2007).

Zainah (2009) states that public capital in infrastructure enhances private physical capital formation and economic growth because of its impact on private activity. Public spending on infrastructure such as roads, highways, education, sewer and water systems, and power plants often results in a reduction in costs facing the private sector, raising the productivity of private capital. By raising the marginal productivity of private inputs, it raises the perceived rate of return on, and increases the demand for, private sector physical capital. Alternatively, a complementarity effect between public capital in infrastructure and private investment may also operate through adjustment costs.

There is also broad consensus among economists and politicians that public infrastructure investment is an important aspect of a competitive location policy. Often it is argued that infrastructure lowers fixeded costs, attracting companies and factors of production and, thereby, raising production (Haughwout, 2002 and Egger and Falkinger, 2003).

Kalaitzidakis and Kalaitzidakis (2007) argue that in principle, public spending enhances economic growth through its external effect in the production function of private firms. This effect can be modelled by adding into the production function either the aggregate flow of public spending, following Barro (1990), or the aggregate stock of public capital, as in Turnovsky (1997).

Canning and Pedroni (2004) estimate the effect of infrastructure on long run economic growth for a large panel of countries using data from 1950 to 1992, therefore allowing them to address the question of whether infrastructure levels have been too low, too high, or about right over this period. The study also employs a number of innovations. First, they use physical measures of infrastructure, kilometers of paved roads, kilowatts of electricity generating capacity and number of telephones rather than constructing stock estimates from investment flows. While simple physical measures do not correct for quality, monetary investment in infrastructure may be a very poor guide to the amount of infrastructure capital produced.

Second, the authors find evidence of unit roots in both the GDP per capita (as do Cheung and Lai (2000) and Lee, Pesaran and Smith (1997)) in the infrastructure data. The study finds that GDP per capita and infrastructure stocks are cointegrated, and by exploiting this cointegrating relationship the authors develop a simple approach to isolating the long run effect from the short run effects. The adopted panel approach also permits the authors to compare cross country averages of these effects. The study finds that in general both short run and long run causality is bi-directional, with infrastructure responding to GDP per capita, but GDP per capita also responding to infrastructure shocks. Most importantly, the study finds evidence of a long run impact of infrastructure on GDP per capita. The study also finds that some countries actually have too much infrastructure, which is consistent with Devarajan, Swaroop and Zou (1996) and Ghali (1998), who find evidence of over provision of public capital in a number of developing countries.

Márquez, et al (2010) states that the role of public capital investment has been a critical component for enhancing regional growth. Permanent changes in public capital investment could have important effects on regional economic activity. The theoretical arguments pointing to the role of public capital on economic development are embodied in many of the

“New Growth Theory” (NGT) and “New Economic Geography” (NEG) models. These models challenge traditional Neo-Classical Growth Models, which predict regional convergence without a specific theoretical consideration of the role of public capital: steady state income per capita is assumed to be independent of the initial conditions, no matter the size of the inherited differences in capital stock.

Bom and Litghart (2010) assessed the output elasticity of public capital by means of a metaregression analysis using results of previous studies. They find that the average output elasticity of public capital is positive and significant despite a wide variation in primary estimates. They estimate the output elasticity to be 0.15 but suggest substantial heterogeneity across countries. Their results also suggest that the high output elasticities found in the early time-series literature are compatible with long-run (cointegrating) estimates found more recently. The conditional output elasticity of public capital in their benchmark specification which captures typical study characteristics is estimated to be 0.17, which is not that far from its unconditional (without controlling for study design parameters) value of 0.15. These values imply a marginal productivity of public capital for the United States in the range of 28.8–32.6 percent in 2001.

Onakoya and Somoye (2013) examine the impact of public capital expenditure on economic growth in Nigeria in the context of macro-econometric framework at sectoral levels. The research adopted a three-stage least squares (3SLS) technique and macro-econometric model of simultaneous equations to capture the disaggregated impact of public capital expenditure on the different sectors of the economy. The study shows that public capital expenditure contributes positively to economic growth in Nigeria. The results also indicate that public capital expenditure directly promotes the output of oil and infrastructure but is directly deleterious to the output of manufacturing and agriculture. The results suggest a positive but insignificant relationship to the services sector. The results however confirm that public capital spending indirectly enhances economic growth by encouraging private sector investments due to the facilitating role of government in the provision of public goods.

Nannan and Jianing (2012) examined the effect of infrastructure investment on economic growth in China. The study presents an empirical investigation of the relationship between infrastructure investment and economic growth in China using a dataset for a 20-year period, 1988-2007. The study established a gross productive equation about the contribution of productive elements on economic growth based on Cobb-Douglas production function and estimates the output elasticity of every productive element. The empirical results suggest that physical infrastructure development contributes positively to Chinese economic growth.

In this context, China's aggressive investment (around 15% of GDP) on infrastructure is justified to sustain growth and minimize the impact of the global financial crisis. The contribution of investment to growth reflects the investment-oriented growth strategy followed by China.

In their article, Sava and Zugravu (2010) stated that in Romania there were, at that stage, no empirical studies to test the correlation between public capital investment and economic growth. Based on the data from the general consolidated budget provided by the Ministry of Public Finance and also on data from National Institute of Statistics, they tested, using the correlation coefficient, the relationship between the public capital investments and gross domestic product in Romania, during 2006-2009. After calculating the correlation coefficient between public capital investment and gross domestic product during 2006-2009, there was found a weak correlation, but a positive one, which shows that an increase of state capital participation is likely to contribute to a low proportion of economic development.

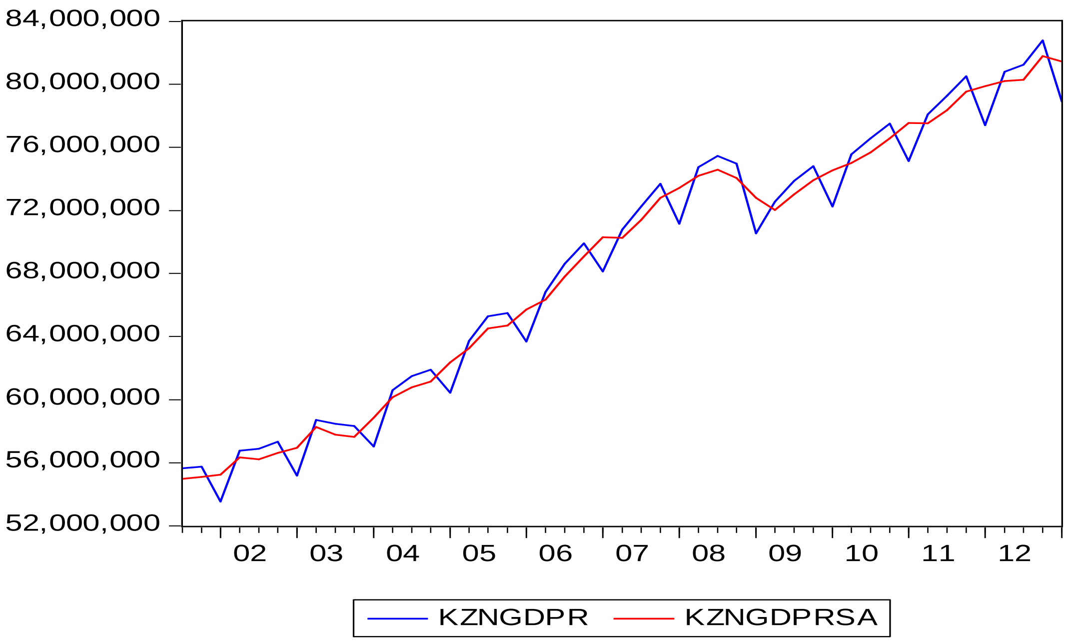
Zainah (2009) states that their study attempted to supplement the literature by analysing the link between public capital accumulation and economic growth for the case of an African country, namely the island of Mauritius. Mauritius, according to Zainah, provides an interesting case study as the island is one among the economic success stories of the continent where it is claimed that government has been acting as an important support to the development process. The study employed a Solow growth model augmented by two measures of physical infrastructure over the period 1970 - 2006 to assess the hypothesised link. Dynamic econometric technique is used, namely a Vector Error correction model (VECM), to analyse feedback effects in the system. Public capital is found to have significantly contributed to the Mauritian economic performance. Moreover, results suggest that there may be indirect effects via private capital accumulation and the openness channel as well.

On the other hand, there are also studies showing a negative relationship between public capital expenditure and long-term growth. Typical is the study by Ghosh and Gregoriou (2009) for 15 industrialized countries. For Brazil and Thailand, public capital expenditure had a significant negative effect, while current expenditure has a significant positive role on economic growth; on the other hand, for countries like Sudan and Zimbabwe, none of the two types of expenditure has a substantial impact on growth. Everaert and Heylin (2004) analyzed the situation of Belgium in the period 1965-1966, and their views have shown a clear negative effect between public capital and employment, whereas an increase in public capital stock by 1% reduces the employment in the private sector by around 0.32%, indicating a substitution relationship between two variables (Sava and Zugravu, 2010).

3. PROVINCIAL GROWTH PERFORMANCE

In 2012, KwaZulu-Natal GDP was estimated at about R322 billion. Provincial output increased from R56 billion during the 3rd quarter of 2001 to R79 billion during the 1st quarter of 2013 in real terms (constant 2005 prices). Economic activity picked up robustly from 2000 to 2008 (4.42 percent average annual growth), thereafter growth moderated and ultimately decreased (-1.78 percent) in 2009 due to the global financial crisis. Positive growth resumed during 2010 albeit at a very modest pace with the provincial economy recording a very modest 3.76 percent, 3.69 percent and 2.95 percentage growth during 2010, 2011 and 2012, respectively (figure 3.1). Provincial growth has steadily decreased from the 1st quarter of 2010 to the 1st quarter of 2013 mostly because of domestic risk factors including growing labour unrest, electricity shortages and political uncertainties. Figure 3.1 also includes a seasonal adjusted provincial GDP series generated using the seasonal adjustment ratio to moving average method in EViews.

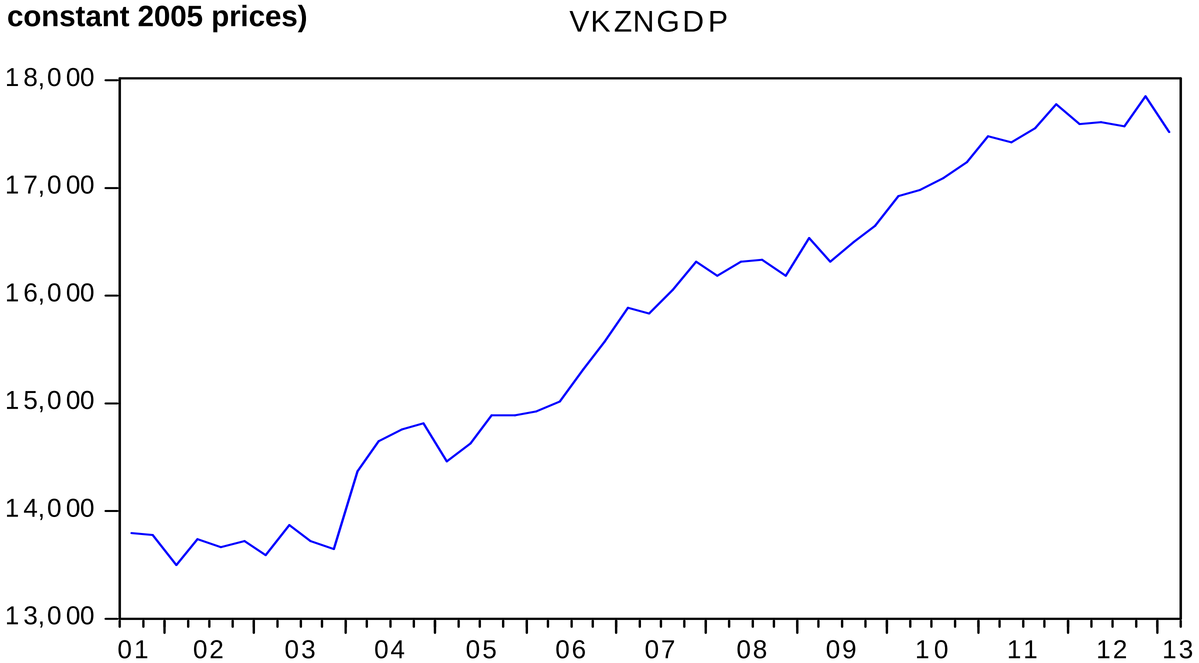
Figure 3.1: Provincial GDP and Seasonal Adjusted Provincial GDP (R'billions, constant 2005 prices)



(Source: Stats SA and KZN Provincial Treasury)

