The Interdependence between the Saving Rate and Technology across Regimes: Evidence from South Africa

Kevin S. Nell and Maria M. De Mello

ERSA working paper 674

March 2017

The Interdependence between the Saving Rate and Technology across Regimes: Evidence from South Africa*

Kevin S. Nell† and Maria M. De Mello‡

November 2016

Abstract

This paper hypothesises that the saving rate and technological progress are interdependently determined by a common exogenous source, so that an exogenous shock to the saving rate determines long-run growth transitions. In an open economy, the saving rate measures the quality of capital investment. The evidence shows that the down-break across South Africa's 'faster-growing' regime (1952-1976) and 'slower-growing' regime (1977-2003) was caused by a negative exogenous shock to the saving rate that simultaneously led to a slowdown in the growth rate of technology through a structural decrease in the learning-by-doing parameter. The down-break results suggest that the saving rate is potentially an important policy variable to engineer a sustainable up-break. To assess this prediction with real data, the analysis looks at the post-2003 period (2004-2012). The results show that the up-break in the fixed investment rate was not matched by the saving rate, which implies that capital investment did not generate a faster rate of technological progress. The stylised facts suggest that a *sustained* increase in the *total* investment rate, which includes infrastructure investment, machinery and equipment investment and complementary foreign direct investment, may be an effective investment-led strategy to raise the economy's growth rate on a sustainable basis.

Keywords: growth transitions; investment rate; learning-by-doing; multiple regimes; saving rate; Solow model; South Africa; technological progress; time-series econometrics

JEL Classification: C22, O11, O41, O47, O55

---

* The authors would like to acknowledge valuable comments from seminar participants at the University of Johannesburg (UJ), Department of Economics and Econometrics; conference participants at the 6th biennial Value 2016 Conference hosted by the Faculty of Economic & Financial Sciences (UJ), and an anonymous reviewer of Economic Research Southern Africa (ERSA).

† University of Johannesburg, Department of Economics & Econometrics, South Africa.

‡ Faculty of Economics and Center for Economics and Finance of the University of Porto (CEF.UP), Portugal.

1. INTRODUCTION

A major policy issue in developing economies is whether a faster rate of physical capital accumulation is a key determinant of growth transitions, or whether growth shifts are primarily the outcome of an 'unexplained' or 'mysterious' total factor productivity (TFP)/technology progress component (King and Levine, 1994; Easterly and Levine, 2001; Bosworth and Collins, 2003; Helpman, 2004; Baier et al., 2006; Aghion and Howitt, 2007; Jones and Olken, 2008; Bond et al., 2010; Herrerias and Orts, 2012; Gollin, 2014; Tang and Tan, 2014; Nell, 2015). An overview of the cross-country empirical literature suggests that there is no clear consensus on the relative importance of physical capital accumulation in the growth and development process. For example, on the one hand, there is Easterly and Levine (2001) who attribute the bulk of per capita income growth rate differences across countries to TFP growth, both in a quantity and causal sense. On the other hand, the growth accounting exercise of Bosworth and Collins (2003) and causality tests of Bond et al. (2010) show that physical capital accumulation remains an important source of growth.[1]

To shed some new light on the issue, this paper hypothesises that there exists an interdependent relationship between the saving rate (as a measure of the quality of capital investment) and technological progress in a 'typical' developing country with multiple regimes.[2] The empirical application re-examines the role of physical capital accumulation and technological progress across South Africa's different growth regimes during 1952-1976, 1977-

[1] Similarly, studies that use non-parametric production-function techniques also provide conflicting evidence on the importance of physical capital accumulation. For example, Kumar and Russell (2002) and Henderson and Russell (2005) find that labour productivity growth is primarily driven by physical and human capital accumulation. In contrast, Badunenko and Romero Ávila (2013) emphasise the importance of financial development.

[2] Pritchett's (2000) influential study shows that, in contrast to industrialised countries, most developing economies exhibit shifts in growth rates that lead to distinct patterns, and that these patterns remain unexplained in cross-country growth regressions. Motivated by Pritchett and earlier work by Easterly et al. (1993), several recent studies, such as Hausmann et al. (2005), Jerzmanowski, (2006), Jones and Olken (2008), Rodrik (2000), and Kerekes (2012) have attempted to identify the key determinants of growth transitions.

2003 and 2004-2012, and then uses the modelling framework to predict how the economy can improve its future growth performance on a sustainable basis.

In this context, the paper makes several contributions to the existing literature. First, we conduct the empirical analysis in a multiple-regime framework. Granger causality-type tests between output growth and the saving/investment rate, such as those employed and reviewed in King and Levine (1994), Attanasio et al. (2000), Easterly and Levine (2001), Bond et al. (2010), and Tang and Tan (2014), are typically performed in a single-regime framework. If, however, there are multiple regimes, then the results obtained from structurally unstable single-regime regression models may lead to misleading inferences about the causal role of the saving/investment rate. Indeed, our full sample period results for South Africa show that the saving rate is endogenous, but once regime changes are controlled for, the saving rate becomes a causal determinant of per capita income across regimes. This may also explain why empirical studies to date provide ambiguous evidence on the causal role of the saving/investment rate in South Africa.[3] Second, we advance the idea that in an open economy the saving rate, rather than the investment rate, may be the most suitable indicator to determine whether physical capital accumulation is accompanied by technological progress. In this framework, the saving rate is a measure of the quality or productivity of capital investment, and may serve as a broad indicator to assess whether policies are successful in attracting foreign direct investment (FDI), as well as raising investment in machinery and equipment with embodied technical progress and supportive investment in productive structures. This hypothesis has some affinity with the model developed in Aghion et al. (2009), in which the domestic saving rate determines FDI, but we emphasise the

[3] Odhiambo (2007) finds no causal effect of the saving rate on per capita income over the period 1950-2005. Romm (2005), in contrast, shows that there is bi-directional causality between the private saving rate, private investment rate and per capita income over the period 1946-1992. Both studies, however, do not control for regime changes in the South African economy.

importance of investment incentives and *'animal spirits'* of entrepreneurs as the driving force of saving (see Deaton, 1999). Third, growth accounting exercises typically assume a share of capital in income of around one-third. In this regard, we accord with Bosworth and Collins (2003) who remark that this assumption may understate the growth-inducing effect of capital when there is embodied technical progress with associated learning-by-doing effects. In contrast to most studies, this paper fully incorporates the potential growth effect of learning-by-doing, and how it may change across multiple regimes.

Finally, the main hypothesis of the paper can be stated as follows. We wish to test whether there exists an *interdependent* relationship between the saving rate and technological progress across regimes, instead of an *independent* relationship as assumed in the original Solow (1956) model. The modelling framework we develop assumes that a semi-endogenous growth model, with positive learning-by-doing effects ($0 < \phi < 1$), describes South Africa's 'faster-growing' (*FGR)* regime. A 'Solow-type' model (1956), with close to zero learning-by-doing effects ($\phi \approx 0$), becomes the relevant theoretical framework in the economy's 'slower-growing' (*SGR*) regime. The down-break across the learning-by-doing model and the Solow-type model is initiated through a negative exogenous shock that simultaneously decreases the domestic saving rate and the rate of technological progress. The interdependence arises due to a common set of exogenous factors that jointly determine the saving rate and the growth rate of technological progress, and the fact that both sources of growth are causal determinants of the regime shift. The key policy implication of the interdependence hypothesis is that the growth rate of technology is no longer fixed – policies that increase the saving rate, which measures the quality of capital investment, will also increase the rate of technological progress.

The empirical results for the South African economy over the period 1952-2012 show the following. The period 1952-1976 represents South Africa's *FGR* and the period 1977-2003 its *SGR*. The rest of the sample period is characterised by a phase of 'super-fast' growth (2004-2007) and a slowdown in growth after the global financial crisis (2008-2012). After controlling for the gold price bubble over the period 1979-1981, our analysis suggests that the down-break across the *FGR* and *SGR* occurred simultaneously with a significant drop in the growth rate of the fixed capital stock and large downward trend breaks in both the saving and fixed investment rate. Correlation, of course, does not necessarily mean causality, so we also test the exogeneity of the saving rate in a theory-consistent structural cointegrating vector-autoregressive (VAR) model. The results indicate that the saving rate long-run causes per capita income across South Africa's *FGR* and *SGR*. This implies that the down-break in the saving rate is a causal determinant of the slowdown in growth across South Africa's *FGR* and *SGR*. In addition to the growth effect of the saving rate, the sharp drop in the learning-by-doing parameter from 0.54 in the *FGR* to 0.10 in the *SGR* indicates that a negative shock to technological progress can also account for the slowdown in growth. Taken together, the empirical evidence suggests that the saving rate and technological progress are interdependently determined by a common exogenous source, rather than independently determined as assumed in the Solow model. Thus, policies that raise the quality of capital investment, which is measured by the saving rate, will also increase the rate of technological progress and, in the process, perpetuate the growth effect of capital accumulation through stronger learning-by-doing effects.

To assess these predictions with real data, we examine the role of the saving rate in South Africa's post-2003 growth performance. We find that the investment rate increased sharply relative to the saving rate over the period 2004-2012, while the learning-by-doing (technology) parameter remained 'constant'. Overall, the results suggest that although physical capital accumulation is an important (potential) source of growth, not every type of investment shock will automatically generate a faster rate of technological progress. From a practical policy-making point of view, the main implication is that a large scale government-led infrastructure programme, such as the recent one launched under the Accelerated and Shared Growth Initiative for South Africa (ASGI-SA) programme, may, on its own, not be enough to initiate a *long-run* growth transition, unless it is complemented with other investment incentives that relax some of the binding constraints on the source of technological progress, such as machinery and equipment investment and FDI[4]. This highlights the key policy implication of the paper: to generate a sustained growth transition, a refined set of investment-led policies should be implemented to ensure that a faster rate of capital accumulation is accompanied by technological progress.

The rest of the paper is structured as follows. Section 2 identifies several stylised facts of South Africa's growth performance over the period 1952-2012. This section serves as important background information to set up the interdependence hypothesis in section 3. Section 4 discusses the empirical methodology and section 5 presents the empirical results. Section 6 uses the results of South Africa's down-break to predict how the economy can engineer a sustainable up-break in its growth performance. Section 7 concludes.

2. STYLISED FACTS OF SOUTH AFRICA'S GROWTH PERFORMANCE: 1952-2012

This section uses a statistical breakpoint detection method, descriptive evidence and previous growth narratives to identify several stylised facts of South Africa's growth performance over the period 1952-2012. The analysis serves as essential background information to set up the interdependence hypothesis in the next section and to interpret the econometric results later on.

[4] For a critical evaluation of the ASGI-SA programme, see Frankel et al. (2008).

2.1 Identifying Growth Regimes in the South African Economy

Following the large literature on growth shifts mentioned in footnote 2, a useful way of indentifying the timing of these shifts is to employ a statistical procedure that searches for unknown breaks endogenously, such as Bai and Perron's (1998, 2003) multiple breakpoint detection test (see, for example, Jones and Olken, 2008; Berg et al., 2012). We use Bai and Perron's method to test for structural breaks in the following log-linear trend model:

$$\ln\left(y_{p/c}\right)_t = b_0 + b_R t + u_t, \tag{1}$$

where $\ln\left(y_{p/c}\right)_t$ is the natural logarithm (ln) of real GDP per capita, b_0 is a constant, t is time trend measured in years, b_R is the average growth rate in regime R, and u_t is an unobserved disturbance term. The data cover the period 1952-2012.[5] Appendix A provides a detailed description of all the variables.

By specifying a maximum of five potential breakpoints, the Bai and Perron procedure identifies structural breaks in 1976, 1985, 1994 and 2003, where the breakdates denote the last date of the preceding regime.[6] The 1976 breakdate differs from those reported in previous studies. The Bai and Perron test used in Jones and Olken (2008) and Kar et al.'s (2013) new breakpoint test both detect a structural break in 1981.

The breakdate in 1976, however, is consistent with one of the main historical events that occurred in South Africa over the sample period. Growth narratives typically identify the Soweto riots of 1976 as a major turning point in the South African economy (Mohr and Rogers, 1995;

[5] The South African Reserve Bank's real GDP per capita series dates back to 1946. However, due to excessive growth volatility in the immediate aftermath of World War II, we exclude the three-year period 1946-1948 from the sample, and only consider the period 1949 to 2012. In addition, the use of lagged and differenced variables in the econometric section further reduces the effective sample period to 1952-2012.

[6] The Bai and Perron test is computed with EViews 9. We specify a trimming parameter of 15%, a breakpoint detection significance level of 5%, and allow the time trend in equation (1) to vary across regimes but not the constant.