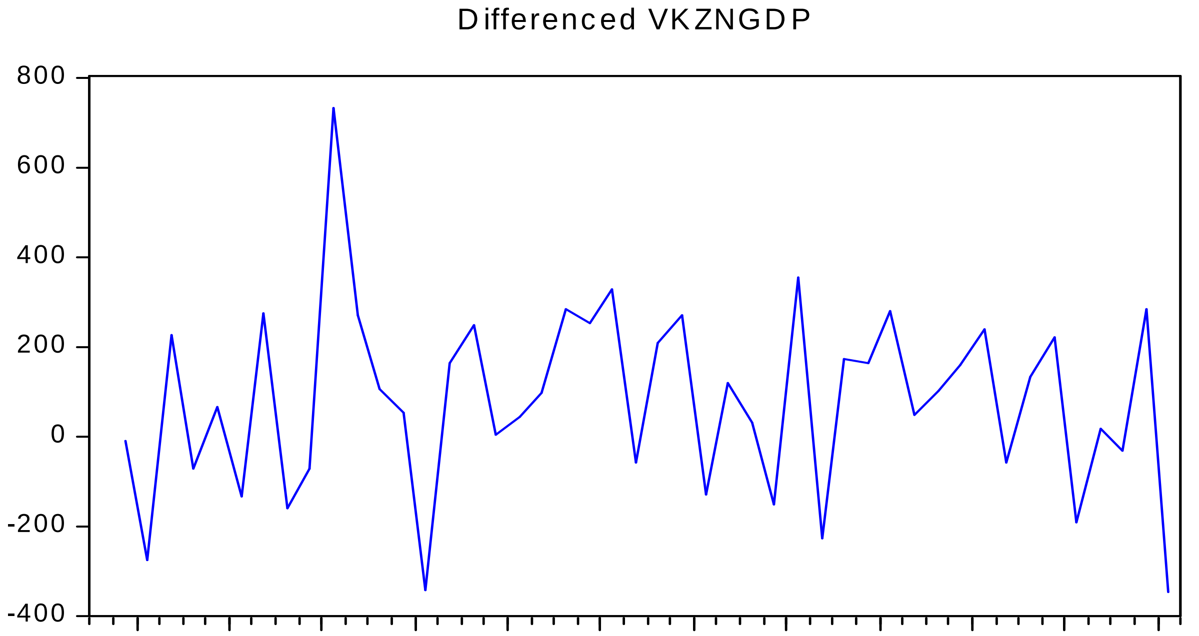
The provincial seasonal adjusted GDP per skill adjusted labour supply is displayed in figure 3.2 whereas the year-on-year change in the provincial seasonal adjusted GDP per skill adjusted labour supply is displayed in figure 3.3. The slowdown in the provincial economic performance (2007 and 2008) and subsequent provincial economic recession (2009) is very evident.

Figure 3.2: Provincial Seasonal Adjusted GDP per Skill Adjusted Labour Supply (R constant 2005 prices)



(Source: Stats SA and KZN Provincial Treasury)

Figure 3.3: Change in the Provincial Seasonal Adjusted GDP per Skill Adjusted Labour Supply (R constant 2005 prices)



(Source: Stats SA and KZN Provincial Treasury)

The log of the per skill adjusted labour supply value (figure 3.2) is tested for non-stationarity against the alternative that the variable is trend stationary. To perform the Unit Root test on a AR(p) model the following regression will be estimated:

$$y_t = \alpha + \delta t + \beta y_{t-1} + \sum_{j=1}^{k} \theta_j \Delta y_{t-j} + u_t$$

where:

y_t = variable to be tested (provincial per skill adjusted labour supply seasonal adjusted GDP)

α = constant

t = trend

Δ = lag operated of the dependent variable

u_t = white noise innovation

The ADF Unit Root Test is based on the following three regression forms:

- with constant and trend (τ_τ)
- with constant (τ_μ)
- without constant and trend (τ)

and the testable hypothesis is β = **0** (i.e., p = **1**, y_t has a unit root).

The time series will consist of 47 observations and four lags will be included in the test procedures. The Schwarz Info criteria are used to determine the number of lags. The results are displayed for each variable in the table below. Comparing the ADF test statistics with the critical test values at 1 percent, 5 percent and 10 percent levels (tau values) and the F-statistics at the 1 percent, 5 percent and 10 percent levels (phi values) suggests that both the variables or time series are non-stationary in level format.

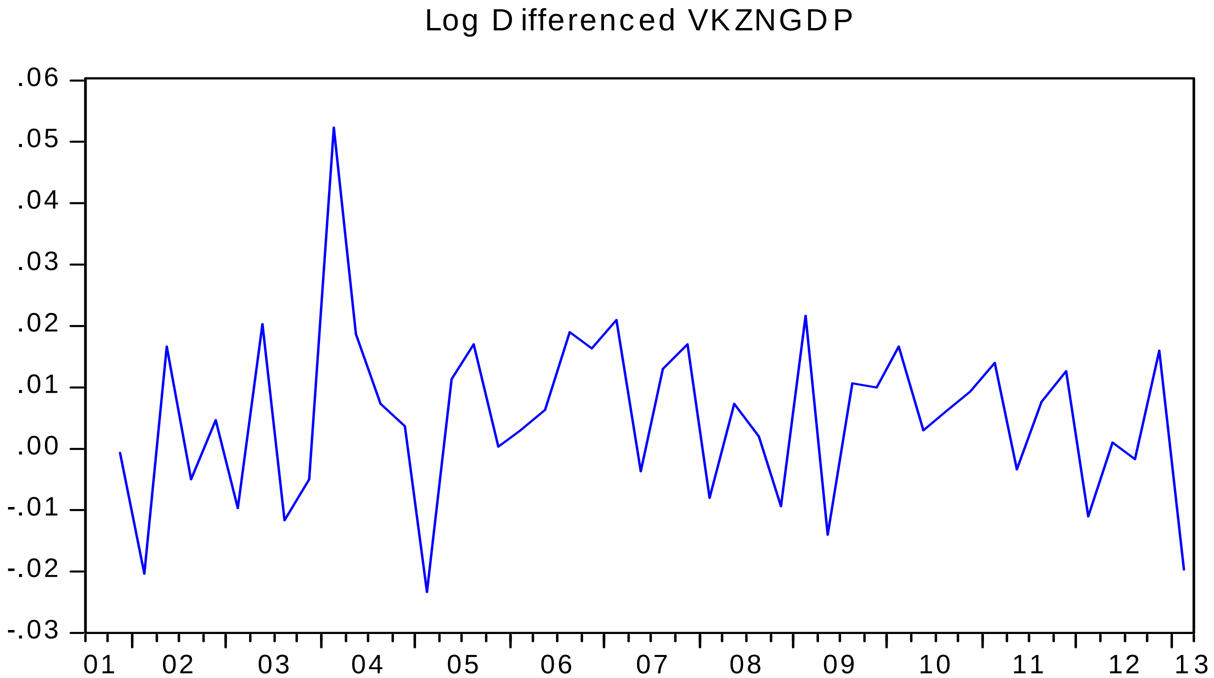
The test statistics suggest that the variable is stationary in the 1^{st} difference format and therefore integrated to the order of 1 or I(1). The stationary variable (1^{st} difference of the log of the provincial seasonal adjusted GDP per skill adjusted labour supply in constant 2005 prices) is displayed in the figure below.

Table 3.1: Augmented Dickey-Fuller using Level and 1st Difference Data

Series	Model	ADF		
		Lags	$\tau_\tau \tau_\mu \tau$	$\varphi_3 \varphi_1$
Level	τ_τ	4	-0.54	0.29
	τ_μ	4	-3.25*	5.27
	τ	4	2.56	
		Lags	$\tau_\tau \tau_\mu \tau$	$\varphi_3 \varphi_1$
1st Difference	τ_τ	4	-7.65***	58.45***
	τ_μ	4	-3.53***	28.56***
	τ	4	-6.51***	

(** significant the 5 percent level, *** significant at the 1 percent level)

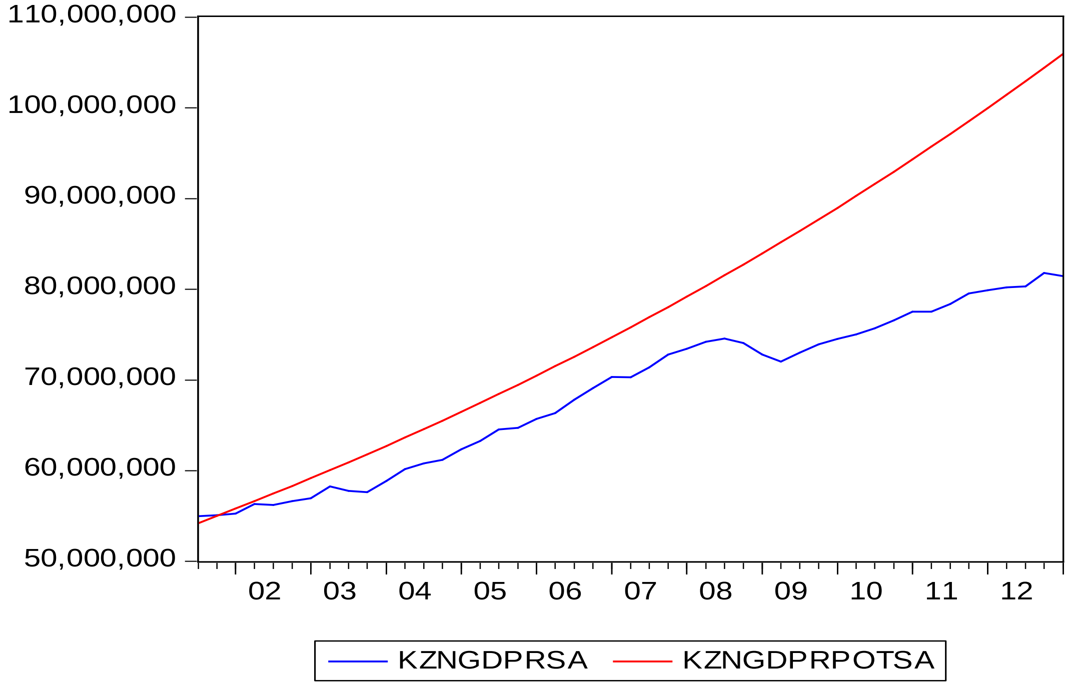
Figure 3.4: Log of the Provincial Seasonal Adjusted GDP per Skill Adjusted Labour Supply in Constant 2005 Prices in 1st Difference Format



(Source: Stats SA and KZN Provincial Treasury)

Figure 3.5 displays the seasonal adjusted actual provincial GDP versus the seasonal adjusted potential provincial GDP that has been calculated using a 6 percent annual growth rate. The figure clearly illustrates the growing output gap.

Figure 3.5: Actual vs. Potential Provincial Seasonal Adjusted GDP in constant 2005 prices (R'billions)



(Source: Stats SA and KZN Provincial Treasury)

4. CONSTRUCTING A NET FIXEDED PROVINCIAL GOVERNEMNT CAPITAL STOCK SERIES FOR THE PROVINCE

Berlemann and Wesselhöft (2012) state that in theoretical models of economic growth the physical capital stock, consisting of e.g. machinery, buildings and computers, is one of the major input factors of the production function. In order to study the contribution of the existing capital stock to aggregate output, data on the capital stock is necessary. However, since the capital stock of a country is not easily observable, data on the development of the capital stock has been unavailable for most countries for a considerable time.

Against the background of the considerable efforts to construct capital stock data it is not too surprising that only a few attempts have yet been made in the literature to generate larger capital stock datasets. Interestingly enough, these few attempts all rely on applying the Perpetual Inventory Method (PIM), a methodology which is also most often used in statistical offices. Examples include Griliches (1980), Nehru and Dhareswhar (1993) Domenech and De La Fuente (2000), Kamps (2006) and Derbyshire, Gardiner and Waights (2010).

The basic idea of the PIM is to interpret an economy`s capital stock as an inventory. The stock of inventory increases with capital formation (investments). Once an investment enters the economy's inventory, it remains there forever and provides services to the inventory's owner. The quantity of services, the investment provides, is at its maximum directly after the investment has been made and decreases in the course of time. The amount by which the capital stock falls per period is the depreciation rate. However, while the value of the investment decreases in the course of time, it never falls to zero. Thus, an investment principally has a perpetual use. The perpetual inventory method uses the following formula:

$$K_t = K_{t-1} - \delta K_{t-1} + GFK_t = (1-\delta)\,K_{t-1} + GFK_t$$

Here, K_t is the time t level of capital stock, GFK_t is the time t level of gross fixeded capital formation and δ is the rate of depreciation (assumed constant over time). In order to calculate the capital stock series, it's clear that three pieces of information are needed, i.e,

- a time series on gross fixeded capital formation (in constant rand value),
- an assumption on the rate of depreciation, and
- an estimate of the initial capital stock level.

Over the years, various researchers have used the PIM to construct capital stock data. While the basic technique is quite similar and follows the idea outlined in the previous section, the specific implementation of the PIM differs to some extent. Methodological differences especially exist with respect to the method to estimate the initial capital stock. The three different approaches used most frequently in the literature are:

- Steady State Approach
- Disequilibrium Approach
- Synthetic Time Series Approach

This paper will not employ any of the above three approaches but rather a national disaggregation approach. Since reliable provincial government gross capital formation data is only available from 2001 we need to estimate the total provincial government capital stock in 2001. This will be done using the total national government gross capital stock as published by the SA Reserve Bank and disaggregating the data to a provincial level. Calculating the total provincial government capital stock is based on the following three steps and illustrated in table 4.1.

- Step 1. The total fixeded capital stock (General government) based on the SA Reserve Bank statistics was R719 billion in 2001 (constant 2005 prices).
- Step 2. National government distributes on average about 32 percent of its resources to the nine provinces through the equitable share system and therefore it's estimated that the total fixeded capital stock (Provincial government) was R230 billion in 2001 (constant 2005 prices).
- Step 3. Of this 32 percent the province of KwaZulu-Natal receives about 21 percent and therefore the estimated total fixeded capital stock (KwaZulu-Natal) was R48 billion in 2001(constant 2005 prices).