Fedderke and Liu, 2002).[7] As shown in Fedderke and Liu (2002), the permanent increase in political instability that followed the Soweto uprising triggered a disinvestment campaign by foreign investors and long-term capital flight. The impact of increased political and social instability on South Africa's economic performance, however, was to some extent mitigated by the high dollar gold price that prevailed during the period 1979-1981. South Africa, as a major exporter of gold, directly benefited from the high and increasing gold price since the late 1970s, with per capita income growth surging to an average annual rate of 3.5% over the period 1980-1981. These historical events suggest that it may be misleading to treat 1981 as a breakpoint in South Africa's long-run growth performance.[8]

The second (1985) and third (1994) breakdates we obtain are broadly consistent with Du Plessis and Smit's (2007) growth accounting exercise. They examine the determinants of South Africa's growth revival in the 10 years after the democratic transition in 1994 relative to the period 1985-1994. Nevertheless, by the authors' own account, the 'growth revival' was still modest by international standards and South Africa's own historical performance (Du Plessis and Smit, 2007: p. 669). To put South Africa's 'growth revival' into perspective, over the period 1994-2003 per capita income growth averaged 0.73%. Although this was an impressive transition from the negative averaged rate of -1.22% during 1985-1993, it still remained well below the average rate of 2.28% during the period 1952-1976. For now, and given that we are interested in identifying long-run growth shifts, we assume that 1985 and 1994 do not signify turning points in South Africa's long-run growth performance.

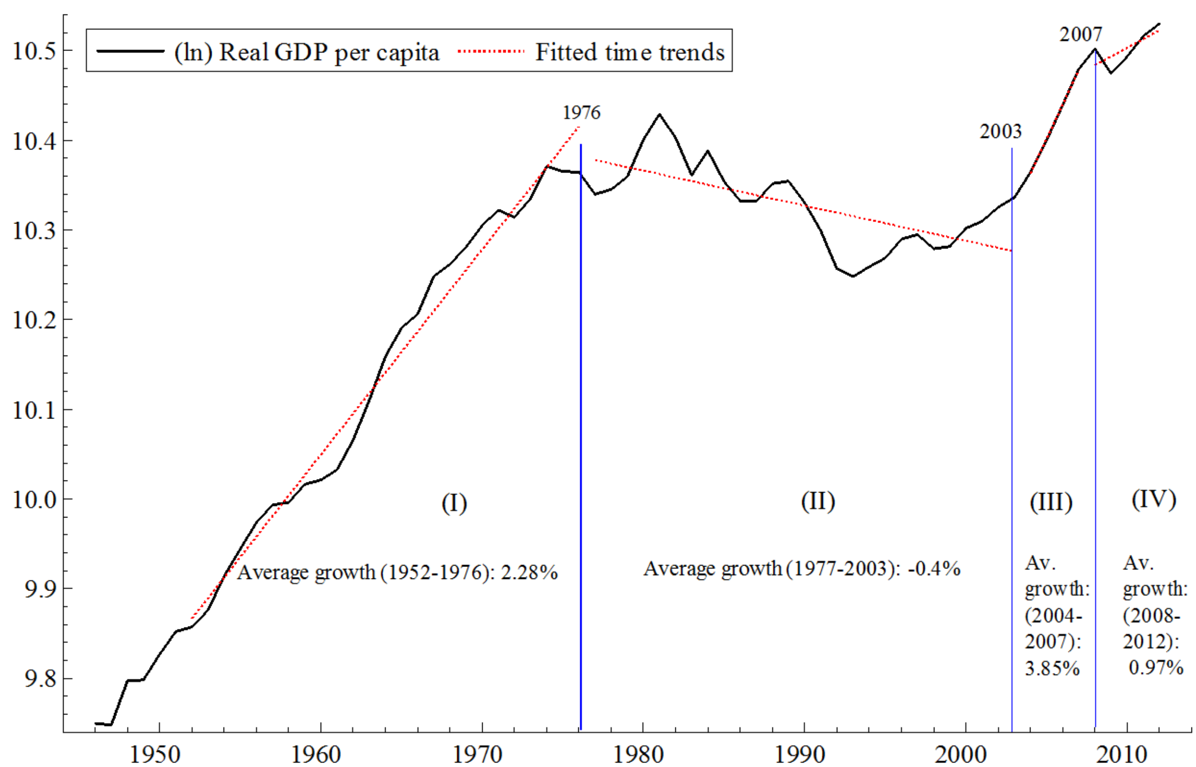
[7] For more on the Soweto uprising, see Ndlovu (2006).

[8] The main reason why the Bai and Perron test in this study detects a break in 1976 and not in 1981 could be related to the way in which we specify our growth equation. The log-linear trend model in equation (1) may be less sensitive to outlying growth associated with the high dollar gold price when compared with Jones and Olken's (2008) specification, in which per capita income growth is simply regressed on an intercept term.

The final breakpoint is identified in 2003. Although the breakpoint test shows that there is only one regime after 2003, we further divide it into a ‘super-fast’ growing period (2004-2007) when per capita income growth averaged 3.85%, and a global financial crisis period (2008-2012) when growth slowed down to an average rate of 0.97%. Socio-economic instability, related to deteriorating labour market conditions in 2012, also contributed to the slowdown in growth (see Smit et al., 2014).

Figure 1 plots the natural logarithm (ln) of South Africa’s real GDP per capita over the period 1952-2012, together with a sub-division of the different regimes identified in the preceding discussion and their corresponding average growth rates.

Figure 1: South Africa’s Different Growth Regimes, 1952-2012



Note: Data source: South African Reserve Bank (see Appendix A). The average growth rate in each regime is obtained from the estimation results of the log-linear trend model in equation (1).

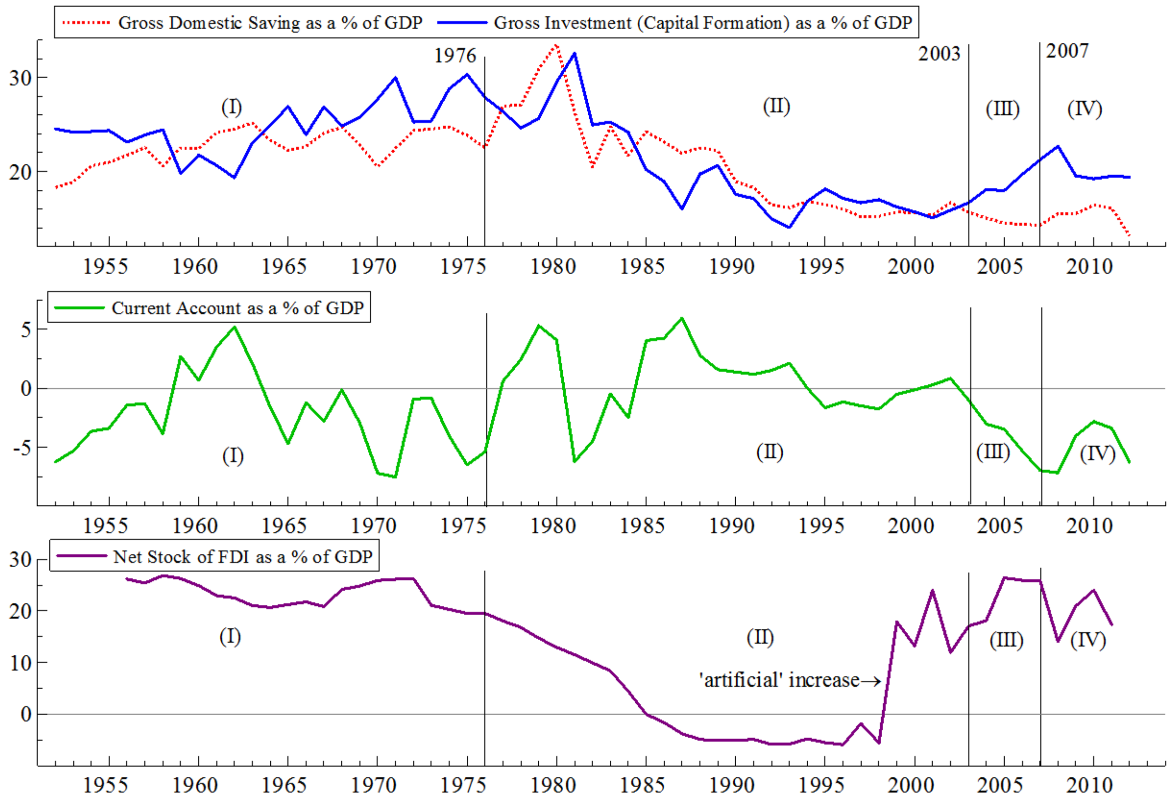
The following regimes are identified: (I) the ‘faster growth’ period up until the Soweto uprising: 1952-1976; (II) the ‘slower growth’ period: 1977-2003; (III) the ‘super fast’ growth period before the financial crisis: 2004-2007; and (IV) the slowdown in growth during the global financial crisis years: 2008-2012. We now examine to what extent South Africa’s growth regimes are correlated with movements in the total gross domestic investment rate, which includes FDI, and the gross domestic saving rate.

2.2 South Africa’s Growth Regimes and the Saving/Investment Rate

Going back to Figure 1, consider regime (I) when the per capita income growth rate averaged 2.28% over the period 1952-1976. The top panel in Figure 2 below shows that for most of the time during the first regime the total gross domestic investment rate (i) exceeded the total gross domestic saving rate (s). This is reflected in the current account ratio of the balance of payments (s – i) in the middle panel, which records an average deficit of -2.28% during the same regime. The high net stock of FDI (liabilities – assets) to GDP ratio in the bottom panel of Figure 2 implies that net FDI inflows played a significant role in financing the current account deficit. [9]

[9] FDI liabilities are defined as investment by foreigners in undertakings in South Africa in which they have at least 10% of the voting rights. FDI assets are investment by South African residents in undertakings abroad in which they have at least 10% of the voting rights (Data source and definitions: South African Reserve Bank).

Figure 2: The Saving, Investment, Current Account and FDI ratios of South Africa, 1952-2012



Note: Data Source: South African Reserve Bank (see Appendix A). Due to the lack of data at the time of writing, the net stock of FDI ratio in the bottom panel covers the period 1956-2011.

In regime (II), the growth rate averaged -0.4% during the period 1977-2003. The poor growth performance over this period corresponds with a much closer relationship between the investment and saving rate in the top panel of Figure 2 which, in turn, is reflected in an average current account surplus ratio of 0.63% in the middle panel. Controlling for the gold price bubble over the period 1979-1981, both rates show a visible decreasing trend in regime (II). It is also apparent that both the investment rate and the saving rate are maintained at high levels in regime (I) relative to regime (II).

One of the underlying reasons for the significant change in South Africa's balance-of-payments position in regime (II) relative to regime (I) was the slowdown in net FDI inflows. The net stock of FDI ratio in the bottom panel of Figure 2 shows a declining trend in the aftermath of the Soweto riots in 1976, and then becomes negative since the mid-1980s, following the debt moratorium and economic sanctions imposed by Western nations in reaction to President P.W Botha's infamous 'Rubicon Speech' in 1985[10]. Despite the democratic elections in 1994, the ratio remains negative until the late 1990s.

The sharp and persistent increase in the net stock of FDI ratio since 1999 seems to signify a major turnaround in FDI flows. However, as pointed out in Gwenhamo and Fedderke (2013: p. 764), the large increase in the stock of FDI liabilities (investment by foreigners in South Africa) from 1999 to 2001 was largely due to four of South Africa's largest multinational companies (MNCs) moving their major listing from the Johannesburg Stock exchange to the London Stock exchange, which required these companies to move their headquarters to London. As a result, the South African based plants of these firms became part of South Africa's FDI liabilities in an accounting sense, which gives the artificial impression that there has been a large and permanent increase in the net stock of FDI ratio since 1999.

Finally, returning to Figure 1, regime (III) captures 'super fast' growth of 3.85% over the period 2004-2007, and regime (IV) slower growth of 0.97% during the global financial crisis years (2008-2012). These regimes are correlated with a large current account deficit ratio in the middle panel of Figure 2. Although the net FDI ratio in the bottom panel of Figure 2 fluctuates substantially over these regimes, it shows no persistent trend movements from the levels that prevailed in the late 1990s and early 2000s.

[10] In his 1985 speech, the then president P.W. Botha alienated his Western allies by refusing to consider immediate and major changes to the country's apartheid system.

2.3 Summary

Based on the preceding analysis, the 'long-run' stylised facts of South Africa's growth performance can succinctly be summarised in Table 1. The table only summarises the data related to South Africa's long-run growth shift over the sub-periods 1952-1976 and 1977-2003. In section 6, we provide a detailed analysis of how the theoretical model and empirical results over these sub-periods relate to South Africa's post-2003 growth performance.

Table 1: 'Long-Run' Stylised Facts of South Africa's Growth Performance, 1952-2003

Growth regime	Average Growth Rate of Real GDP per capita (%)	Average Growth Rate of Capital per capita (%)	Current Account as a % of GDP	Average Net Stock of FDI as a % of GDP
FGR: 1952-1976	2.28	2.48	-2.28	23.30
SGR: 1977-2003	-0.40	-0.60	0.62	4.46

Note: Data Source: South African Reserve Bank. The average growth rates of real GDP and total fixed capital stock per capita, both in constant 2005 prices, were obtained from the estimation results of the log-linear trend model in equation (1). *FGR* denotes 'faster-growing' regime and *SGR* 'slower-growing' regime.

Table 1 shows that South Africa's growth performance over the period 1952-2003 can broadly be characterised by two regimes: a 'faster-growing' regime (*FGR*) during the period 1952-1976, with an average per capita income growth rate of 2.28%, and a 'slower-growing' regime (*SGR*) over the period 1977-2003, with a negative average growth rate of -0.40%.

The downward shift in per capita income growth in Table 1 coincides with a significant slowdown in the average growth rate of the total fixed capital stock per capita from 2.48% in the *FGR* to a negative rate of -0.60% in the *SGR*. Going back to the top panel in Figure 2, the large drop in the growth rate of capital per capita is reflected in downward trend breaks in both the total saving and investment rate across the two regimes. In the next section, we discuss in more detail the precise turning points of the saving rate, the investment rate and the capital per capita growth rate but, for now, it is informative to note that shifts in these variables broadly correspond with the slowdown in per capita income growth during the post-1976 period.

Lastly, net FDI inflows played a key role in financing the average current account deficit ratio of -2.28% in the *FGR*. This is captured by a high net stock of FDI ratio of 23.30% over the period 1952-1976. The structural change in the balance of payments, triggered by the Soweto riots of 1976, is evident in a surplus ratio of 0.62% over the *SGR*. Net FDI outflows were a characteristic feature during most of this regime, with a low net stock of FDI ratio of 4.46% over the period 1977-2003. Moreover, following the discussion in section 2.2, the average net stock of FDI ratio would be much lower without the 'artificial' increase from 1999 to 2001, as shown in the bottom panel of Figure 2.

3. AN INTERDEPENDENCE HYPOTHESIS OF SOUTH AFRICA'S GROWTH SHIFT

To match the stylised facts of South Africa's long-run growth performance in Table 1, we propose an interdependence hypothesis, in which both the saving/investment rate and technological progress are causal factors of the down-break across the sub-periods 1952-1976 and 1977-2003. Consistent with empirical tests of endogenous growth models and development and growth accounting exercises in the literature, we analyse the *proximate sources* of growth (see, for example, Bond et al. 2010; Hsieh and Klenow, 2010; Easterly and Levine, 2001; Bosworth and Collins, 2003). Thus, even though the stylised facts in Table 1 imply that FDI could be a potential source of growth, we do not explicitly model this variable. Because FDI is part of gross domestic investment, its impact is captured through the *total* saving/investment rate and the exogenous rate of technological progress in the models below. This approach allows us to clearly examine how technological progress and the saving/investment rate interact across regimes, which otherwise would become increasingly cumbersome with more complicated models. Moreover, we argue that even in an open economy, the saving rate may be a better proxy for physical capital accumulation *and* technological progress than the fixed investment rate. Or, put in another way, the saving rate becomes a measure of the quality or productivity of capital investment.

3.1 The Main Equations[11]

The production function with constant returns to scale is given by

$$Y_t = (K_t)^{\alpha}(A_t L_t)^{1-\alpha}, \qquad 0 < \alpha < 1 \tag{2}$$

where *t* denotes time, Y_t is real output, K_t is capital input, A_t is 'technology' or 'knowledge' input, and L_t is labour input.

The stock of knowledge at time *t* is modelled as

$$A_t = B_t K_t^{\phi}, \qquad 0 \leq \phi < 1 \tag{3}$$

where ϕ is a learning-by-doing or capability parameter that measures the new knowledge and skills workers gain from installing and using new capital. A positive learning-by-doing parameter ($0 < \phi < 1$) implies that new technology is embodied in new machinery and equipment. When workers and managers use new capital with embodied technical progress, it triggers a process of learning-by-doing, which makes them more knowledgeable on how to adapt and use modern technologies in the most efficient way. In this framework, knowledge accumulation is endogenous with respect to capital accumulation (DeLong and Summers, 1992, 1993). With disembodied technical progress and a resulting learning-by-doing parameter of zero ($\phi = 0$), technology or knowledge becomes completely unexplained ($A_t = B_t > 0$), and we go back to the underlying assumption of the original Solow (1956) model.

[11] Some parts of the modelling framework draw on Nell (2015).

Given the initial value of the capital stock, K_0, the capital accumulation equation is

$$K_{t+1} = sY_t + (1-\delta)K_t \,, \tag{4}$$

where s is the saving/investment rate and δ is the rate at which existing capital depreciates. Hence, the growth rate of the capital stock can be written as:

$$\frac{K_{t+1}}{K_t} - 1 = s\frac{Y_t}{K_t} - \delta \tag{4'}$$

For initial values of the labour force, L_0, and technology, B_0, their respective growth rates are given by

$$L_{t+1} = (1+g^n)L_t \,, \tag{5}$$

and

$$B_{t+1} = (1+g^B)B_t \,, \tag{6}$$

where g^n is the population growth rate, which is equal to the growth rate of the labour force, and g^B is the growth rate of technology.

3.2 A Learning-by-Doing Model in South Africa's FGR

It is hypothesised that the high saving/investment rate in Figure 2 and the large net stock of FDI ratio in Table 1 during South Africa's *FGR* can broadly be associated with a faster rate of technological progress and positive learning-by-doing effects relative to the *SGR*. In a later section (6.1), we show that South Africa's high and increasing fixed investment rate over the *FGR* is closely tracked by the machinery and equipment investment rate (see Figure 7). Following the key hypothesis of DeLong and Summers (1992, 1993) referred to earlier, machinery and equipment investment goods may be associated with technological progress. On the other hand, FDI, which is part of the total investment rate, may contribute to faster growth by supplying the necessary skills and technical know-how to utilise the productive potential of these goods in the most efficient way (De Mello, 1997, 1999; Borenszein et al., 1998; Fedderke and Romm, 2006; Harding and Javorcik, 2011). Based on these propositions, we assume a positive learning-by-doing parameter ($0 < \phi < 1$) in equation (3) and, for now, zero population growth in equation (5). From equations (2)-(6), the steady-state *level* of output per worker ($y_{FGR,t} \equiv Y_{FGR,t} / L_{FGR,t}$) along a balanced growth path in South Africa's *FGR* can be derived as

$$y_{FGR,t} = \left(\frac{s_{FGR}}{\left\{ \left[\left(1 + g^B_{FGR}\right) \right]^{\frac{1}{1-\phi}} - \left(1 - \delta\right) \right\}} \right)^{\frac{\beta}{1-\beta}} L_0^{\frac{\phi}{1-\phi}} B_0^{1+\frac{\phi}{1-\phi}} \left(1 + g^A_{FGR}\right)^t, \quad 0 < \phi < 1 \tag{7}$$

where $\beta = \alpha + \phi(1-\alpha)$ is the elasticity of output with respect to capital[12] and $g^A_{FGR} = (1 + g^B_{FGR})^{1+\frac{\phi}{1-\phi}} - 1$. The long-run growth rate of output per worker is g^A_{FGR}, which is sustained through the exogenous rate of technological progress, $\tilde{g}^B_{FGR}$. The steady-state growth path of output per worker is similar to the model derived in Sørensen and Whitta-Jacobsen (2010: p. 222), except that in their model population growth is the source of sustained growth.

To arrive at an econometric specification of equation (7), take logs to obtain:

$$\ln(y_{FGR,t}) = c + \frac{\beta}{1-\beta} \ln(s_{FGR}) + \kappa(t) + \varepsilon_t, \tag{8}$$

where ε_t is an error term and *t* is a time trend. The intercept term is given by

$$c \equiv -\frac{\beta}{1-\beta} \ln\left\{ \left[\left(1 + g^B_{FGR}\right) \right]^{\frac{1}{1-\phi}} - (1-\delta) \right\} + \frac{\phi}{1-\phi} \ln\left(L_0\right) + \left[1 + \frac{\phi}{1-\phi} \right] \ln(B_0)$$

and the long-run growth rate of output per worker is equal to

[12] The elasticity of output with respect to capital is obtained by substituting equation (3) into equation (2): $Y_t = K_t^{\alpha+\phi(1-\alpha)} B_t^{1-\alpha} L_t^{1-\alpha}$.

$$\kappa \equiv \tilde{g}^{A}_{FGR} = \left[1 + \frac{\phi}{1-\phi}\right]\tilde{g}^{B}_{FGR}\,, \tag{8'}$$

where the tilde denotes the approximate growth rate of variable *x:* $\tilde{g}^{x}_{FGR} \equiv \ln x_{t+1} - \ln x_t$. Equation (8′) shows that the rate of technological progress ($\tilde{g}^{A}_{FGR}$) in the *FGR* is composed of an exogenous TFP or technology progress component, $\tilde{g}^{B}_{FGR}$, and an exogenous learning-by-doing parameter given by ϕ.[13]

3.3 A 'Solow-type' Model in South Africa's SGR

In South Africa's *SGR*, it is assumed that the decelerating saving/investment rate in Figure 2 and low net stock of FDI ratio in Table 1 imply a much lower, but not necessarily zero, learning-by-doing parameter. For ease of exposition we set $\phi = 0$ in equation (7), and then take logs to derive the specification in South Africa's *SGR* as

$$\ln(y_{SGR,t}) = d + \frac{\alpha}{1-\alpha}\ln(s_{SGR}) + \tilde{g}^{B}_{SGR}(t) + \xi_t\,, \tag{9}$$

where ξ_t is an error term and the long-run growth rate ($\tilde{g}^{B}_{SGR}$) in the *SGR* is exogenously determined by the rate of technological progress. The intercept term is given by

$$d \equiv -\frac{\alpha}{1-\alpha}\ln\left(g^{B}_{SGR} + \delta\right) + \ln(B_0)\,.$$

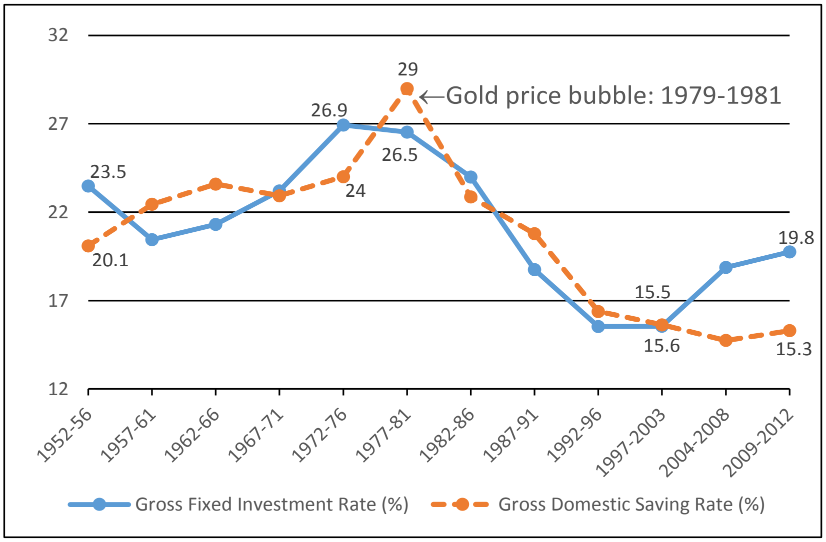
Equation (9) is similar to the Solow model derived in Mankiw et al. (1992), except that in our specification population growth is set to zero and the model is formulated in discrete time.

[13] The reason why the learning-by-doing parameter is a component of the long-run growth rate can be seen more clearly by expressing equation (3) in growth rates, and then re-writing equation (8′) as $\kappa \equiv \tilde{g}^{A}_{FGR} = \tilde{g}^{B}_{FGR} + \phi(\tilde{g}^{k}_{FGR})$, where $\tilde{g}^{k}_{FGR}$ is the growth rate of the capital stock. With zero population growth, the exogenous technology progress component sustains growth in the capital stock, $\tilde{g}^{B}_{FGR}\phi/(1-\phi) = \phi(\tilde{g}^{k}_{FGR})$, and, via learning-by-doing effects, generates long-run growth.