Table 4.1 Estimated Fixeded Capital Stock of the KZN Provincial Government in 2001

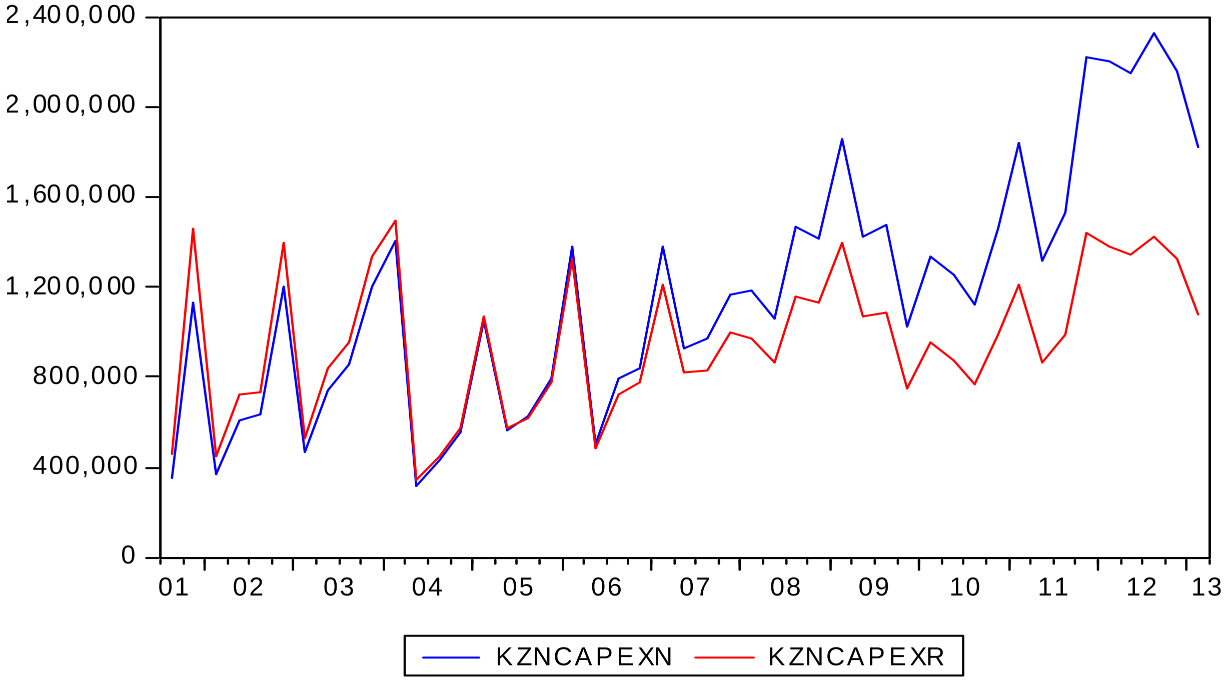
	Fixeded capital stock : KZN Provincial Government
	Fixeded capital stock : General government
2001	R 718 963 000 000
	Provincial Equitable Share
32%	R 230 068 160 000
	KZN Provincial Equitable Share
21%	**R 48 314 313 600**

(Source: SA Reserve Bank, National Treasury, own calculations)

The rate of depreciation is assumed at 5 percent since the majority of total fixeded provincial government capital stock consists of long service lives capital.

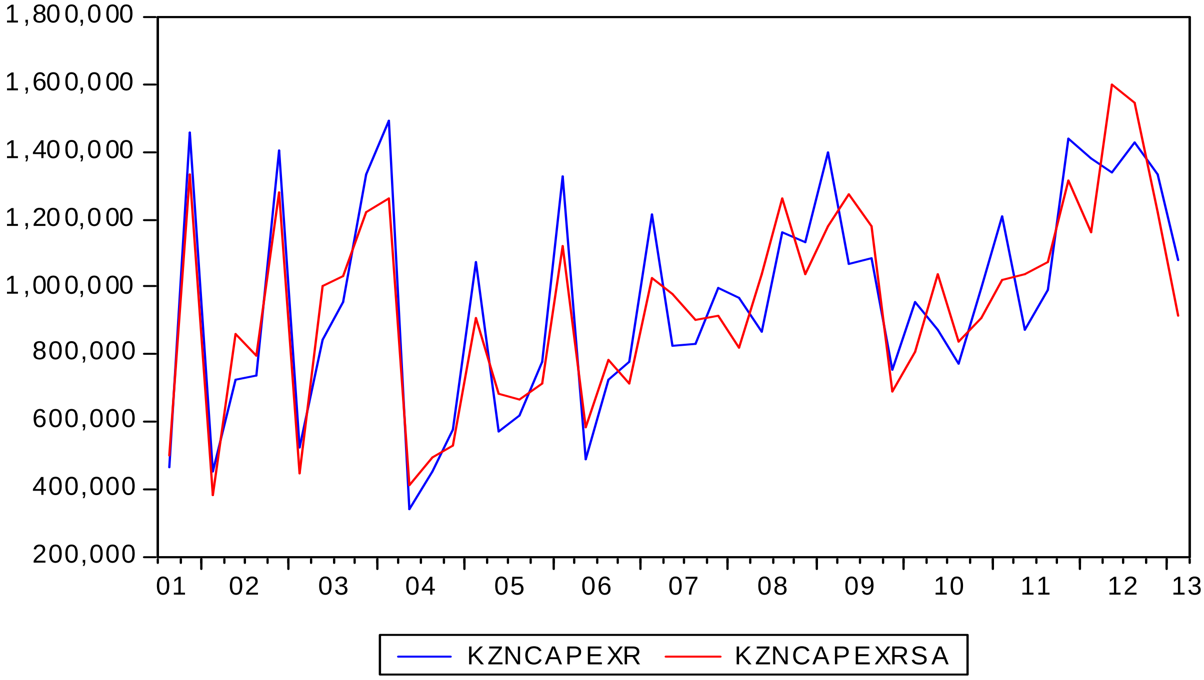
Gross fixeded capital formation is defined as the acquisition, less disposals of tangible and intangible fixeded assets plus major improvements to, and transfer costs on, land and other non-produced assets. The assets acquired may be new or they may be used assets that are traded on second-hand markets. The assets disposed of may be sold for continued use by another producer, they may be simply abandoned by the owner or they may be sold as scrap and be broken down into reusable components, recoverable materials, or waste products. Figure 4.1 displays the provincial government gross fixeded capital formation in both nominal and real terms. The GDP deflator was used to calculate the real provincial government gross fixeded capital formation. Figure 4.2 displays the non-season and seasonal adjusted real provincial government gross fixeded capital formation. The seasonal adjusted real provincial government gross fixeded capital formation was determined using the ratio to moving average method in EViews.

Figure 4.1: Nominal and Real Provincial Government Total Capital Expenditure (R'000)



(Source: KZN Provincial Treasury)

Figure 4.2: Real Provincial Government and Real Seasonal Adjusted Provincial Government Total Capital Expenditure (R'000)



(Source: KZN Provincial Treasury)

Figure 4.3 displays the real net seasonal adjusted fixed provincial government capital stock applying the perpetual inventory method where;

- K_{2001} = **R 48 314 313 600**
- GFK_{2001} = **R500 124 400**
- δ = **5%**

Figure 4.3: Real Net Seasonal Adjusted Fixed Provincial Government Capital Stock (Constant 2005 prices)

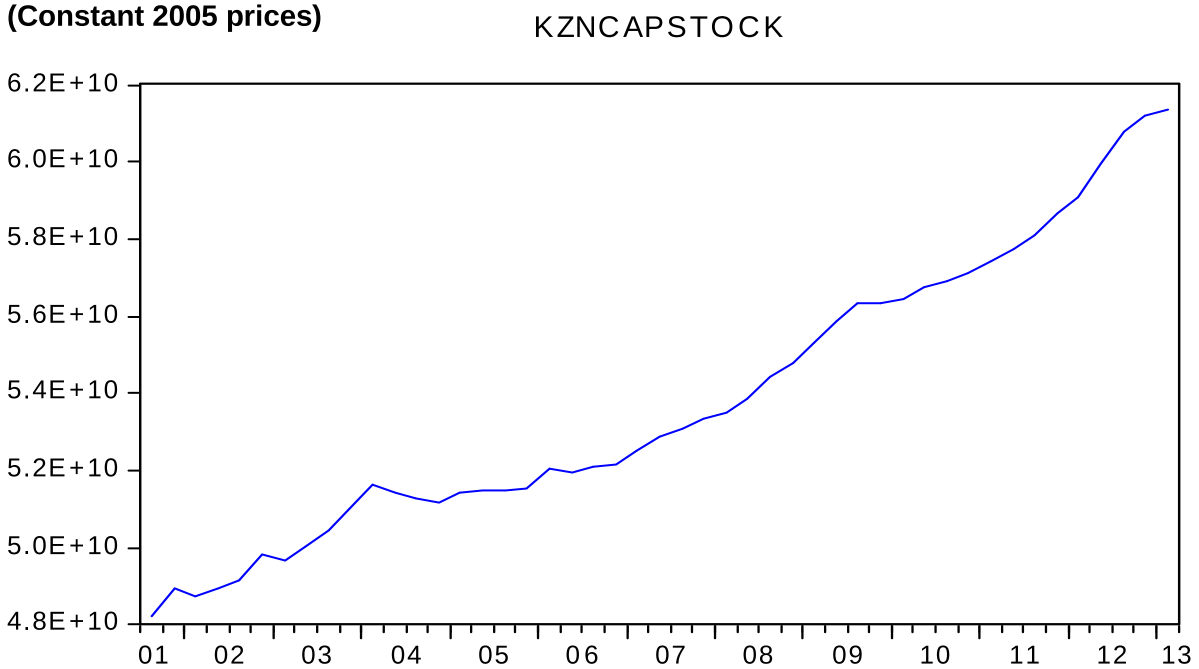
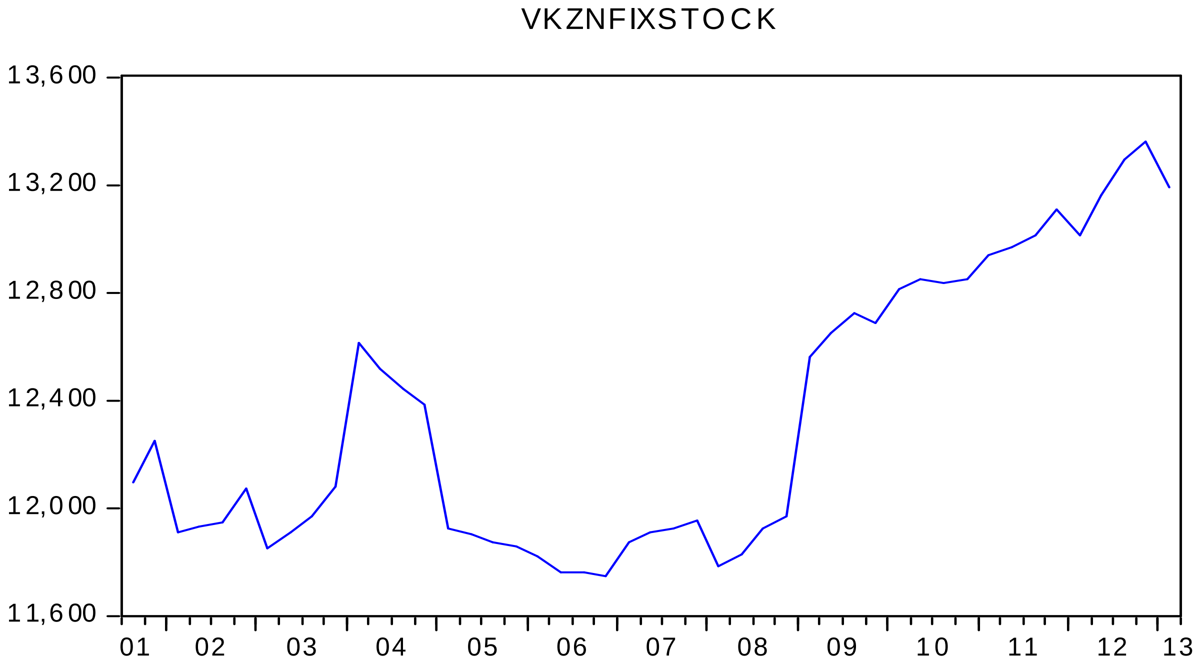
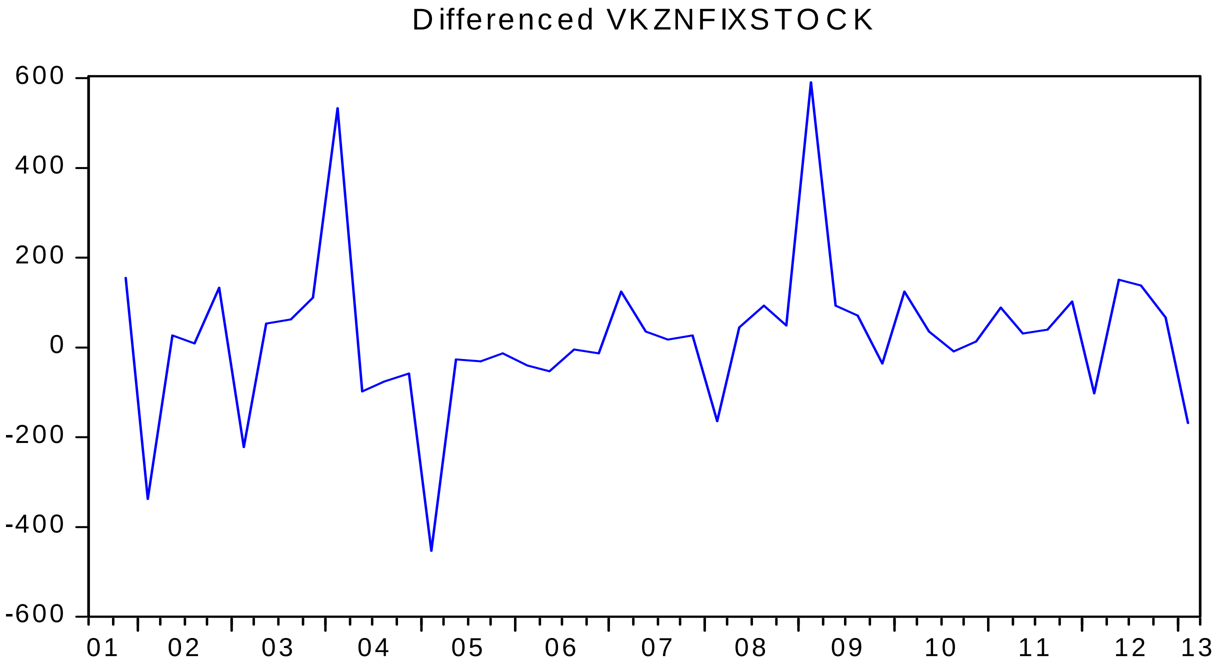