3.4 Modelling South Africa's Regime Shift

The learning-by-doing specification in equations (8-8′) and the Solow model in equation (9) can now be used to model South Africa's regime shift across its *FGR* and *SGR*. As a starting point, it is informative to plot non-overlapping averages of South Africa's gross domestic saving rate and gross domestic fixed investment rate over the period 1952-2012. Figure 3 shows that both rates display an increasing trend during the *FGR* (1952-1976). The fixed investment rate gradually levels off after 1976, while the saving rate reaches a peak in the early 1980s. Thereafter, there is a visible decreasing trend in both rates until 2003. As already emphasised in section 2, the reason why the turning points in these series do not match the real GDP per capita shift in 1976 is due to the gold price bubble that gained momentum in 1979 and continued until the early 1980s. Indeed, an application of Bai and Perron's (1998, 2003) breakpoint test to the log-linear trend model in equation (1) shows that the saving rate, fixed investment rate and the growth rate of the fixed capital stock all contain a down-break in the early 1980s.

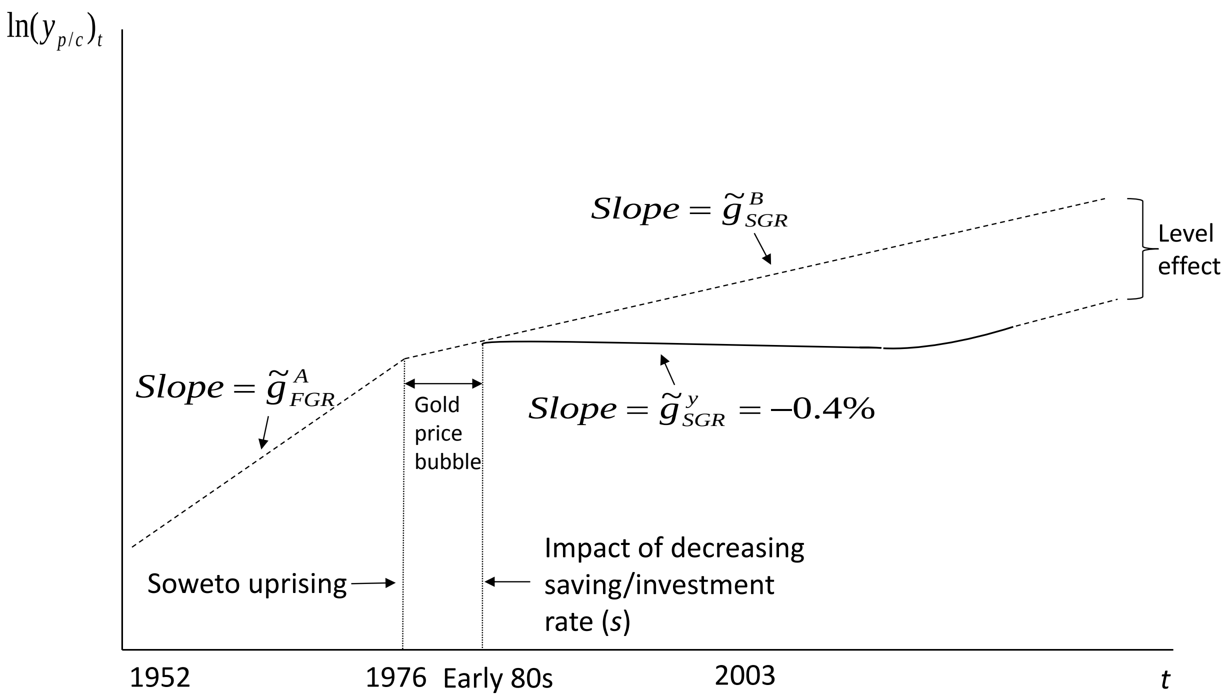
Figure 3: Non-Overlapping Averages of South Africa's Aggregate Fixed Investment Rate and Gross Domestic Saving Rate, 1952-2012



Note: Data Source: South African Reserve Bank (see Appendix A).

Given the information contained in Figure 3, Figure 4 uses a Solow-type diagram to simulate the interdependence between the saving/investment rate and technological progress across South Africa's *FGR* and *SGR*.

Figure 4: A Solow-Type Diagram of South Africa's Down-Break



The figure plots the natural logarithm of real GDP per capita income ($\ln(y_{p/c})_t$) on the vertical axis and time (t) on the horizontal axis.[14] Over the *FGR*, it is assumed that the economy grows at the exogenous rate of technological progress, $\tilde{g}^A_{FGR}$, given by equation (8′) of the learning-by-doing model. The trend line in Figure 4, therefore, rises at this rate over the *FGR*. Note, however, that this growth rate is not directly observable. Since the saving and investment rate both increase over time during the *FGR*, the growth rates of the capital stock in equation (4′) and, hence, output

[14] From the available sources, such as the South African Reserve Bank and Penn World Tables 8.1 (PWT 8.1), data on South Africa's workforce are only available from 1960 and not the full sample period (1952-2012) covered in this paper. Output is therefore expressed in per capita rather than per worker terms.

per capita growth via the production function in equation (2), are faster than it otherwise would have been with a constant saving/investment rate.[15] In other words, South Africa's observable growth rate over the *FGR* captures *transition dynamics*. Because the saving/investment rate cannot rise forever, the economy will eventually, in some hypothetical long-run, grow at its exogenous rate of technological progress.

Based on all these considerations, the hypothetical long-run real GDP per capita series in Figure 4 rises along a flatter upward sloping trend line than South Africa's observable (actual) per capita income series during the *FGR*. Returning to the stylised facts of South Africa's growth performance in Table 1, consider the 1976 down-break in South Africa's growth performance, which was triggered by the Soweto uprising and resulting net FDI outflows. Figure 4 models the down-break as a slowdown in the exogenous rate of technological progress from $\tilde{g}^{A}_{FGR}$, given by equations (8-8′) of the learning-by-doing model, to $\tilde{g}^{B}_{SGR}$, as depicted by the Solow model in equation (9). The impact of the negative exogenous shock on the saving/investment rate was effectively delayed by the gold price bubble over the period 1979-1981 (see Figure 3). Figure 4 simulates this effect, by showing that the negative growth effect of the decelerating saving/investment rate occurred since the early 1980s, after the growth effect of the gold price bubble had dissipated. This is modelled as a decrease in the saving/investment rate from s_{FGR} in equation (8) to s_{SGR} in equation (9). Note further that the observed growth effect resulting from

---

[15] Note from equation (4′), holding everything else constant, that an increasing saving/investment rate (s) implies an accelerating growth rate of the capital stock. However, unit root tests that allow for structural breaks suggest that the growth rates of the capital stock and output (as well as their rates in per capita terms) are stationary during South Africa's *FGR*. From these results it can be inferred that, although the rising s generates faster rates of growth of capital and output than otherwise would have been the case with a constant s, these rates do not accelerate during the *FGR* because they are offset by a falling output-capital ratio (Y_t/K_t) in equation (4′). A falling output-capital ratio, in turn, implies diminishing returns to capital, which is consistent with our assumption that the learning-by-doing parameter (ϕ) is less than one in the *FGR*. In contrast, a learning-by-doing parameter equal to one would give constant returns to capital. The proposition that $0 < \phi < 1$ in the *FGR* will be tested formally in section 5.

the down-breaks in the saving/investment rate, which we assume for simplicity is equal to g^{y}_{SGR} = -0.4% in Table 1, falls below the unobserved exogenous rate of technological progress, $\tilde{g}^{B}_{SGR}$, in Figure 4. Thus, the actual growth rate of -0.4% over the period 1977-2003 captures transition dynamics.[16] Due to the diminishing returns to capital assumption of the model, the growth rate will eventually return to the exogenous rate of technological progress in some hypothetical, post-2003 long-run period. The decrease in saving/investment rate, therefore, permanently reduces the level of per capita income but not the growth rate.

Figure 4 implies that there is an *interdependent* relationship between the saving/investment rate and technological progress across South Africa's growth regimes. This arises, first, because both these proximate sources of growth are hypothesised to be causal determinants of South Africa's post-1976 down-break and, second, because both the saving/investment rate and technological progress are jointly determined by a common exogenous source, which we can explain as follows. The interdependence hypothesis is supported by one of the key stylised facts in Table 1, which records a sharp drop in the net stock of FDI ratio across the *FGR* and *SGR*. We hypothesise that FDI outflows since 1976 may account for the immediate slowdown in the exogenous rate of technological progress. Since FDI forms part of the gross domestic fixed investment rate, one would expect a concurrent decrease in the investment rate, but as we have argued throughout, the negative impact on the *aggregate* saving/investment rate is only *clearly* visible after the gold price bubble. It follows that increased

[16] For simplicity, it is assumed that the post-1976 down-break in the exogenous rate of technological progress occurred instantaneously. Theoretically, however, a negative exogenous shock to technological progress will generate dynamics via a falling output-capital ratio in equation (4′), which then transmits itself into slower output per capita growth via the production function in equation (2). This implies that the observed growth rate of -0.40% will not only capture the dynamics of a decelerating saving/investment rate for a given output-capital ratio in equation (4′), but also those related to a slowdown in the exogenous rate of technological progress. For ease of exposition, but without loss of generality, it is assumed that the observed growth rate only reflects the transition dynamics related to a falling saving/investment rate.

investment uncertainty, which was triggered by the Soweto uprising in 1976 and gained further momentum with the debt moratorium imposed by Western nations in 1985, is a potential exogenous shock that may simultaneously account for the slowdown in the rate of technological progress and the decelerating trend in the saving/investment rate.

3.5 The Saving Rate Versus the Investment Rate as the Appropriate Variable

Thus far, we have interchangeably referred to the saving rate and the investment rate as the 'saving/investment rate'. In a closed economy the saving rate is equal to the investment rate, but in an open economy these rates may diverge in a significant way due to net capital flows. Although there are some notable exceptions, the growth literature generally regards the investment rate as the appropriate variable, either as a proxy for physical capital accumulation or to construct a capital stock series for growth accounting purposes. The implicit assumption is that the domestic saving rate would be an inappropriate proxy for fixed capital formation when substantial net capital flows generate large and persistent deviations between the domestic investment rate and the domestic saving rate.

Alternatively, we advance the idea that the saving rate may be a good proxy for the quality of investment, that is, whether physical capital accumulation is accompanied by technological progress. This proposition can be motivated as follows. In simple Keynesian models, investment is not determined by prior saving, as in the conventional neoclassical model, but rather by investment incentives and the *'animal spirits'* of entrepreneurs (Deaton, 1999). Investment determines growth, and saving rises out of increased profit income (Deaton, 1999, Kaldor, 1955-56, 1957, 1961). The close relationship between domestic investment and saving may also hold in an open economy when foreign lenders impose a long-run solvency constraint, so that an economy's foreign debt cannot rise indefinitely. In the long-run, investment must be financed out of domestic saving (Coakley et al., 1996; Nell and Santos, 2008).

Whether investment finances itself, however, will depend on the quality of the investment projects and the type of incentives. For example, a rise in equipment investment with embodied technical progress, coupled with productive (supportive) infrastructure investment and FDI, may be effective in raising the rate of technological progress, profit income of local firms and, hence, the domestic saving rate. Although investment is the driving force, the saving rate may be a better proxy of an economy's long run performance in an open economy. Going back to the actual data in Figure 3, note that although the saving and investment rate do share a common long-run trend across South Africa's *FGR* and *SGR*, they diverge during certain periods. Volatile capital flows may cause unstable short-run movements in the investment rate relative to the saving rate, which are unrelated to the economy's long-run performance. In this scenario, movements in the saving rate, as a measure of the quality of capital investment, is hypothesised to be a more reliable determinant of South Africa's long-run performance. In short, the saving rate may be a more useful indicator to assess whether capital investment is accompanied by technological progress.

In the empirical section below, we use the gross domestic saving rate in equations (8) and (9) rather than the investment rate. This proposition is supported by supplementary tests (not reported here but available on request), which show that the saving rate models outperform the investment rate models across South Africa's *FGR* and *SGR*. The exception is South Africa's post-2003 regime. We analyse the policy implications of these findings in section 6.

4. ECONOMETRIC METHODOLOGY AND SPECIFICATION

4.1 Econometric Methodology

South Africa's simulated down-break in Figure 4 implies a structural shift across the learning-by-doing model in equations (8) and the Solow model in equation (9). Note that both steady-state models assume, by implication, that the saving/investment rate is constant in each regime. From Figures 1 and 3, however, it appears as if real GDP per capita income, as well as the saving and investment rate, are non-stationary variables. To verify this proposition in a more formal way, we perform a battery of unit root tests on all the variables in equations (8)-(9) over the full sample period and the different sub-samples identified in Table 1. Overall, the unit root test results (not reported here) strongly suggest that all the variables in levels are non-stationary, but their first differences are stationary, that is, the level variables are I(1) and their first differences are I(0).[17] Cointegration techniques are therefore essential to establish whether these non-stationary variables cointegrate to form a long-run relationship, which would then provide empirical support for the steady-state models in equations (8) and (9). Moreover, following Granger (1988), cointegration implies that long-run causality must exist in at least one direction, so it is possible to directly test the exogenous saving/investment rate assumption of the models.

In this context, the econometric methodology employed in this paper follows the structural cointegrating vector autoregressive (VAR) approach first developed by Johansen (1988, 1992) and later advanced in Garratt et al. (2000); Pesaran et al. (2000); and Pesaran and

[17] The unit root tests include those developed by Dickey and Fuller (1979), Phillips and Perron (1988), Kwiatkowski et al. (1992), and Ng and Perron (2001). We also employed unit root tests that allow for an endogenous structural break in the spirit of Vogelsang and Perron (1998). All the unit root test results were calculated with the software programme, EViews 9, and are available on request.

Shin (2002). The statistical framework for the structural cointegrating VAR approach is the following general vector error-correction model (VECM):

$$\Delta y_t = a_{0y} + a_{1y}t - \mathbf{\Pi}_y y_{t-1} + \sum_{i=1}^{p-1} \mathbf{\Gamma}_{iy} \Delta y_{t-i} + \Psi_y w_t + v_t \ , \qquad (10)$$

where y_t is a vector of I(1) endogenous variables; a_{0y} is a vector of intercept terms; t is a vector of deterministic trends; and w_t is a vector of I(0) exogenous variables and event-specific dummy variables. The matrix $\mathbf{\Pi} = \alpha_y \beta'$ contains the cointegrating relationships, where the α_y matrix includes the error-correction coefficients, or the speed of adjustment towards long-run equilibrium, and β includes the long-run coefficients.

4.2 VECM Specification

From the learning-by-doing specification in equation (8) and the Solow model in equation (9), the vector of endogenous I(1) variables can be written as $y_t' = [\ln(y_{p/c}), \ln(s)]$, where ln($s$) is the logarithm of the gross domestic saving to nominal GDP ratio, and $\ln(y_{p/c})$ is the logarithm of real GDP per capita. In section 3.5 we motivated why the saving rate rather than the investment rate is the most suitable variable, while footnote 14 explains why output per capita is used as a proxy for output per worker. Appendix A provides a detailed description of all the variables and data source.

Following South Africa’s simulated down-break in Figure 4 and the stylised facts in Table 1, we adopt a split-sample methodology and estimate the models over the *FGR* (1952-1976) and *SGR* (1977-2003). More structure is given to the VECM in equation (10) by including several event-specific dummy variables in the w_t vector. The vector of dummy variables in each regime is defined as $w'_{FGR,t} = (D_{(60-61)})$ and $w'_{SGR,t} = (D_{(80-84)}, D_{(92)})$. Note the importance of the dummy variable, D_{80-84}, in the context of South Africa's down-break in Figure 4. This dummy variable takes the value one during 1980-1984 and zero otherwise to capture the growth effect of the gold price bubble and the downward shift in the saving rate immediately after the initial growth surge had dissipated. Appendix A also provides a detailed description of all the dummy variables and motivates their inclusion in terms of actual events that occurred in the South African economy.

Finally, to determine the optimal lag length of the VECM in equation (10), we start with an unrestricted VAR model of p = 3 in each regime. Akaike's (1974) and Schwarz's (1978) model selection criteria choose an order one (p = 1) VAR for each regime. In addition, the intercept terms are restricted to lie in the cointegrating space without trends in South Africa's *FGR*, while the option of restricted trends and unrestricted intercept terms is chosen for the *SGR*.

5. EMPIRICAL RESULTS

5.1 Cointegration Tests

To examine whether the learning-by-doing specification in equation (8) and the Solow model in equation (9) represent long-run (steady-state) relationships, we test for cointegration between the I(1) level variables that enter $y_t' = [\ln(y_{p/c}), \ln(s)]$ in the *FGR* and *SGR*. The trace ($\hat{\lambda}_{\text{trace}}$) test statistics and maximum eigenvalue ($\hat{\lambda}_{\max}$) statistics in Table 2 all exceed the 95% critical values, so the null of no cointegration (r = 0) can be rejected at the 5% significance level in each regime.[18] By normalising on $\ln(y_{p/c})$, the error-correction mechanism (*ecm*) or cointegrating vector in each regime can be written as (standard errors in parentheses):

[18] The cointegration results are computed with Microfit 4.0 (Pesaran and Pesaran, 1997).

$$ecm_{FGR,t} = \ln(y_{p/c}) - \underset{(0.496)}{1.757} \cdot \ln(s) - \underset{(0.771)}{13.080} \quad (11)$$

$$ecm_{SGR,t} = \ln(y_{p/c}) - \underset{(0.065)}{0.400} \cdot \ln(s) - \underset{(0.001)}{0.008} \cdot trend\ , \quad (12)$$

where, as before, *FGR* denotes South Africa's growth regime over the period 1952-1976 and *SGR* its growth regime over the period 1977-2003. The solved long-run per capita equations of (11) and (12) show that the saving rate variable is correctly signed (+) and statistically significant at the 1% level in each regime.

Table 2: Cointegration Tests in Each Sub-Sample

Hypothesis		$\hat{\lambda}_{max}$			$\hat{\lambda}_{trace}$		
H_0	H_A	Statistic	95% CV	90% CV	Statistic	95% CV	90% CV
		'Faster-growing' regime (*FGR*): 1952-1976					
r = 0	r = 1	36.51**	15.87	13.81	48.67**	20.18	17.88
		'Slower-growing' regime (*SGR*): 1977-2003					
r = 0	r = 1	46.24**	19.22	17.18	51.39**	25.77	23.08

Notes: The critical values (CVs) of the λ_{max} and λ_{trace} test statistics are obtained from Pesaran et al. (2000). ** denotes significance at the 5% level.

5.2 Long-Run Causality and Structural Stability Tests

A crucial empirical issue is to determine whether the saving rate long-run causes per capita income in equations (8) and (9). Following the weak exogeneity test procedure developed in Johansen and Juselius (1992), we test whether the *ecms* in equations (11) and (12) enter significantly in the per capita income growth rate [$\Delta\ln(y_{p/c})_t$] and saving rate [$\Delta\ln(s)_t$] equations of the VECM. Table 3 reports the long-run causality tests conducted in an unrestricted error-correction modelling framework.

Table 3: Long-Run Causality Tests

	FGR:1952-1976		*SGR*: 1977-2003		*FGR/SGR*: 1952-2003
Equation	$\Delta\ln(y_{p/c})_t$	$\Delta\ln(s)_t$	$\Delta\ln(y_{p/c})_t$	$\Delta\ln(s)_t$	$\Delta\ln(y_{p/c})_t$
Intercept	–	–	4.310*** (0.573)	–12.346*** (4.3093)	4.355*** (0.427)
$ecm_{FGR,t-1}$	–0.067*** (0.008)	0.001 (0.029)	–	–	–0.068*** (0.008)
$ecm_{SGR,t-1}$	–	–	–0.397*** (0.052)	1.138*** (0.396)	–0.411*** (0.040)
$D_{(60-61)}$	–0.021*** (0.003)	0.035 (0.020)	–	–	–0.021*** (0.003)
$D_{(80-84)}$	–	–	0.015*** (0.005)	–0.101** (0.047)	0.016*** (0.005)
$D_{(92)}$	–	–	–0.042*** (0.003)	–0.109*** (0.015)	–0.042*** (0.003)
	Diagnostic tests				
R^2	–	–	0.70	0.32	0.69
F_{ar}	0.004 [0.945]	0.043 [0.836]	1.679 [0.208]	0.000 [0.997]	0.478 [0.493]
F_{reset}	0.007 [0.934]	0.102 [0.752]	1.512 [0.232]	2.694 [0.115]	0.329 [0.569]
$\chi_n^2(2)$	0.522 [0.770]	1.732 [0.421]	1.089 [0.580]	2.910 [0.233]	1.678 [0.432]
F_{het}	0.001 [0.973]	0.795 [0.382]	0.511 [0.481]	2.481 [0.128]	0.981 [0.327]

Notes:
1) Newey-West robust standard errors are in parentheses (·) and *p*-values are given in brackets [·] (see Pesaran and Pesaran, 1997). *** denotes significance at the 1% level and ** at the 5% level.
2) R^2 is the coefficient of determination. The diagnostic tests are given as F_j, which indicates an F-test against the alternative hypothesis *j* for: first-order serial correlation (F_{ar}); functional form misspecification (F_{reset}); heteroscedasticity (F_{het}). χ_n^2 is a chi-square test for normality. For more details, see Pesaran and Pesaran (1997).

In the *FGR*, the error-correction mechanism ($ecm_{FGR,t-1}$) enters significantly in the $\Delta\ln(y_{p/c})_t$ equation but insignificantly in the $\Delta\ln(s)_t$ equation. The results show that per capita income adjusts towards its long-run equilibrium value in reaction to changes in the saving rate, but not the other way around. Or put differently, the saving rate is exogenous with respect to per capita income. Looking at the *SGR*, there is evidence of bi-directional long-run causality – the error-correction mechanism ($ecm_{SGR,t-1}$) is significant in both the $\Delta \ln(y_{p/c})_t$ and $\Delta \ln(s)_t$ equations.[19] The results across the *FGR* and *SGR* support one of the key predictions of the learning-by-doing model in equation (8) and the Solow model in equation (9), which postulates a long-run causal effect from the saving rate to per capita income.

The last column of Table 3 reports the results when the per capita income growth rate error-correction models in the *FGR* and *SGR* are combined into one model and estimated over the extended sample period 1952-2003. The combined *FGR/SGR* model is specified by setting the intercept term equal to one in the *SGR* and zero otherwise, whereas $ecm_{FGR,t-1}$ and $ecm_{SGR,t-1}$ take their actual values during the *FGR* and *SGR*, respectively, and zero otherwise. The dummy variables are defined as before. As one would expect, the results are virtually identical to the split-sample models estimated over the different sub-samples. It is nevertheless convenient to focus on the overarching model estimated over the period 1952-2003.