Figure 4.4: Real Net Seasonal Adjusted Fixed Provincial Government Capital Stock per Skill Adjusted Labour Supply (R constant 2005 prices)



The real net seasonal adjusted fixed provincial government capital stock per skill adjusted labour supply is displayed in figure 4.4. The year-on-year change in the real net seasonal adjusted fixed provincial government capital stock per skill adjusted labour supply is displayed in figure 4.5.

Figure 4.5: Change in the Real Net Seasonal Adjusted Fixed Provincial Government Capital Stock per Skill Adjusted Labour Supply (R constant 2005 prices)



The log of the per skill adjusted labour supply value (figure 4.4) is tested for non-stationarity against the alternative that the variable is trend stationary. To perform the Unit Root test on a AR(p) the same methodology as earlier will be used. The results are displayed for each variable in the table below. Comparing the ADF test statistics with the critical test values at 1 percent, 5 percent and 10 percent levels (tau values) and the F-statistics at the 1 percent, 5 percent and 10 percent levels (phi values) suggests that both the variables or time series are non-stationary in level format.

Table 4.2: Augmented Dickey-Fuller using Level and 1st Difference Data

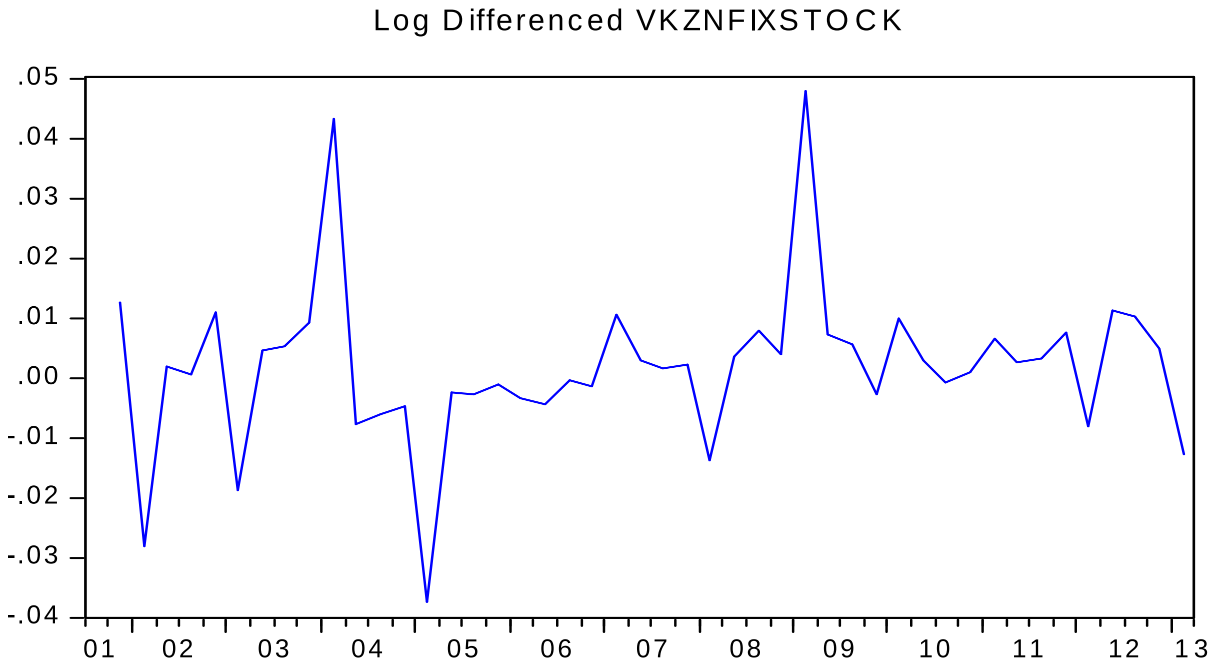
Series	Model	ADF		
		Lags	$\tau_\tau \tau_\mu \tau$	$\varphi_3 \varphi_1$
Level	τ_τ	4	-0.49	0.23
	τ_μ	4	-1.75	2.01

	τ	4	0.95	
		Lags	$\tau_\tau \tau_\mu \tau$	$\varphi_3 \varphi_1$
1st Difference	τ_τ	4	-6.32***	39.95***
	τ_μ	4	-6.45***	20.83***
	τ	4	-6.31***	

(** significant the 5 percent level, *** significant at the 1 percent level)

The test statistics suggest that the variable is stationary in the 1st difference format and therefore integrated to the order of 1 or I(1). The stationary variable (1st difference of the log) of the real net seasonal adjusted fixed provincial government capital stock per skill adjusted labour supply is displayed in the figure below.

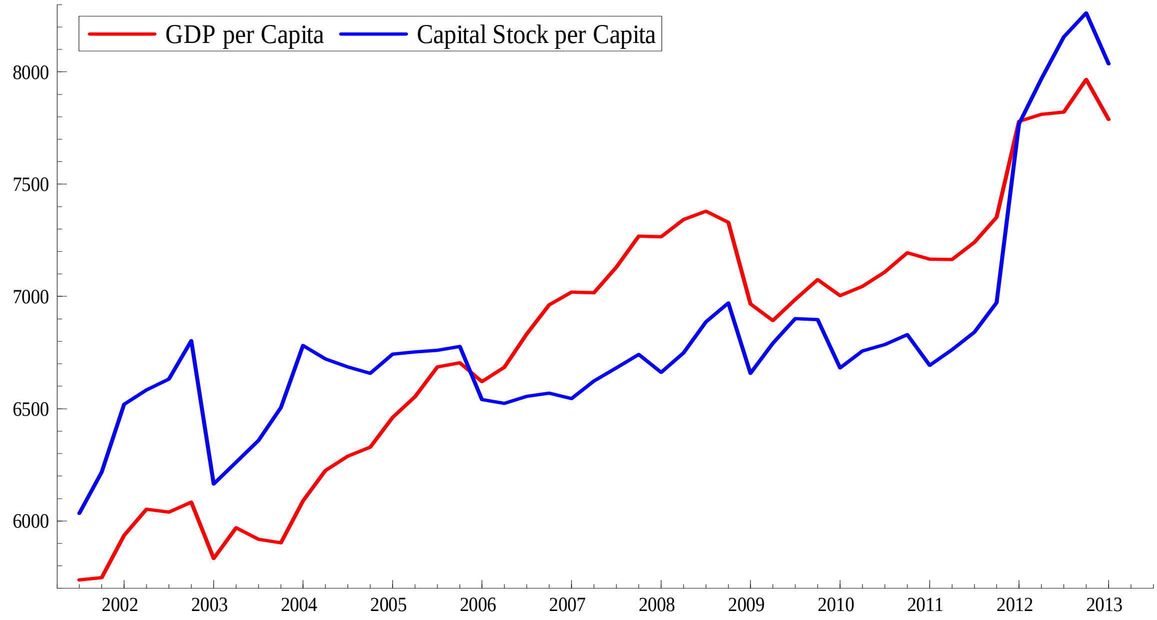
Figure 4.6: Log of the Real Net Seasonal Adjusted Fixed Provincial Government Capital Stock Skill Adjusted Labour Supply in 1st Difference



5. PROVINCIAL FIXED CAPITAL STOCK AND PROVINCIAL ECONOMIC PERFORMANCE

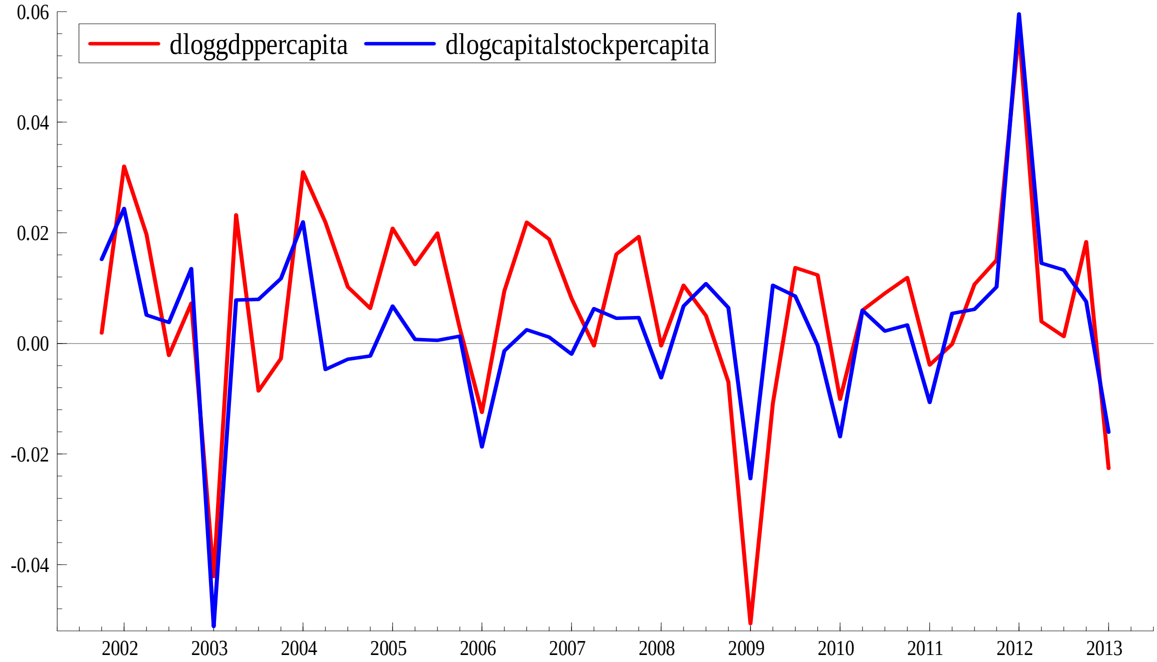
The behaviour of the provincial gross domestic product per skill adjusted labour supply and total fixed capital stock per skill adjusted labour supply over the period 2001 quarter 3 to 2013 quarter 1 are displayed in the figure below (figure 5.1). There seems to be high degree of correlation between the two variables. The correlation coefficient is estimated at 0.76.

Figure 5.1: Co-movement of Provincial Gross Domestic Product per Skill Adjusted Labour Supply and Total Fixed Capital Stock per Skill Adjusted Labour Supply (Rand)



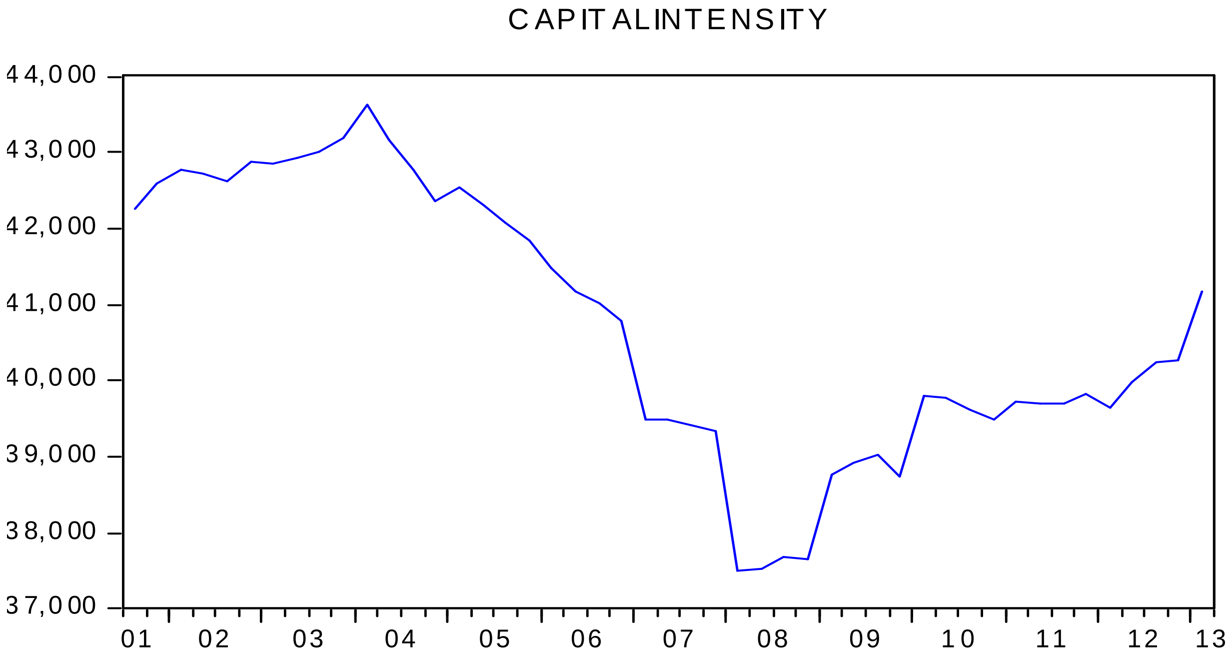
The co-movement is also apparent in the first differences of the natural log values of the two variables as per the figure below. The correlation coefficient is estimated at 0.74.