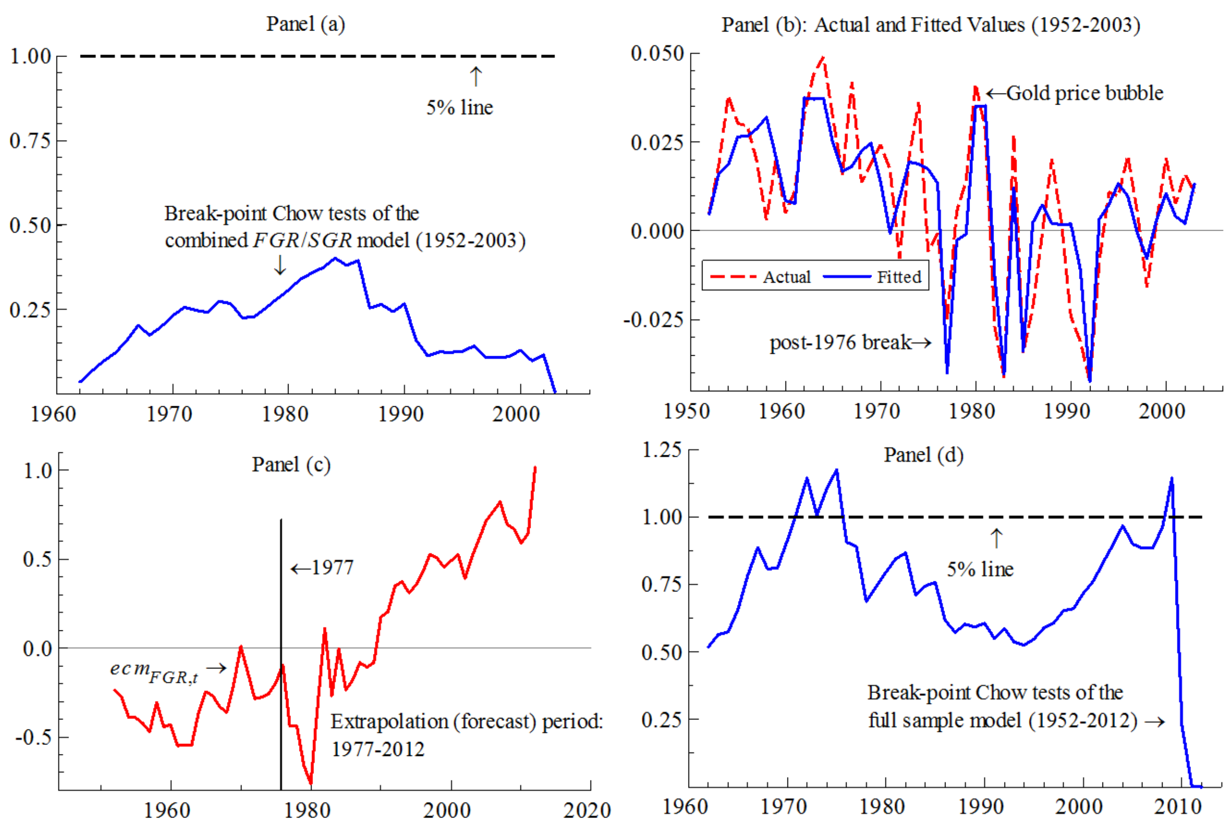
The empirical evidence of a long-run causal effect from the saving rate to per capita income in each regime is statistically robust based on all the diagnostic tests in Table 3, and the structural stability tests in Figure 5. Figure 5(a) reports the recursively estimated break-point Chow tests of the combined *FGR*/*SGR* per capita income growth rate error-correction model in Table 3.[20] The figure shows that the combined model is structurally stable, with all the Chow tests falling well below the 5% critical value. The statistical quality of the combined model is further underlined by plotting the actual and fitted values in Figure 5(b). The figure shows how well the fitted values track the actual values across the *FGR* and *SGR*. More specifically, the

[19] Because the VECM controls for endogeneity bias, valid inferences on the long-run saving rate coefficient can still be drawn, even though there is bi-directional causality. Long-run feedback effects from per capita income to the saving rate in South Africa's *SGR* may capture the desire by households to maintain their consumption levels in the face of falling incomes. Further note that the *ecm* coefficient of 1.13 in the *SGR* is not significantly different from unity based on a Wald test [$\chi^2(1) = 0.12$]. This shows that the saving rate adjusts towards its long-run equilibrium value in the same year.

[20] The break-point Chow tests are computed with PcGive version 14 (see Doornik and Hendry, 2013).

average of the actual per capita income growth rate over the *FGR* (2.05%) is virtually identical to the average of the fitted values (2%). Similarly, the actual and fitted average growth rate over the *SGR* are both equal to -0.10%.[21]

Figure 5: Structural Stability Tests



Counterfactually, it is informative to examine what would happen when the model specifications ignore the regime change in 1976. Figure 5(c) extrapolates the *FGR* error-correction mechanism in equation (11) over the *SGR*. The visual plot shows that $ecm_{FGR,t}$ represents a stationary, cointegrated relationship over the period 1952-1976, but thereafter drifts

[21] Note that the per capita income growth rate of the error-correction model is calculated as $\Delta\ln(y_{p/c})_t$. Thus, the averages derived from the growth rate defined in this way will differ somewhat from those in Table 1, which are derived from the estimates of the log-linear trend model in equation (1).

upwards and becomes non-stationary over the extrapolation (forecast) period 1977-2012. To show the relevance of the 1976 regime change in a different way, we test for cointegration over the full sample period 1952-2012. The results (not reported here but available on request) show that the null of no cointegration cannot be rejected at the 90% confidence level. Given that the cointegration test statistics fall marginally below the 90% critical values, we proceed by estimating the resulting error-correction models. In contrast to the split sample results in Table 3, the saving rate is now endogenous with respect to per capita income, which is inconsistent with the predictions of the theoretical models in equations (8) and (9).[22] These results, however, are derived from misspecified models. Figure 5(d) clearly illustrates that the per capita income growth rate error-correction model over the full sample period 1952-2012 is structurally unstable, with the break-point Chow tests exceeding the 5% critical value during the first half of the 1970s and in 2008.

To summarise, without explicitly incorporating the 1976 regime change, the models are structurally unstable and misspecified. However, when the cointegration analysis is modified to capture the structural shift across the *FGR* and *SGR*, we obtain statistically robust and theory-consistent empirical results in Table 3.

5.3 Deriving the Learning-by-Doing Parameter

To derive the learning-by-doing parameter in each regime, we proceed as follows. The saving rate elasticities of the long-run cointegrating vectors in equations (11) and (12) are recorded in column 1 of Table 4. Note that the saving rate elasticity estimates in column (1) are equal to $\hat{\beta}_i/(1-\hat{\beta}_i)$ in the learning-by-doing model of equation (8), where $\hat{\beta}_i$ is the elasticity of

[22] These results are available on request.

output with respect to capital, i = 1 denotes South Africa's *FGR*, and i = 2 its *SGR*. Column (2) reports the solved capital elasticity estimate ($\hat{\beta}_i$) for each regime.

Table 4: Structural Change in the Learning-by-Doing Parameter

	(1)	(2)	(3)	(4)
Growth Regime	Saving Rate Elasticity: $\hat{\beta}_i/(1-\hat{\beta}_i)$	Capital Elasticity: $\hat{\beta}_i = \alpha + \hat{\phi}_i(1-\alpha)$	Assumed α	Implied $\hat{\phi}_i$
FGR:1952-1976	1.757*** (0.496)	$\hat{\beta}_1$ = 0.64*** (0.060)	0.21	$\hat{\phi}_1$ = 0.54*** (0.060)
SGR:1977-2003	0.400*** (0.065)	$\hat{\beta}_2$ = 0.29*** (0.037)	0.21	$\hat{\phi}_2$ = 0.10*** (0.037)
Estimates over a Different Sub-Sample				
1977-2012	0.462*** (0.077)	$\hat{\beta}_2$ = 0.32*** (0.038)	0.21	$\hat{\phi}_2$ = 0.14*** (0.038)

Note: Standard errors are in parentheses (·). *** denotes significance at the 1% level.

Noting that $\hat{\beta}_i = \alpha + \hat{\phi}_i(1-\alpha)$ in equations (7) and (8), it is possible to derive an implied learning-by-doing parameter estimate ($\hat{\phi}_i$) for a given value of capital's share in total income (α). From the labour share data provided by PWT (8.1), we calculate the capital share (one minus the labour share) to be around 0.40, which is consistent with the value used in Du Plessis and Smit's (2007) growth accounting exercise and Caselli and Feyrer's (2007) unadjusted measure. [23] Caselli and Feyrer, however, argue that the conventional way of deriving capital's share may overstate its contribution to income. Their main argument is as follows. When capital's share is derived from labour's share in the national accounts, the measure includes payments accruing to both reproducible and non-reproducible capital, such as land and natural resources. Since standard

[23] The capital share of 0.40 is the average over the period 1952-2003. Over South Africa's *FGR* and *SGR* the corresponding values are 0.40 and 0.41, respectively.

growth models, such as the ones used in this paper, include reproducible capital, capital's share derived from national accounts would tend to overestimate its contribution. Instead, Caselli and Feyer calculate an adjusted capital share (adjusted for the income contributions of land and natural resources) for South Africa of only 0.21. By using the adjusted estimate of α = 0.21 in column 3 of Table 4, we derive learning-by-doing parameters in column 4 of 0.54 in the *FGR* and 0.10 in the *SGR*.[24]

5.4 South Africa's Simulated Down-Break in Figure 4

Consider the slowdown in the rate of technological progress from $g^A_{FGR} = g^B_{FGR} + \phi/(1-\phi) g^B_{FGR}$ in the *FGR* to g^B_{SGR} in the *SGR*. For illustrative purposes, Figure 4 assumes that there is a down-break across the learning-by-doing model in equations (8-8′) and the Solow model, with zero learning-by-doing effects, in equation (9). In reality, the results in Table 4 show a small, although not zero, learning-by-doing parameter of $\hat{\phi}_2 = 0.10$ in the *SGR*. Thus, given $\hat{\phi}_2 = 0.10$, the downward shift in the rate of technological progress can be rewritten in the following way:

$$[g^A_{FGR} = g^B_{FGR} + \hat{\phi}_1/(1-\hat{\phi}_1) g^B_{FGR}] \Rightarrow [g^A_{SGR} = g^B_{SGR} + \hat{\phi}_2/(1-\hat{\phi}_2) g^B_{SGR}] \qquad (13)$$

From equation (13), we assume that the slowdown in the rate of technological progress across South Africa's *FGR* and *SGR* can be modelled as a downward shift in the unobserved technology progress component from g^B_{FGR} to g^B_{SGR}. In addition to this growth effect, the slowdown in the

[24] As an additional robustness check, we also examine what happens when population growth is included in the VECM specifications. The population growth rate variable turns out to be an insignificant determinant in all the specifications, which supports the zero restriction in equations (8-8′). The zero restriction, of course, does not literally mean that population growth is zero. Rather, the insignificance of population growth suggests that its scale effects in the learning-by-doing model may operate in conjunction with other growth determinants that appear in the long-run growth rate component of g^B_{FGR} in equation (8′).

rate of technological progress can also be attributed to the sharp drop in the learning-by-doing parameter from $\hat{\phi}_1 = 0.54$ in the *FGR* to $\hat{\phi}_2 = 0.10$ in the *SGR* (see Table 4). In effect, because the rate of technological progress is unobserved due to transition dynamics, the estimates of the learning-by-doing parameters in Table 4 allow us to conclude that South Africa's down-break involved a slowdown in the rate of technological progress.[25] The empirical results, therefore, support the simulated slowdown in the growth rate of technological progress across South Africa's *FGR* and *SGR*, as depicted in Figure 4.

The simulation in Figure 4 further hypothesises that the impact of the negative exogenous shock to technological progress on the saving/investment rate was effectively delayed by the gold price bubble that started in 1979 and ended in the early 1980s. The results in Table 3 support this contention. The dummy variable, D_{80-84}, is positive and significant in the per capita income growth rate error-correction model over the *SGR*, and negative and significant in the saving rate equation. The dummy variable is specified to capture the initial growth surge of the gold price bubble during 1980-1981 and the sharp drop in the saving rate in the immediate aftermath. The actual decelerating trend in the saving/investment rate since the early 1980s is depicted in Figure 3. The empirical results in Table 4 show that the saving rate is a long-run causal determinant of per capita income across the *FGR* and *SGR*, which implies that the *actual* decelerating trend is a causal factor of South Africa's down-break. Thus, the saving rate, operating through the *ecms* of the combined per capita growth rate *FGR/SGR* model in the last column of Table 3, is a direct determinant of the slowdown in South Africa's growth rate. This is further underlined by the close track of the actual and fitted values of the combined model across South Africa's *FGR* and *SGR* in Figure 5(b).

[25] Recall from the discussion in section 3.4 that one can only observe the rate of technological progress directly when the saving/investment rate is constant.

Overall, the empirical results strongly support the simulated down-break in Figure 4: both the saving rate, which captures the quality of the total investment rate, and the rate of technological progress are causal determinants of the downward shift in South Africa's growth rate. By implication, once we control for the delayed effect of the gold price bubble, both these sources of growth are jointly determined by a common exogenous source, which was most likely triggered by an increase in investment uncertainty following the Soweto riots in 1976, and gained further momentum with the debt crisis in 1985 (see the discussion in sections 2.2 and 3.4).

It is informative to compare the *interdependence* hypothesis advanced in this paper with the original Solow (1956) model. In the single-regime setting of the conventional Solow model, the saving/investment rate and the growth rate of technology are both exogenous and *independently* determined. Thus, policies that raise the saving/investment rate generate transition dynamics that occur independently from the fixed rate of technological progress. In effect, growth accounting exercises in the spirit of Easterly and Levine (2001) and Bosworth and Collins (2003) rely on the independence hypothesis of the Solow model. This assumption allows researchers to express output per worker growth as a weighted average of capital per worker and TFP growth, and to assess which proximate source of growth is more important in a quantity sense.