Figure 5.2: Co-movement of Provincial Gross Domestic Product per Skill Adjusted Labour Supply and Total Fixed Capital Stock per Skill Adjusted Labour Supply (in 1st difference log format)



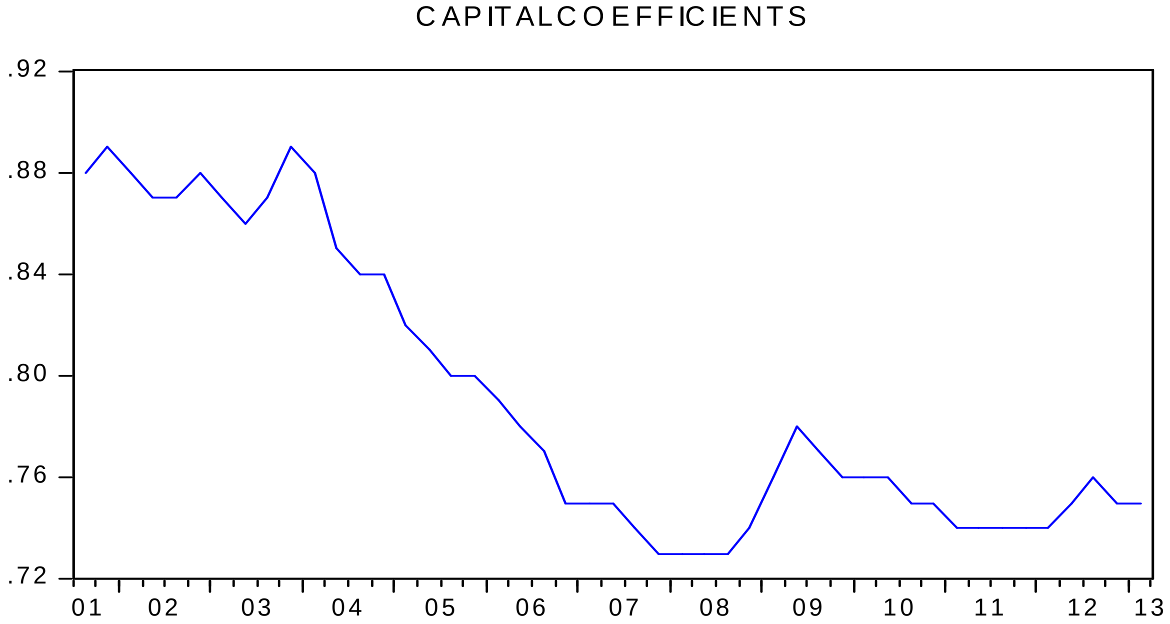
While absolute aggregate capital stock data are often useful for empirical analyses it can be argued that the capital stock available per worker, i.e. capital intensity, is - at least from some perspectives - the more interesting variable. High capital intensities indicate that the amount of physical capital available per worker in the production process is also high. It is evident from the below figure that the provincial capital intensity decreased substantially through the economic “boom” period where after it recovered because of the slowdown in the provincial economic growth rate. It seems that the aggregate provincial capital stock unfortunately has not increased at the same pace as the provincial economy, i.e., lowering of the productivity of labor. This is indicative of diminishing marginal product of provincial capital, or stated differently, a provincial capital accumulation rate that is below optimum. On the other hand, it is possible to argue that in the efficiency of the use of the provincial capital stock the production process has improved.

Figure 5.3: Provincial Capital Intensity Ratio



It is also an interesting question, how much capital a country needs to generate the current output. In order to study this question, the capital coefficient for the province is calculated. The capital coefficient is simply the amount of capital divided by the gross domestic product. The capital coefficient informs how much capital is needed to generate one unit of output. The figure suggests that in 2001, 88 cents of total provincial capital stock was needed to produce R1 of provincial gross domestic product compared to 75 cents in 2012. The diminishing marginal product of provincial capital implies that in the absence of technological progress, high growth rates cannot be sustained over an extended period of time by capital accumulation alone (Braude and Menashe, 2004).

Figure 5.4: Provincial Capital Coefficient



It is possible to estimate the regression function for the variables as displayed in figure 5.2, i.e., provincial gross domestic product per skill adjusted labour supply and total fixed capital stock per skill adjusted labour supply in 1st difference log format using the following equation:

$$\mathbf{dly_t = \alpha + dl\beta g_t + \varepsilon_t}$$

where:

$\mathbf{y_t}$ = provincial gross domestic product per skill adjusted labour supply in 1st difference log format, i.e., $dl(\frac{yt}{st})$

$\mathbf{g_t}$ = provincial total fixed capital stock per skill adjusted labour supply in 1st difference log format, i.e., $dl(\frac{gt}{st})$

$\boldsymbol{\varepsilon_t}$ = error term

The coefficients (α + β) will be estimated using Ordinary Least Squares (OLS) and regression makes use of time series data from 2001 quarter 3 to 2013 quarter 1. The results of the regression are displayed in the table below. The test statistics (t-Statistics and adjusted R-squared) shows that the α and β coefficients and the regression function is statistically significant.

Table 5.1: Output of the Regression Equation

Dependent Variable: DLOG(VKZNGDP)

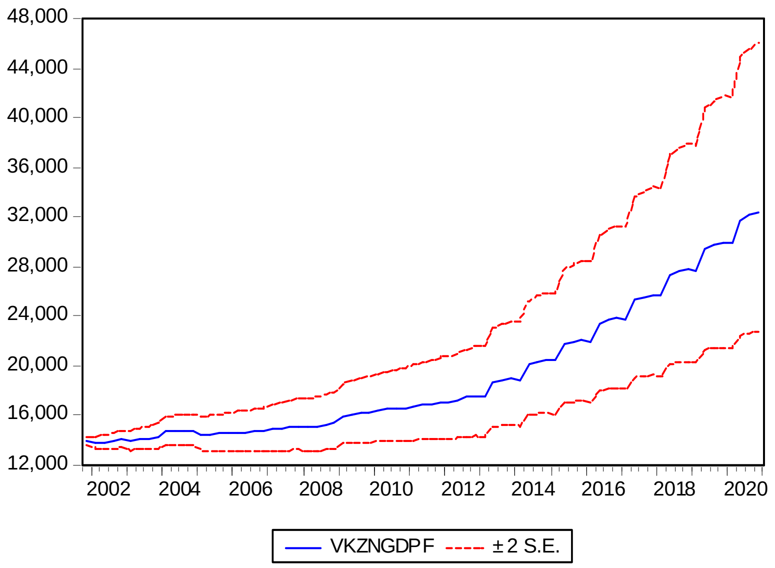
Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(VKZNFIXEDSTOCK)	0.633797	0.118612	5.343444	0.0000
C	0.003984	0.001609	2.476248	0.0172

R-squared	0.393542	Mean dependent var	0.005178
Adjusted R-squared	0.379759	S.D. dependent var	0.013720
S.E. of regression	0.010805	Akaike info criterion	-6.175120
Sum squared resid	0.005137	Schwarz criterion	-6.095613
Log likelihood	144.0278	Hannan-Quinn criter.	-6.145336
F-statistic	28.55239	Durbin-Watson stat	1.505528
Prob(F-statistic)	0.000003		

To test the hypothesis that the coefficient on the provincial capital stock per capita term is equal to 0.77, a Wald test will be performed. The results suggest that the null Hypothesis (D(LKZNCAPSTOCKPOP) = 0) can be rejected. The regression equation suggests that if the difference (change) in provincial capital stock increases by 1 percent then the difference (change) in the provincial gross domestic product will increase by 63 percent.

Forecasting the provincial gross domestic product per skill adjusted labour supply using the above equation yields the below results. The results suggest that an average quarterly 10 percent increase in the provincial total fixed capital stock per skill adjusted labour supply will cause an average quarterly 7.9 percent increase in the provincial gross domestic product per skill adjusted labour supply.

Figure 5.5: Forecast of the Regression Equation



Forecast: VKZNGDPF
Actual: VKZNGDP
Forecast sample: 2001Q3 2020Q4
Adjusted sample: 2001Q4 2020Q4
Included observations: 46

Root Mean Squared Error	579.2042
Mean Absolute Error	480.3114
Mean Abs. Percent Error	3.012053
Theil Inequality Coefficient	0.018561
Bias Proportion	0.350151
Variance Proportion	0.176037
Covariance Proportion	0.473813

The single-equation regression model used (supported by Aschauer, 1989) has, however potential econometric problems like the misspecification of the production function, endogeneity and/or the direction of causality from public capital to productivity. More recently, in the context of the Vector Auto Regressions (VAR) models, the impulse response analysis has been used as a fundamental tool to simulate the effect that an unexpected change of the public capital would have on another variable, for example, on the value of regional production. The use of the VAR approach to test the significance of the dynamic effects of public capital on economic growth presents some advantages, for example, by imposing as few economic restrictions as possible; VAR models try to solve some of the causality and endogeneity problems related to the single equation approach.

Estimating a VAR involves choosing which variables to include in the system, and deciding on the number of lags. The results obtained can be sensitive to both of these choices. The number of lags is usually determined by statistical criteria and variable selection is generally informed by economic theory. These considerations highlight a few of the potential problems in estimating VARs. First, estimation problems increase as the number of variables and lags included in the system rises. More specifically, problems with degrees of freedom will occur if there are large numbers of parameters to be estimated. And the degree of correlation between the lagged variables is likely to reduce the precision of estimated coefficients. The application of economic theory to help determine which variables to include in the VAR is a type of restriction. This implies that VARs are not completely theoretic. However, such concerns can be addressed by making the theory determining the choice of variables sufficiently general or uncontentious. Finally, it should be noted that if the restrictions imposed by more traditional macro econometric models are valid, the parameter estimates derived from such models are likely to be more precise than those derived from the VAR.

Aschauer (1997) employed a Cobb-Douglas production function;

$$y = k^{\alpha k} \, kg^{\alpha kg} \qquad \alpha_k + \alpha_{kg} = 1$$

where:

y is output,

k is a broad measure of private capital (inclusive of tangible and human capital),

and k_g is public infrastructure capital.

All variables are expressed in per worker terms. Thus, the production function exhibits constant returns to scale across the private and public capital inputs, but increasing returns to scale across raw labour and capital. The model ignores technological progress, population growth, and depreciation of private or public capital in order to bring out the essential points in the clearest manner.

The VAR model that will be estimated is based on the Aschauer Cobb-Douglas production function and displayed below. We can let the time path of the $\{y_t\}$ be affected by current and past realizations of the $\{k_t$, s_t and $g_t\}$ sequence and let the time path of the $\{k_t$, s_t and $g_t\}$ sequence be affected by current and past realizations of the $\{y_t\}$ sequence. The VAR (in I(1) format) system is as follows:

$$y_t = a_{10} + a_{11}y_{t-1} + a_{12}k_{t-1} + a_{13}g_{t-1} + e_{1t}$$

$$k_t = a_{20} + a_{21}y_{t-1} + a_{22}k_{t-1} + a_{23}g_{t-1} + e_{2t}$$

$$g_t = a_{40} + a_{31}y_{t-1} + a_{32}k_{t-1} + a_{33}g_{t-1} + e_{3t}$$

where;

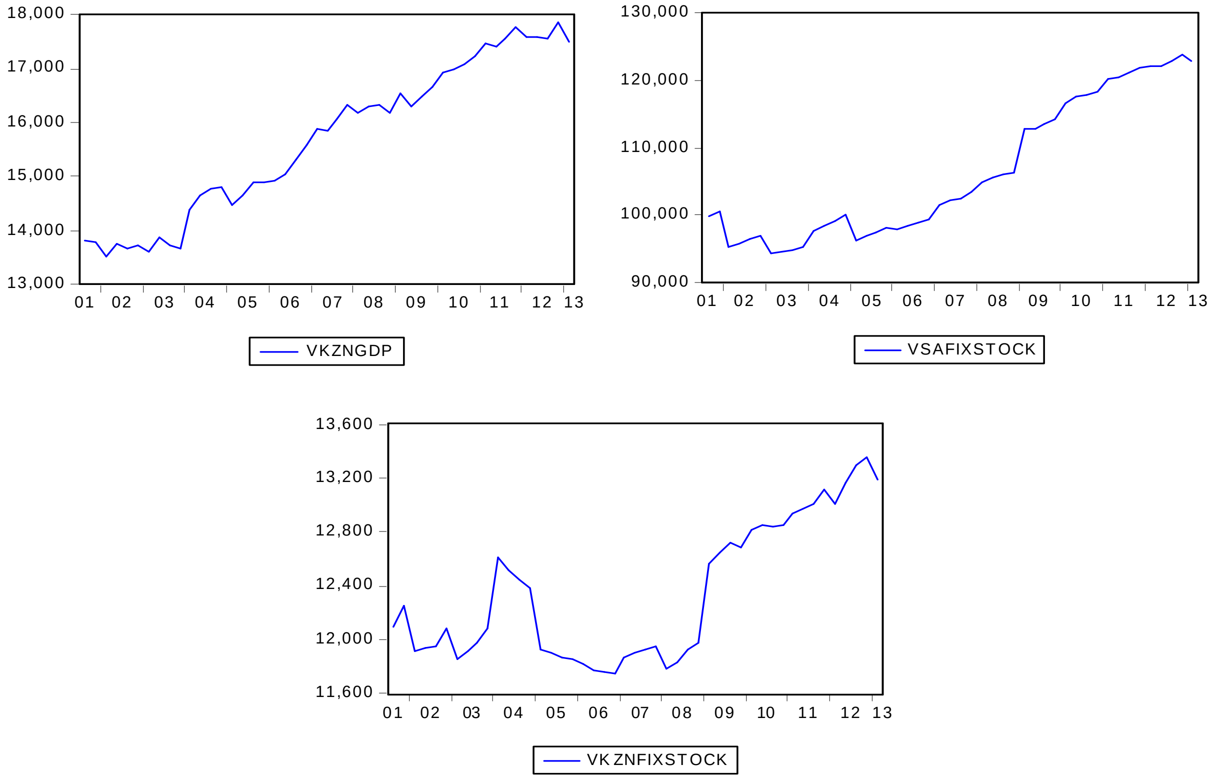
y_t = provincial gross domestic product per skill adjusted labour supply in 1st difference format, i.e., $d(\frac{yt}{st})$

k_t = total national capital stock (general government and private) per skill adjusted labour supply in the province in 1st difference format, i.e., $d(\frac{kt}{st})$

g_t = provincial total fixed capital stock per skill adjusted labour supply in 1st difference format, i.e., $(\frac{gt}{st})$

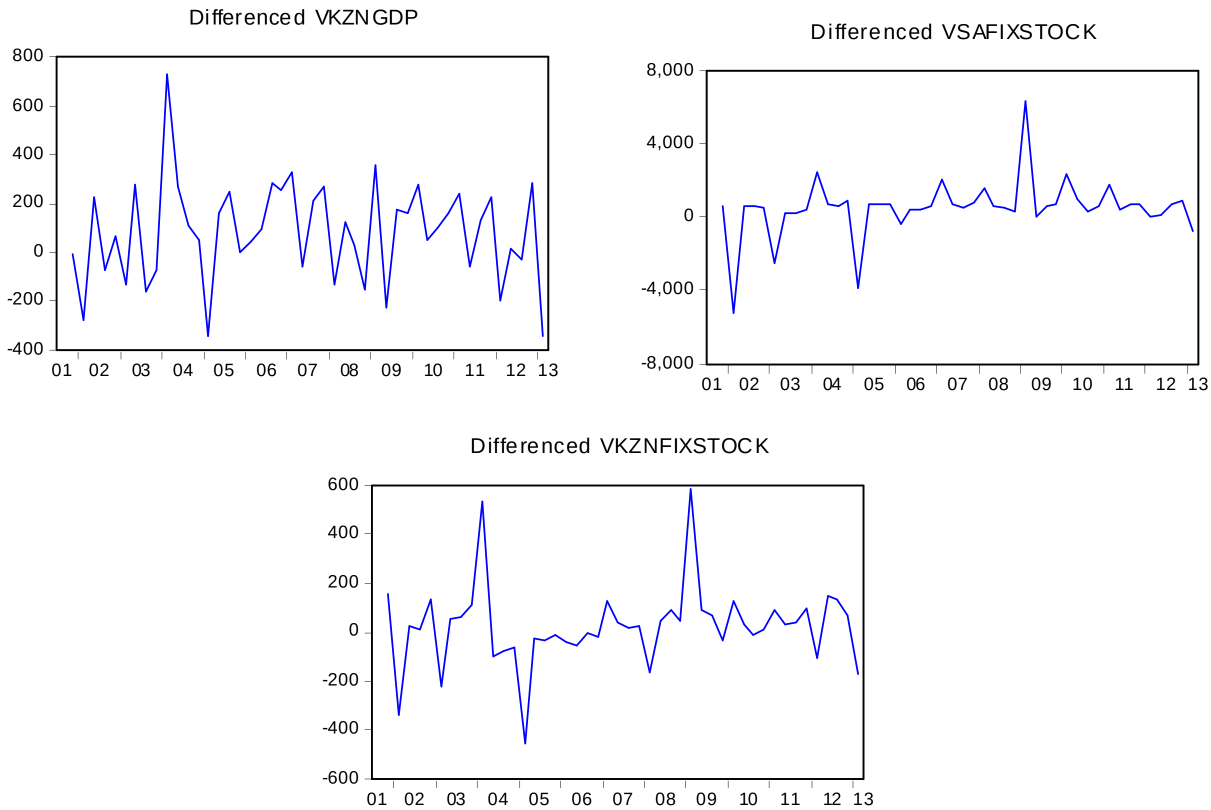
and where it is assumed (i) that $\mathbf{y_t}$, $\mathbf{k_t}$ and $\mathbf{g_t}$ are stationary; (ii) $\mathbf{e_{1t}}$, $\mathbf{e_{2t}}$ and $\mathbf{e_{3t}}$ are white-noise disturbances with standard deviations of $\boldsymbol{\sigma_y}$, $\boldsymbol{\sigma_k}$ and $\boldsymbol{\sigma_g}$ respectively; and (iii) the error terms are uncorrelated. The equations constitute a first-order VAR since the longest lag length is unity. However, additional lags will be included if deemed necessary. The structure of the system incorporates feedback since $\mathbf{y_t}$, $\mathbf{k_t}$ and $\mathbf{g_t}$ are allowed to affect each other. The variables (in non-stationary format) are displayed in the figure below (figure 5.6). On the other hand, the variables (in stationary format) are displayed in the figure 5.7.

Figure 5.6: VAR Variables in Non-stationary format (R constant 2005 prices)



The model will be estimated using EViews and will make use of quarterly data ranging from quarter 3:2001 to quarter 1:2013. Four lags will be included in the model. No exogenous variables, except the constant have been included.

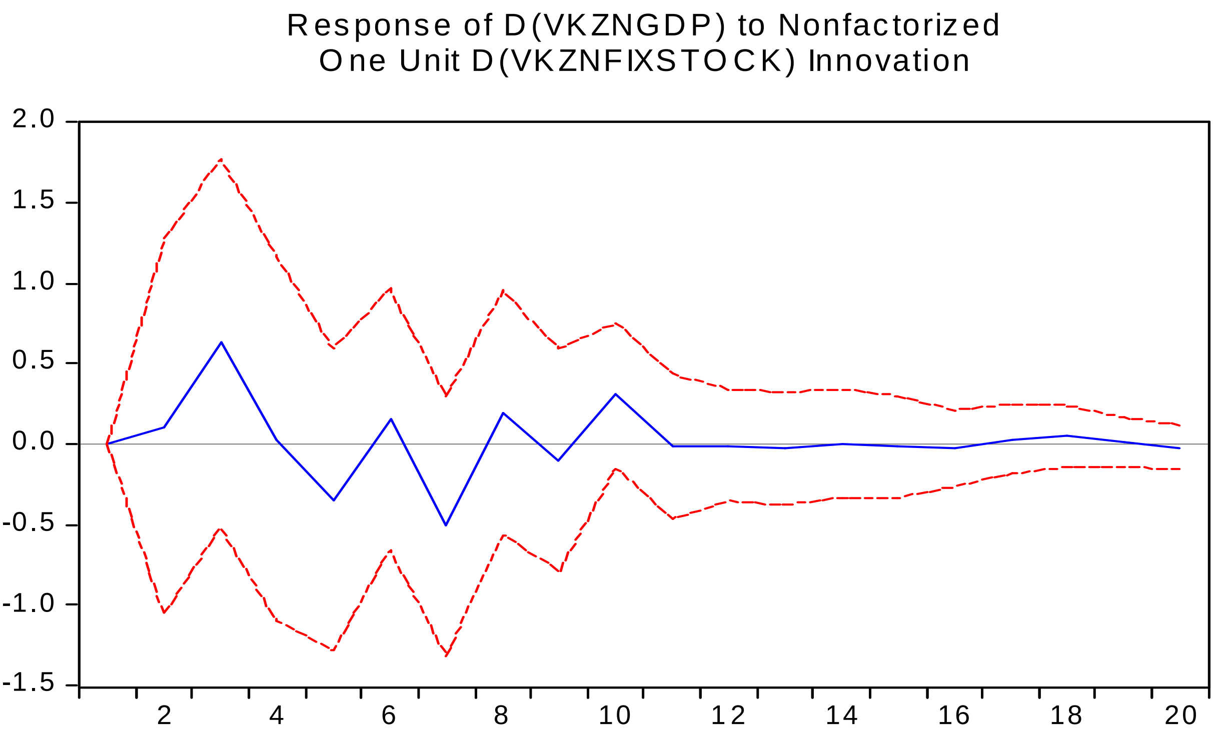
Figure 5.7: VAR Variables in Stationary format (R constant 2005 prices)



A number of tests were performed on the model suggesting that 1) the estimated VAR is stable (stationary) in that all roots have modulus less than one and lie inside the unit circle, 2) the Granger Causality test (p=0.69) suggests that the model is stationary and that there is no problem of spurious Granger causality, 3) the lag length criteria supports the use of 4 lags, 4) the residual Portmanteau tests for autocorrelations suggests no residual autocorrelations (p at lag 5 = 0.004), 5) the residual serial correlation LM test indicates no serial correlation at lag order 6 and 6) the White Heteroskedasticity test indicates the joint significance of the repressors (p=0.71). The results of the diagnostic statistics in general support the appropriateness of the estimated VAR model.

Impulse response traces out the response of current and future values of each of the variables to a one-unit increase in the current value of one of the VAR errors, assuming that this error returns to zero in subsequent periods and that all other errors are equal to zero. The implied thought experiment of changing one error while holding the others constant makes most sense when the errors are uncorrelated across equations, so impulse responses are typically calculated for recursive and structural VARs. The figure below displays the impulse-response functions for the estimated VAR model over the following 20 quarters. The residual—one unit (one percent) decomposition method (sets the impulses to one unit of the residuals) suggests that over a 5 year period, increases in total provincial government stock actually has a very small positive impact (in fact it's almost insignificant) on the provincial gross domestic product (average 0.02 percent per quarter).

Figure 5.8: Impulse Response Output of the VAR Model (20 quarters)



The figure below (figure 5.9) displays the impulse response output as per figure 5.8. It also includes a linear regression function (y = -0.0047x + 0.0712) where y is the effect of the nonfactorized one unit provincial total fixed capital stock per capita innovation on the provincial gross domestic product per capita and x = time (20 quarters). The sign of the coefficient itself is positive suggesting an overall long term positive effect. However, the coefficient is not statistically significant (p=0.61). It is therefore at this stage an open question whether a permanent increase in provincial public investment induces a permanent, or merely a temporary, increase in provincial economic growth.

The figure below (figure 5.10) displays the impulse-response functions for the estimated VAR model over the 50 quarter horizon. The results suggest that at best the effect of the nonfactorized one unit provincial total fixed capital stock per capita innovation on the provincial gross domestic product per capita is temporary. This is in line with the traditional neoclassical growth model of Solow (1956) that predicts that any positive effect of an increase in the national savings and investment rate on economic growth will be transitory; the steady-state growth rate is fully determined by population growth and exogenous technological progress.