In contrast, evidence of an interdependent relationship in this paper implies that it is not possible to attribute specific quantities to capital accumulation and technological progress, and to evaluate their relative importance in these terms. Given that the saving rate and technological progress are jointly determined by a common exogenous source, the policy implication of this paper is directly related to causality.[26] Policies that succeed in reversing the downward trend in

[26] As emphasised in footnote 15, Figure 4 is simplified to show that both the saving rate and the exogenous rate of technological progress contributed to South Africa's down-break in a causal sense. However, because both these

South Africa's saving rate will, at the same time, generate a faster rate of technological progress, and perpetuate the growth-inducing effect of capital accumulation via learning-by-doing effects. The importance of this finding is that South Africa's growth rate is not completely 'mysterious' via an unexplained TFP/technology progress component, as argued in Easterly and Levine (2001). The next section examines these predictions with real data by looking at South Africa's post-2003 growth performance.

6. EVALUATING THE GROWTH PREDICTIONS

In this section, we examine the conditions necessary to generate a sustainable up-break in the economy's growth performance based on the theoretical models and empirical results of South Africa's down-break in the previous section. A sustainable up-break would require a reversal across the models in equations (8-8′) and equation (9). In other words, a long-lasting growth transition would entail a structural shift out of the Solow-type model, with close to zero learning-by-doing effects in South Africa's *SGR*, into a model with substantial learning-by-doing effects, such as the one in the economy's *FGR*. More specifically, the empirical evidence in the previous section suggests that the saving rate and the growth rate of technology are jointly determined by a common exogenous source, so that a permanent increase in the saving rate would lead to a faster rate of growth of technological progress *and* capital accumulation. To show this, we can rewrite equation (13) to make the current (actual) regime the *SGR* and the *desired* regime the *FGR*:

---

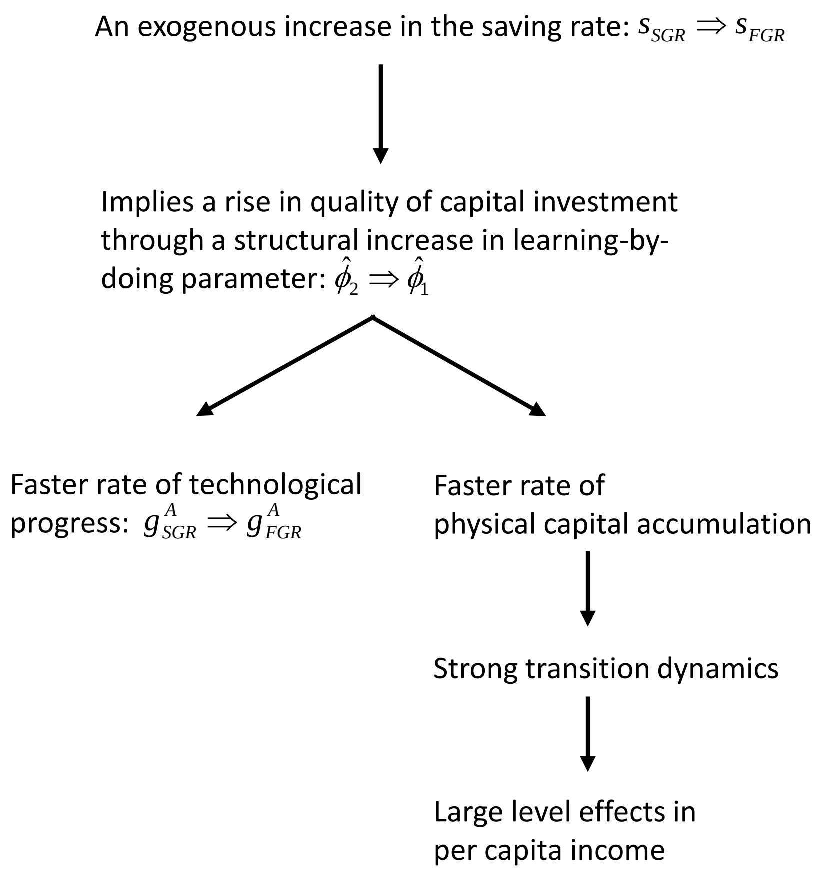
sources of growth determine the growth rate of the capital stock via equation (4′), it is not possible to know how important each source of growth is in terms of its quantity contribution to output per capita growth. Thus, the downward shift in the growth rate of capital per capita from 2.48% to -0.60% across the *FGR* and *SGR* in Table 1 is the joint outcome of the decelerating trend in the saving/investment rate and the slowdown in the growth rate of technology. Because capital is an input in the production function given by equation (2), the same argument applies to output per capita growth.

$$[g_{SGR}^{A} = g_{SGR}^{B} + \hat{\phi}_2 /(1-\hat{\phi}_2) g_{SGR}^{B}] \Rightarrow [g_{FGR}^{A} = g_{FGR}^{B} + \hat{\phi}_1 /(1-\hat{\phi}_1) g_{FGR}^{B}] \quad (14)$$

A permanent increase in the saving rate, which measures a rise in the quality of capital investment (see section 3.5), would increase the exogenous rate of technological progress from g_{SGR}^{A} to g_{FGR}^{A} in equation (14). This would occur through a structural increase in the learning-by-doing parameter from, say, $\hat{\phi}_2 = 0.10$ to $\hat{\phi}_1 = 0.54$ (using the empirical results obtained in Table 4). At the same time, the rise in the saving rate would also generate strong transition dynamics via a faster rate of capital accumulation. To see this, note from equations (7-8) that the elasticity of output with respect to capital is larger with the learning-by-doing parameter, as opposed to the Solow model in equation (9) that imposes zero learning-by-doing effects: $\beta = \alpha + \phi(1-\alpha) >$ $\beta = \alpha$. Indeed, from Table 4 it is apparent that the saving rate elasticity in South Africa's *FGR* by far exceeds the saving rate elasticity in the *SGR* due to larger learning-by-doing effects: $[\hat{\beta}_1 /(1-\hat{\beta}_1) = 1.75]$ > $[\hat{\beta}_2 /(1-\hat{\beta}_2) = 0.40]$. Thus, a permanent increase in the saving rate, with a concomitant increase in the learning-by-doing parameter, will induce strong transition dynamics in the growth rates of capital and output per capita as the economy moves to its new steady-state position. Although the growth rate dynamics will eventually fizzle out due to diminishing returns to capital, the exogenous shock to the saving rate will generate substantial level effects in per capita income.

The impact of an exogenous increase in the saving rate is summarised in Figure 6. In short, the analysis implies that the saving rate is potentially an important policy variable in the South African economy.

Figure 6. A Sustainable UP-Break Scenario



6.1 South Africa's Post-2003 Growth Performance

What role did the saving rate play in South Africa's post-2003 growth performance? Recall from section 2 that the Bai and Perron (1998, 2003) procedure identifies another structural break in per capita income growth in 2003. We use the same procedure to test for additional breaks in the gross domestic saving rate, as well as the total and gross domestic fixed investment rate. The Bai and Perron tests show that there is a corresponding 2003 up-break in both the total and fixed investment rate but not in the saving rate. This is evident in Figure 3, which shows a large increase in the investment rate relative to the saving rate in the post-2003 period.

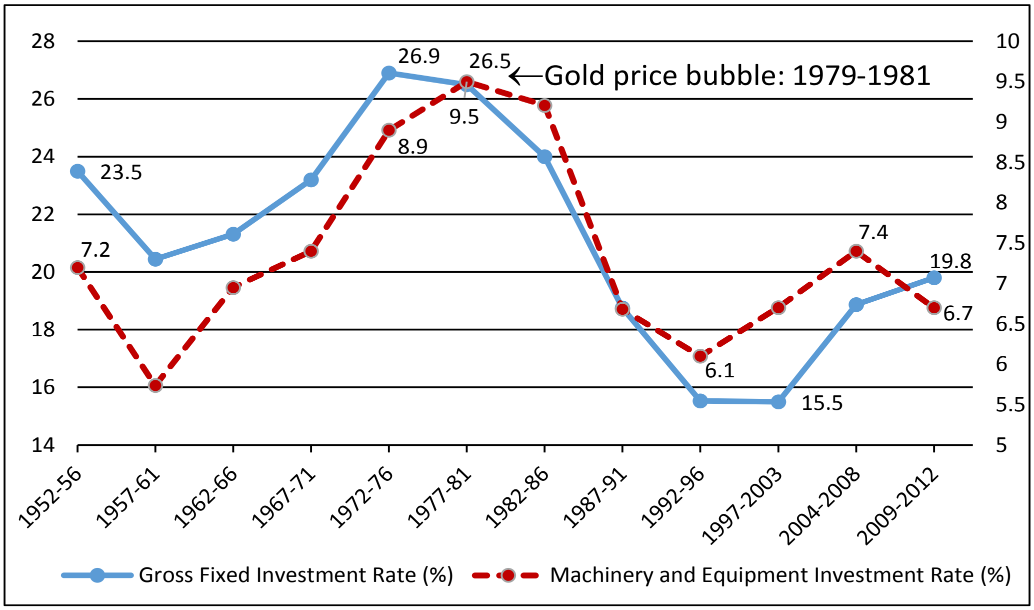
To interpret the policy implications of these results, it is important to reiterate what exactly the saving rate is picking up across South Africa's regimes. Recall, from section 3.5, that movements in the saving rate may serve as an indicator of whether capital investment is accompanied by technological progress. We can rely on the same explanation to predict what should happen in a hypothetical up-break scenario. An initial up-break in the investment rate relative to the saving rate would raise the rate of technological progress via stronger learning-by-doing effects, as hypothesised in equation (14). The positive shock to technological progress, in turn, would increase the profit rate of local firms and allow them to save larger fractions of their profit income. In this setting, the saving and investment rate would closely track each other, which serves as an indicator that capital investment also induces a faster rate of technological progress. This is the scenario depicted in Figure 6, which shows that an increase in the saving rate is associated with a rise in the quality of capital investment.

The divergence between the investment rate and the saving rate in the post-2003 period, however, suggests that the increase in the growth rate of capital per capita from -0.60% in the *SGR* to 2.21% during 2004-2012 did not lead to a faster rate of technological progress. To test this proposition more formally, we redefine the vector of dummy variables in the VECM as $w'_{SGR,t} = (D_{(80-84)}, D_{(92)}, D_{(04-12)})$, where the additional dummy variable, $D_{(04-12)}$, takes the value of unity during 2004-2012 and zero otherwise. The results of the VECM over the extended sample period 1977-2012 are almost identical to the *SGR* in terms of the cointegration analysis, structural stability tests and the long-run elasticity estimates. Going back to Table 4, it can be seen that the saving rate and capital elasticity estimates in columns (1) and (2) over the period 1977-2012 closely match those in the *SGR*. Indeed, the derived learning-by-doing parameter of 0.14 over the extended sample period is close to the 0.10 estimate in the *SGR*. From these results one can infer that capital accumulation did not induce a faster rate of technological progress in the post-2003 period. This also underlines the importance of the saving rate as a quality indicator of whether investment-led policies are successful in raising the growth rate of capital *and* the rate technological progress.

To examine why investment was less productive over the period 2004-2012, it is informative to look at how the fixed investment rate and some of its sub-components have evolved over time. Figure 7 plots non-overlapping averages of the aggregate fixed investment rate, and one of its sub-components, the machinery and equipment investment rate. Following the influential work of DeLong and Summers (1992, 1993), investment in machinery and equipment is often seen as the main source of technological progress via embodied technical progress and associated learning-by-doing effects. This is underlined in Figure 7, which shows that South Africa's *FGR* broadly corresponds with an increasing trend in the machinery and equipment investment rate and the *SGR* a decreasing trend.[27] Looking specifically at what happened in the post-2003 period, Figure 7 shows that the average fixed investment rate starts to level off after the global financial crisis in 2008, while the machinery and equipment investment rate shows a visible decrease.

[27] Of course, to fully utilise the productive potential of machinery and equipment investment would also require supportive investment in infrastructure (Fedderke and Bogetić, 2009). This is illustrated in Figure 7. The machinery and equipment investment rate already starts to increase since the mid-1990s, but the strong growth surge over the period 2004-2007 is only visible when the total fixed investment rate increases as well, suggesting that investment in structures is also important.

Figure 7: Non-Overlapping Averages of South Africa's Aggregate Fixed Investment Rate and Machinery and Equipment Investment Rate, 1952-2012



<u>Note:</u> Data Source: South African Reserve Bank (see Appendix A).

Since FDI forms part of gross domestic investment, and because it can also be considered as a potential carrier of technology, it is also instructive to examine what happened to the net stock of FDI ratio in the post-2003 period. The bottom panel of Figure 2 illustrates that there is substantial up and down variation in the net FDI ratio over the period of 'super fast' growth in regime (III) and the global financial crisis in regime (IV), respectively. It is also apparent from Figure 2 that if the net FDI ratio is shifted downwards to correct for the 'artificial' increase from 1999 to 2001 (see the discussion in section 2.2), it would fluctuate around a much lower average value in the post-2003 period relative to South Africa's *FGR*.