Figure 5.9: Effect of the Nonfactorized One Unit Provincial Total Fixed Capital Stock per Capita Innovation on the Provincial Gross Domestic Product per Capita (20 quarters)

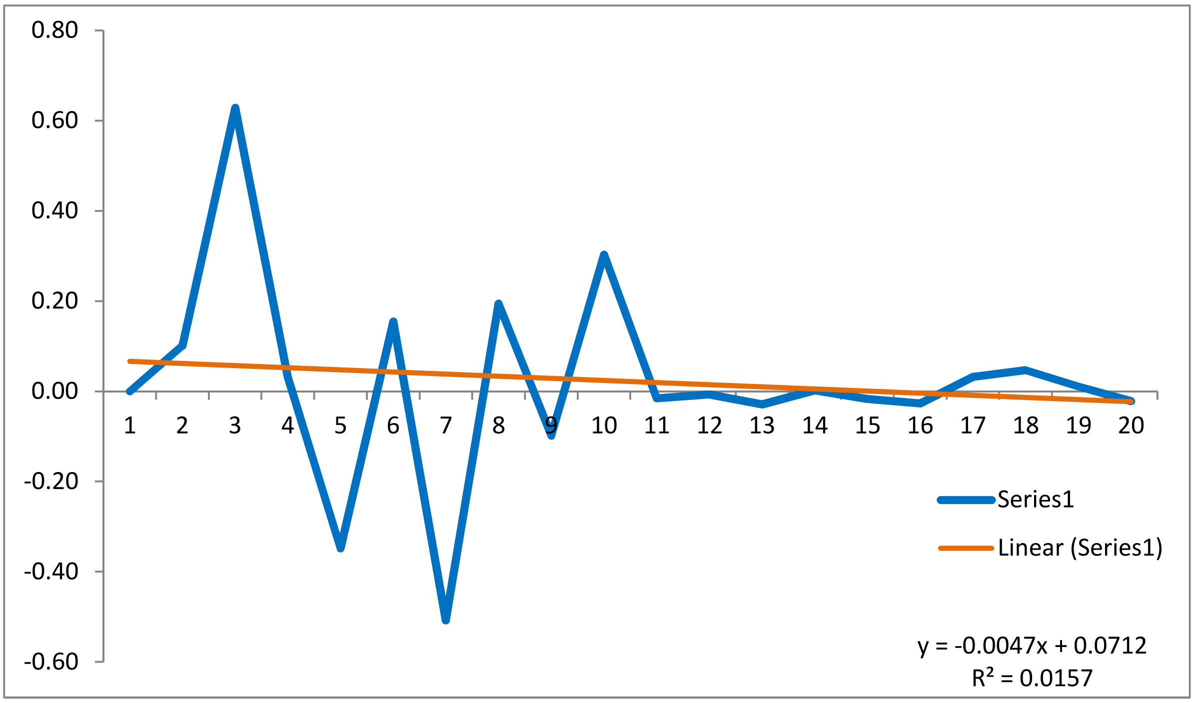
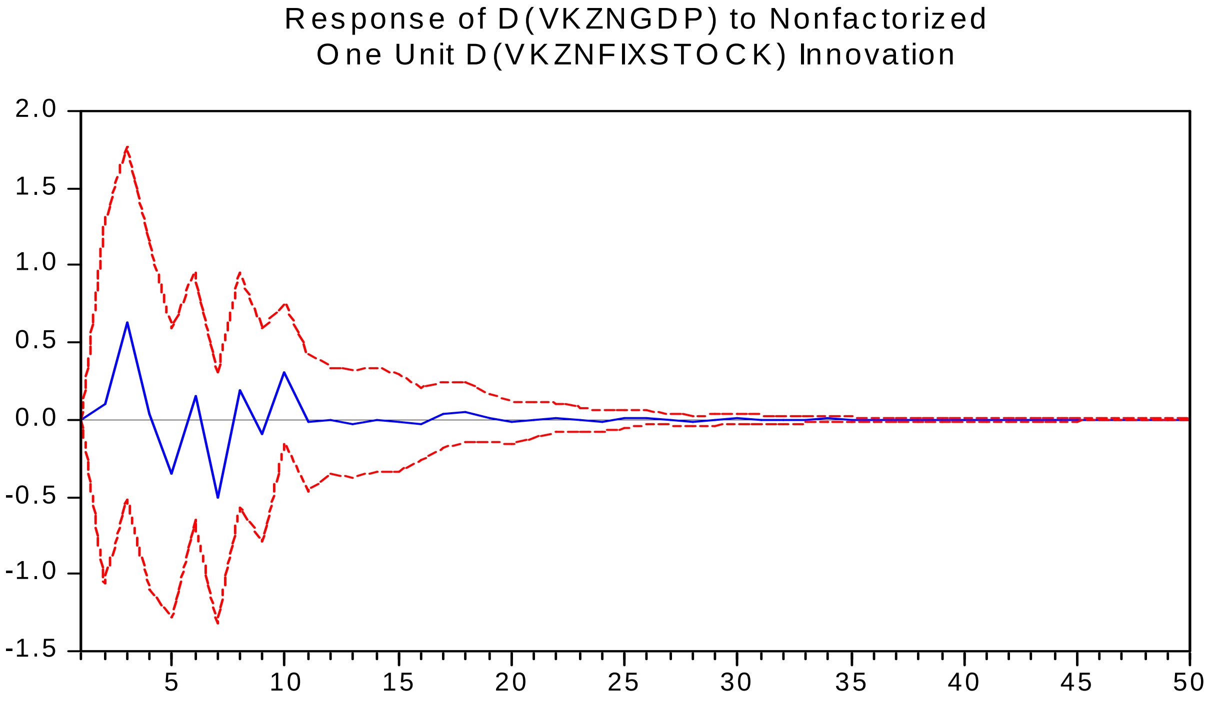
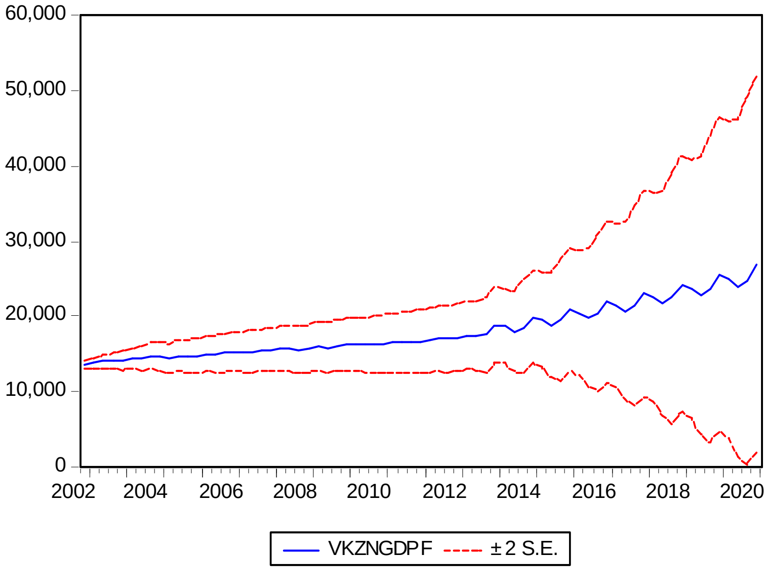


Figure 5.10: Impulse Response Output of the VAR Model (50 quarters)



Forecasting the provincial gross domestic product per skill adjusted labour supply $(d(\frac{yt}{st})_{t\text{-}1\ to\text{-}t\text{-}4})$ using the VAR yields the below results. The results suggest that an average quarterly 10 percent increase in the provincial total fixed capital stock per skill adjusted labour supply will cause an average quarterly 4 percent increase in the provincial gross domestic product per skill adjusted labour supply.

Figure 5.11: Forecast of the VAR



Forecast: VKZNGDPF	
Actual: VKZNGDP	
Forecast sample: 2001Q3 2020Q4	
Adjusted sample: 2002Q4 2020Q4	
Included observations: 42	
Root Mean Squared Error	558.0872
Mean Absolute Error	463.8168
Mean Abs. Percent Error	2.808245
Theil Inequality Coefficient	0.017713
Bias Proportion	0.540769
Variance Proportion	0.302620
Covariance Proportion	0.156611

A number of studies have focused on the possible existence of a long run and short run statistically significant relationship between public capital and economic growth. These studies in most cases employ a co-integration approach and an error-correction process to account for both simultaneous effect of capital stock innovations and responses to deviations from the steady state. This relationship will be tested using the Engle-Granger co-integration and error correction procedure. The assumed co-integrated relationship can be expressed as follows:

$$\ln y_t = \alpha_1 + \beta \ln k_t + \lambda \ln g_t + e_{1t}$$

where;

$\mathbf{y_t}$ = log provincial gross domestic product per skill adjusted labour supply, i.e., $log(\frac{yt}{st})$

$\mathbf{k_t}$ = log total national capital stock (general government and private) per skill adjusted labour supply in the province in 1st difference format, i.e., $log(\frac{kt}{st})$

$\mathbf{g_t}$ = log provincial total fixed capital stock per skill adjusted labour supply in 1st difference format, i.e., $\log(\frac{gt}{st})$

$\boldsymbol{\varepsilon_t}$ = error term

In order to test if the assumed co-integrated relationship indeed exists, it is crucial that the variables be integrated to the same order and that the error terms are stationary. Consider that the two variables Y_t and X_t are both $I(d)$ (i.e., they have compatible long-run properties). In general, any linear combination of Y_t and X_t will be also $I(d)$. However, if there exists a vector (1, - β)', such that the linear combination $\boldsymbol{\varepsilon_t = Y_t - \alpha - \beta X_t}$ is indeed $I(d - b)$, $d \geq b > 0$, then, following Engle and Granger (1987), Y_t and X_t are defined as cointegrated of order (d , b). The ADF test statistics indicate that the variables are indeed I(1) and therefore they are indeed integrated to the same order.

The results of the regression is indicated in the table below, suggesting that the **β** and **λ** consumption is statistically significant (t>2). The adjusted R statistic is fairly high, but the Durban Watson statistic is a cause of concern. However, the biggest surprise is the negative sign of the **λ** coefficient. The cointegrating equation can be expressed as follows:

LOG(VKZNGDP) = 1.33*LOG(VSAFIXEDSTOCK) - 1.11*LOG(VKZNFIXEDSTOCK) + 4.73

Table 5.2: Co-integration Relationship

Dependent Variable: LOG(VKZNGDP)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(VSAFIXEDSTOCK)	1.328496	0.086034	15.44148	0.0000
LOG(VKZNFIXEDSTOCK)	-1.108967	0.197507	-5.614833	0.0000
C	4.732226	1.094021	4.325533	0.0001

R-squared	0.921519	Mean dependent var	9.656050
Adjusted R-squared	0.917952	S.D. dependent var	0.091833
S.E. of regression	0.026305	Akaike info criterion	-4.376437
Sum squared resid	0.030445	Schwarz criterion	-4.258343
Log likelihood	105.8463	Hannan-Quinn criter.	-4.331997
F-statistic	258.3240	Durbin-Watson stat	0.343346
Prob(F-statistic)	0.000000		

The results of the ADF test suggests that the residuals are indeed stationary and therefore a co-integration relationship exists amongst the variables at a 1 percent level of significance (p=0.0025).

Once it has been established that there does exist a long run relationship between the variables, it is possible to construct an error correction model to simulate the short run relationship between the variables. The error correction model is specified as follows:

$$\Delta \ln y_t = \alpha_2 + \beta_2 \Delta \ln k_t + \lambda_2 \Delta \ln g_t + \varepsilon e_{t-1} + v$$

where:

Δy_t = log provincial gross domestic product per skill adjusted labour supply, i.e., dlog$(\frac{yt}{st})$

Δk_t = log total national capital stock (general government and private) per skill adjusted labour supply in the province in 1st difference format, i.e., dlog$(\frac{kt}{st})$

Δg_t = log provincial total fixed capital stock per skill adjusted labour supply in 1st difference format, i.e., dlog$(\frac{gt}{st})$

β and λ = cointegrating coefficient

ε = coefficient on the lagged gap or known as equilibrium error term of one period lag

v_t = white noise innovation

In this form, β_2 and λ_2 are called the long-run parameters and ξ is called the short-run parameter. The residuals that have been calculated using the co-integration equation and that have been tested for stationarity are incorporated in an error correction equation to derive the error correction model. The proposed error correction model is displayed in the table below. Intuitively, the error correction term seems to be statistically insignificant given that the coefficient of the lagged residual is positive and insignificant.

Table 5.3: Error Correction Process

Dependent Variable: DLOG(VKZNGDP)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(VSAFIXEDSTOCK)	0.233045	0.240949	0.967194	0.3390
DLOG(VKZNFIXEDSTOCK)	0.438168	0.271226	1.615509	0.1137
RESID01(-1)	0.054547	0.083941	0.649829	0.5193
C	0.003287	0.001689	1.945869	0.0584

R-squared	0.447200	Mean dependent var	0.005178
Adjusted R-squared	0.407714	S.D. dependent var	0.013720
S.E. of regression	0.010559	Akaike info criterion	-6.180803
Sum squared resid	0.004682	Schwarz criterion	-6.021790
Log likelihood	146.1585	Hannan-Quinn criter.	-6.121236
F-statistic	11.32561	Durbin-Watson stat	1.704300
Prob(F-statistic)	0.000014		

The short run coefficients for β_2 and λ_2 are 0.23 and 0.44 respectively, which indicate that the coefficients for $\Delta \mathbf{k_t}$ and $\Delta \mathbf{g_t}$ are not significant since the p-values are greater than 0.05. The positive sign of (0.05) suggest that there is not a long-run equilibrium relationship among the variables. The coefficient for error term (ξ) of 0.05 implies that the model does not follow and error corrected process, i.e., the model is not a significant long-run model with no long-run equilibrium relationships among the variables.

A possible alternative to the above approach is to develop a vector error correction model (VECM) based on the below Cobb-Douglas production function using the Johansen Co-integration test. The four variables are integrated to the same order, i.e., they are integrated to the order 1.

$$lnYt = \ a_0 + \ \alpha lnS_t + \ \beta lnK_t + \ \gamma lnG_t + \varepsilon_t$$

Y_t is the real aggregate level of provincial output (GDP) at period t, K_t is the aggregate total national capital stock (general government and private) in the province (excluding aggregate provincial public capital stock), G_t is the aggregate provincial public capital stock, and S_t is the skill-adjusted aggregate provincial labour supply. ε_t is the stationary error term. The log transformed variables will be used in the model. The results of the test procedures as per the below table suggest that there is indeed a co-integrating relationship between the four variables.

Table 5.4: Results of the Johansen Co-integration test

Series: LOG(VKZNGDP) LOG(VKZNLABOUR) LOG(VSAFIXEDSTOCK) LOG(VKZNFIXEDSTOCK)
Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.541659	55.65042	47.85613	0.0078
At most 1	0.306579	20.54407	29.79707	0.3867
At most 2	0.080892	4.068764	15.49471	0.8979
At most 3	0.006047	0.272958	3.841466	0.6014

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

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.541659	35.10635	27.58434	0.0045
At most 1	0.306579	16.47531	21.13162	0.1983
At most 2	0.080892	3.795806	14.26460	0.8803
At most 3	0.006047	0.272958	3.841466	0.6014

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

The long run co-integrating equation is displayed in the table below. In both cases the signs of the provincial total fixed capital stock coefficient are positive, suggesting that increases in the provincial total fixed capital stock will positively affect provincial gross domestic product.

Table 5.5: Normalized cointegrating coefficients (standard error in parentheses)

Long Run Co-integrating Model

LOG(VKZNGDP)	LOG(VKZNLABOUR)	LOG(VSAFIXEDSTOCK)	LOG(VKZNFIXEDSTOCK)
1.000000	0.512835	-1.676286	1.599107
	(0.35336)	(0.35495)	(0.63380)

Co-integrating Equation

D(LOG(VKZNGDP)) = LOG(VKZNGDP(-1)) - 0.182651032796*LOG(VKZNLABOUR(-1)) - 0.706033757589*LOG(VSAFIXEDSTOCK(-1)) + 0.0196600977309*LOG(VKZNFIXEDSTOCK(-1)) - 3.67909894887

We can derive the residual of the above co-integrating equation. The error term is negative indicating that the long run co-integrating model will revert back to equilibrium. The co-integrating coefficient of G_t suggests that a 1 percent increase in provincial capital stock will support a 1.9 percent increase the change in the provincial gross domestic product. Unfortunately, the coefficient does not seem to be statistically significant. Given that all four variables are co-integrated we can run the vector error correction model.

Table 5.6: Results of the VECM

Dependent Variable: D(LOG(VKZNGDP))
D(LOG(VKZNGDP)) = C(1)*(LOG(VKZNGDP(-1)) - 0.182651032796
*LOG(VKZNLABOUR(-1)) - 0.706033757589*LOG(VSAFIXEDSTOCK(-1)) +
0.0196600977309*LOG(VKZNFIXEDSTOCK(-1)) - 3.67909894887) + C(2)
*D(LOG(VKZNGDP(-1))) + C(3)*D(LOG(VKZNGDP(-2))) + C(4)
*D(LOG(VKZNLABOUR(-1))) + C(5)*D(LOG(VKZNLABOUR(-2))) + C(6)
*D(LOG(VSAFIXEDSTOCK(-1))) + C(7)*D(LOG(VSAFIXEDSTOCK(-2))) + C(8)
*D(LOG(VKZNFIXEDSTOCK(-1))) + C(9)*D(LOG(VKZNFIXEDSTOCK(-2))) +
C(10)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.068938	0.050913	-1.354035	0.1847
C(2)	0.328744	0.180708	1.819198	0.0777
C(3)	-0.238954	0.195907	-1.219732	0.2310
C(4)	0.062154	0.130521	0.476199	0.6370
C(5)	0.032078	0.131624	0.243707	0.8089
C(6)	0.054467	0.242360	0.224738	0.8235
C(7)	0.467715	0.213265	2.193111	0.0352
C(8)	-0.760067	0.364835	-2.083320	0.0448
C(9)	0.386711	0.326561	1.184191	0.2446
C(10)	0.005381	0.005375	1.001157	0.3238

R-squared	0.327598	Mean dependent var	0.008818
Adjusted R-squared	0.149610	S.D. dependent var	0.009696
S.E. of regression	0.008941	Akaike info criterion	-6.399524
Sum squared resid	0.002718	Schwarz criterion	-5.994026
Log likelihood	150.7895	Hannan-Quinn criter.	-6.249146
F-statistic	1.840558	Durbin-Watson stat	1.880639
Prob(F-statistic)	0.096467		

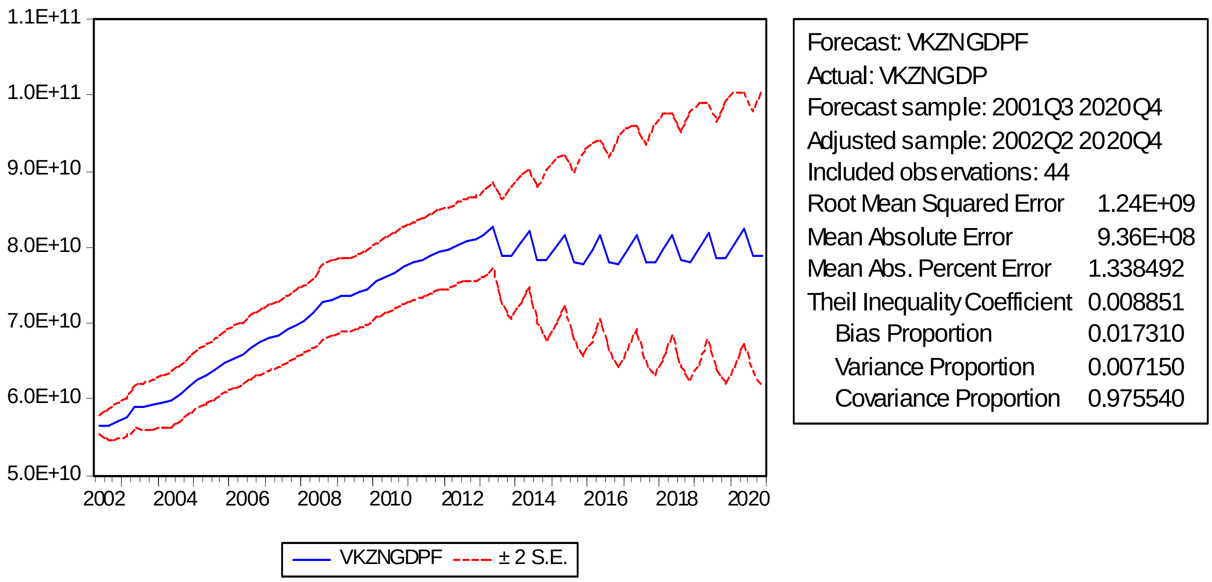
The results indicate that the co-integrating coefficient (c1) (speed of adjustment towards long run equilibrium) have a negative sign suggesting a long run causality from the three independent variables (S_t, K_t and G_t) to the dependent variable (Y_t) i.e., the three independent variables have an influence in the long run on the provincial gross domestic product.

The results of the vector error correction estimates (2 lags included) yield a coefficient of -.76 and 0.39 for the first difference of the log provincial total fixed capital stock (y_{t-1}) and first difference of the log provincial total fixed capital stock 2 lags (y_{t-2}), respectively. Estimating the system using OLS indicates that the y_{t-1} coefficient is statistically significant (p=0.04) where as the y_{t-2} coefficient is not statistically significant (p=0.24). Testing for the joint significance (using the Wald test statistics) of the y_{t-1} and y_{t-2} coefficients indicates that they are not jointly significant (p=0.07). This indicates that there seems to be no short run causality between the provincial capital stock and the provincial gross domestic product.

Testing the above model for statistical errors indicate that 1) the R squared is fairly low, 2) the f statistic (joint significance) is not statistically significant, 3) the Breusch-Godfrey Serial Correlation LM test indicates that the model is not suffering from serial correlation (p=0.35), 4) the Heteroskedasticity Test: Breusch-Pagan-Godfrey indicates that the model does not have Heteroskedasticity (p=0.08) and 5) the residuals are normally distributed (p=0.67).

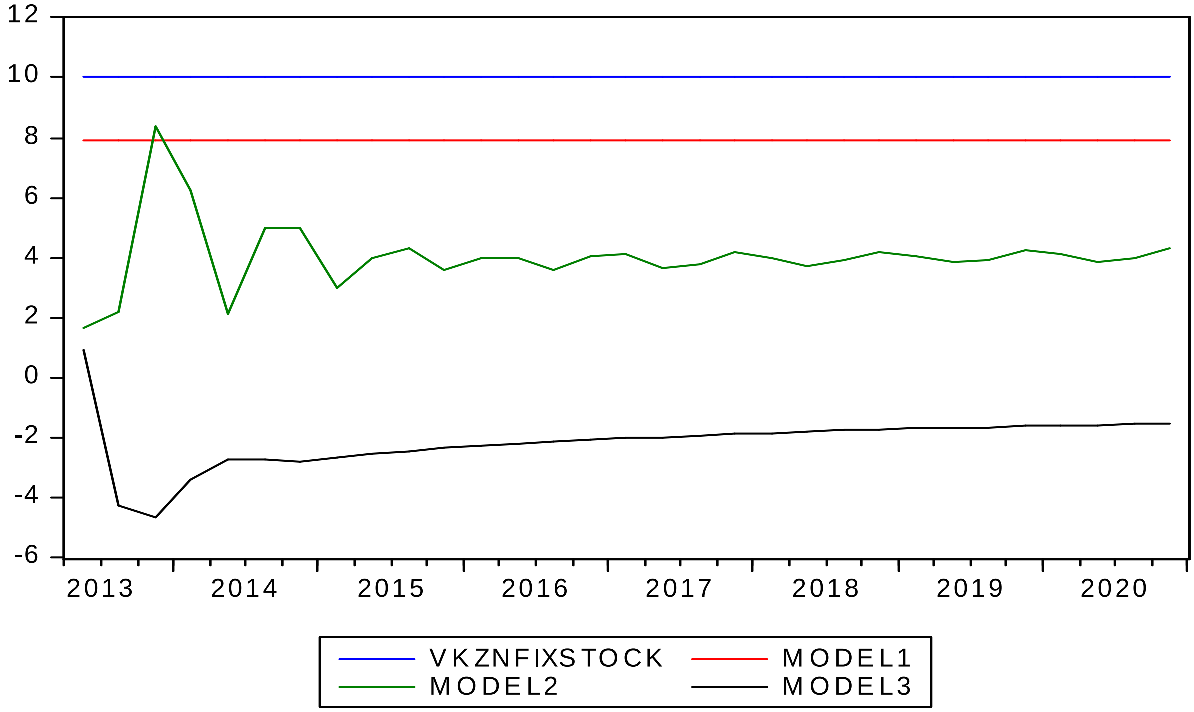
Forecasting the provincial gross domestic product (Y_t) using the VECM yields the below results. The results suggest that an average quarterly 10 percent increase in the provincial total fixed capital stock will cause an average quarterly -2.13 percent increase (decrease) in the provincial gross domestic product.

Figure 5.12: Forecast of the VECM



The figure below illustrates the comparative forecasts of the three models (Y_t) based on a 10 percent average quarterly increase in provincial public capital stock (S_t). Model 1 is the single equation model (average quarterly increase of 8.9 percent), model 2 is the VAR model (average quarterly increase of 5.7 percent), and model 3 is the VECM model (average quarterly increase of -0.13 percent).

Figure 5.13: Comparative Forecasts of the Three Models (%, 2013q2 to 2020q4)



6. SUMMARY AND CONCLUSIONS

Recent studies by various authors have focused on the importance of publicly owned infrastructure in the economy. Publicly owned infrastructure has also gained the attention of a number of economists, arguing that increased investment in public infrastructure improves growth and prosperity. David Aschauer seemingly rekindled the economics profession's interest in infrastructure in the United States with a series of papers asserting that investment in the public sector not only improved quality of life, but it also increased economic growth and improved returns for private investments.

The purpose of this paper has been to assess the empirical contribution of provincial infrastructure accumulation (fixed capital stock) to provincial growth using an explicit model of economic growth using time series data. The paper introduces provincial infrastructure capital into a neoclassical model of economic growth (Cobb Douglas production function) in a fashion symmetric to private and national government capital accumulation, and examines the empirical implications.

The paper first had to construct a new dataset of total provincial public capital stock since national accounts do not report a series for the provincial capital stock. The provincial capital stock was constructed using the perpetual inventory method.
The empirical results support the argument of a long run equilibrium relationship between provincial capital stock and provincial gross domestic product. The results also suggest that the long run causality or effect fades over time, albeit slowly. However, the nature and statistical significance of the long run equilibrium relationship is ambiguous at best. On the other hand, no evidence of a short run equilibrium relationship could be found. Therefore, there does not seem to be any causality between provincial capital stock and provincial gross domestic product in the short run. This is not unsurprising given that provincial public investment projects take numerous years to complete.

The major contribution of this paper is its analysis of the relationship between provincial public stock and provincial growth. It presents models that analyze the link between provincial public stock and provincial growth, in a spatial economic context. The literature in SA is fairly scarce in terms of spatial economic analysis and therefore this paper contributes to the spatial economic research effort.

Literature suggests that there is indeed some sort of growth maximizing level of infrastructure above which the diversion of resources from other productive uses outweighs the gain from having more infrastructure. Unfortunately, given the reliability and inconstancy issues encountered with the models, it was not possible to venture into this particular topic. However, this topic should be high on the agenda for future research.

Using the predictions of growth models to guide infrastructure analyses appears to be a promising avenue for further research. The analysis presented in this paper controls for the level of private and national government capital accumulation, but does not model municipal infrastructure accumulation, nor differentiate between private and national government capital accumulation. An obvious and important extension, therefore, is estimation of the private, national provincial and municipal capital accumulation in the context of a well-specified model.

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