From the foregoing analysis it can be inferred that a *sustained* increase in the *total* investment rate, which includes infrastructure investment, machinery and equipment investment and complementary FDI flows, may be an effective policy strategy to raise the economy's growth rate on a sustainable basis. This has not been the case in South Africa's post-2003 period where the net FDI ratio fluctuated around a low average level, and the machinery and equipment investment rate decreased since 2008. The relatively inefficient nature of physical capital accumulation over the period 2004-2012, in turn, is captured by the low saving rate.

To conclude, the saving rate serves as a key indicator to see whether capital accumulation proceeds with technological progress and, thus, to evaluate the effectiveness of a particular investment-led strategy. It follows that an infrastructure-led growth strategy, such as the recent one stipulated under the ASGI-SA programme (see Frankel et al., 2008), may, on its own, not be enough to initiate a long-run growth transition, unless it is complemented with other technology-enhancing investments, such as machinery and equipment investment and FDI.

7. CONCLUSIONS

The hypothesis advanced in this paper is that the saving rate and the growth rate of technology are interdependently determined by a common exogenous source across regimes, so that an exogenous shock to the saving rate determines long-run growth transitions. In an open-economy setting, as argued in section 3.5, the saving rate serves as a measure of the quality or productivity of investment, that is, whether changes in capital investment induce changes in the growth rate of technology. The evidence shows that the down-break across South Africa's *FGR* (1952-1976) and *SGR* (1977-2003) was caused by a negative shock to the saving rate that simultaneously led to a slowdown in the rate of technological progress. Or put in another way, the negative shock to the saving rate resulted in a downward shift in South Africa's per capita income growth rate via a slowdown in the rate of physical capital accumulation and a structural decrease in the technology (learning-by-doing) parameter.

The down-break results suggest that the saving rate, as a measure of the quality of capital investment, is potentially an important policy variable to engineer a sustainable up-break in South

Africa's growth performance. To assess this prediction with real data, we looked at what happened in the post-2003 period when output per capita grew at a 'super fast' rate during 2004-2007 and then slowed down during the global financial crisis years from 2008 to 2012. During this period the upward break in the aggregate fixed investment rate was not matched by the saving rate, implying that the observed increase in the growth rate of physical capital did not generate a faster rate of technological progress. The econometric evidence verifies this proposition. The stylised facts across South Africa's *FGR* and *SGR*, together with the post-2003 analysis, further suggest that a long-run growth transition would require a sustained increase in the *total* fixed investment rate. Thus, although an infrastructure-led investment strategy on its own may not generate sustained growth, as argued in Frankel et al. (2008), a wide-ranging investment programme, which includes technology-enhancing investment in machinery and equipment and complementary FDI flows, might. In this scenario, as shown in section 6, stronger learning-by-doing effects will raise the elasticity of output with respect to capital which, in turn, will perpetuate the growth-inducing effect of a given shock to the saving/investment rate. Finally, the saving rate appears to be a key policy indicator to evaluate the effectiveness of a specific investment-led strategy.

REFERENCES

Aghion, P. and P. Howitt. 2007. "Capital, Innovation, and Growth Accounting." *Oxford Review of Economic Policy,* 23(1): 79-93.

Aghion, P., D. Comin, P. Howitt, and I. Tecu. 2009. "When Does Domestic Saving Matter for Economic Growth?" *Harvard Business School Working Papers*, 09-080, Harvard Business School.

Akaike, H. 1974. "A New Look at the Statistical Model Identification." *IEEE Transactions on Automatic Control*, 19(6): 716-723.

Attanasio, O.P., L. Picci, and A. E. Scorcu. 2000. "Saving, Growth, and Investment: A Macroeconomic Analysis Using a Panel of Countries." *Review of Economics and Statistics*, 82(2): 182-211.

Badunenko, O. and **D. Romero-Ávila.** 2013. "Financial Development and the Sources of Growth and Development." *International Economic Review,* 54(2): 629-663.

Bai, J. and P. Perron. 1998. "Estimating and Testing Linear Models with Multiple Structural Changes." *Econometrica,* 66(1): 47-78.

Bai, J. and P. Perron. 2003. "Computation and Analysis of Multiple Structural Change Models." *Journal of Applied Econometrics,* 18(1): 1-22.

Baier, S.L., G.P. Dwyer, and R. Tamura. 2006. "How Important are Capital and Total Factor Productivity for Economic Growth?" Economic Inquiry, 44(1): 23-49.

Berg, A., J. D. Ostry, and J. Zettelmeyer. 2012. "What Makes Growth Sustained?" *Journal of Development Economics*, 98(2): 149-166.

Bond, S., A. Leblebicioglu, and F. Schiantarelli. 2010. "Capital Accumulation and Growth: a new look at the empirical evidence." *Journal of Applied Econometrics*, 25(7): 1073-1099.

Borensztein, E., J. De Gregorio, and J-W. Lee. 1998. "How does foreign direct investment affect economic growth?" *Journal of International Economics*, 45(1): 115-135.

Bosworth, B.P. and S.M. Collins. 2003. "The Empirics of Growth: an update." *Brookings Papers on Economic Activity*, 34(2): 113-206.

Caselli, F. and J. Feyrer. 2007. "The Marginal Product of Capital." *Quarterly Journal of Economics*, 122(2): 535-568.

Coakley, J., F. Kulasi, and R. Smith. 1996. "Current Account Solvency and the Feldstein-Horioka Puzzle." *Economic Journal*, 106(436): 620-27.

De Mello, L.R. Jr. 1997. "Foreign Direct Investment in Developing Countries and Growth: A Selective Survey." *Journal of Development Studies*, 34(1): 1-34.

De Mello, L.R. Jr. 1999. "Foreign Direct Investment-Led Growth: Evidence from Time Series and Panel Data." *Oxford Economic Paper*, 51(1): 133-151.

Deaton, A. 1999. "Saving and Growth." In *The Economics of Saving and Growth: theory, evidence, and implications for policy*, ed. Klaus Schmidt-Hebbel and Luis Servén, 33-70. Cambridge: Cambridge University Press.

DeLong, J.B. and L.H. Summers. 1992. "Equipment Investment and Growth: how strong is the nexus?" *Brookings Papers of Economic Activity*, 23(2): 157-199.

DeLong, J.B. and L.H. Summers. 1993. "How Strongly Do Developing Economies Benefit From Equipment Investment?" *Journal of Monetary Economics*, 32(3): 395-415.

Dickey, D.A. and W.A. Fuller. 1979. "Distribution of the Estimators for Autoregressive Time Series with a Unit Root." *Journal of the American Statistical Association*, 74(366): 427-431.

Doornik, J.A. and D.F. Hendry. 2013. *Empirical Econometric Modelling, PcGive 14*, vol. 1. London: Timberlake Consultants.

Du Plessis, S. and B. Smit. 2007. "South Africa's Growth Revival After 1994." *Journal of African Economies*, 16(5): 668-704.

Easterly, W., and R. Levine. 2001. "It's Not Factor Accumulation: stylized Facts and Growth Models." *World Bank Economic Review*, 15(2): 177-219.

Easterly, W., M. Kremer., L. Pritchett, and L.H. Summers. 1993. "Good Policy or Good Luck?: Country Growth Performance and Temporary Shocks." *Journal of Monetary Economics*, 32(3): 459-483.

Fedderke, J.W. and W. Liu. 2002. "Modelling the Determinants of Capital Flows and Capital Flight: With an Application to South African Data from 1960 to 1995." *Economic Modelling*, 19(3): 419-444.

Fedderke, J.W. and A.T. Romm. 2006. "Growth Impact and Determinants of Foreign Direct Investment into South Africa, 1956-2003." *Economic Modelling*, 23(5): 738-760.

Fedderke, J.W. and Z. Bogetić. 2009. "Infrastructure and Growth in South Africa: Direct and Indirect Productivity Impacts of 19 Infrastructure Measures." *World Development*, 37(9): 1522-1539.

Frankel, J., B. Smit, and F. Sturzenegger. 2008. "South Africa: Macroeconomic Challenges after a Decade of Success." *Economics of Transition*, 16(4): 639-677.

Garratt, A., K. Lee, M. H. Pesaran, and Y. Shin. 2000. "A Structural Cointegrating VAR Approach to Macroeconometric Modelling." In *Econometric Modelling: Techniques and Applications*, ed. Sean Holly and Martin Weale, 94-146. Cambridge: Cambridge University Press.

Gollin, D. 2014. "The Lewis Model: A 60-year Retrospective." *Journal of Economic Perspectives*, 28(3): 71-88.

Granger, C.W.J. 1988. "Some Recent Developments in a Concept of Causality." *Journal of Econometrics*, 39(1-2), 199-211.

Gwenhamo, F. and J.W. Fedderke. 2013. "The Composition of Foreign Capital Stocks in South Africa: The Role of Institutions, Domestic Risk and Neighbourhood Effects." *Economic Modelling*, 35: 763-770.

Harding, T. and B.S. Javorcik. 2011. "Roll Out the Red Carpet and They Will Come: investment promotion and FDI inflows." *Economic Journal*, 121(557): 1445-1476.

Hausmann, R., L. Pritchett, and D. Rodrik. 2005. "Growth Accelerations." *Journal of Economic Growth*, 10(4): 303-329.

Helpman, E. 2004. *The Mystery of Economic Growth.* Cambridge: Harvard University Press.

Henderson, D.J. and R. Russell. 2005. "Human Capital and Convergence: a production-frontier approach." *International Economic Review*, 46(4): 1167-1205.

Herrerias, M. and V. Orts. "Equipment Investment, Output and Productivity in China." *Empirical Economics*, 42(1): 181-207.

Hsieh, C-T. and P. J. Klenow. 2010. "Development Accounting." *American Economic Journal: Macroeconomics*, 2(1), 2017-223.

Jerzmanowski, M. 2006. "Empirics of Hills, Plateaus, Mountains and Plains: A Markov-Switching Approach to Growth." *Journal of Development Economics*, 81(2): 357-385.

Johansen, S. 1988. "Statistical Analysis of Cointegration Vectors." *Journal of Economic Dynamics and Control*, 12(2-3): 231-54.

Johansen, S. 1992. "Cointegration in Partial Systems and the Efficiency of Single Equation Analysis." *Journal of Econometrics*, 52(3): 389-402.

Johansen, S., and K. Juselius. 1992. "Some Structural Hypotheses in a Multivariate Cointegration Analysis of Purchasing Power Parity and Uncovered Interest Parity for the U.K." *Journal of Econometrics*, 53(1-3): 211-44.

Jones, B.F. and B.A. Olken. 2008. "The Anatomy of Start-Stop Growth." *Review of Economics and Statistics*, 90(3): 582-587.

Kaldor, N. 1955-56. "Alternative Theories of Distribution." *Review of Economic Studies*, 23(1): 83-100.

Kaldor, N. 1957. "A Model of Economic Growth." *Economic Journal*, 67(268): 591-624.

Kaldor, N. 1961. "Capital Accumulation and Economic Growth." In *The Theory of Capital*, ed. F. Lutz. London: Macmillan.

Kar, S., L. Pritchett., S. Raihan, and K. Sen. 2013. "Looking for a Break: Identifying Transitions in Growth regimes." *Journal of Macroeconomics*, 38(PB): 151-166.

Kerekes, M. 2012. "Growth Miracles and Failures in a Markov Switching Classification Model of Growth." *Journal of Development Economics*, 98(2): 167-177.

King, R.G. and R. Levine. 1994. Capital Fundamentalism, Economic Development, and Economic Growth. *Carnegie-Rochester Conference Series on Public Policy*, 40(1): 259-292.

Kumar, S. and R. Russell. 2002. "Technological Change, Technological Catch-up, and Capital Deepening: relative contributions to growth and convergence." *American Economic Review*, 92(3): 527-548.

Kwiatkowski, D., P.C.B. Phillips, P. Schmidt, and Y. Shin. 1992. "Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root: how sure are we that economic time series have a unit root?" *Journal of Econometrics*, 54(1-3): 159-178.

Lodge, T. 2011. *Sharpeville: an apartheid massacre and its consequences*. Oxford: Oxford University Press.

Mohr, P. and Rogers, C. 1995. *Macroeconomics*. Johannesburg: Lexicon.

Ndlovu, S.M. 2006. "The Soweto Uprising." In *The Road to Democracy in South Africa: Volume 2 (1970-1980)*, ed. South African Democracy Education Trust. Pretoria: UNISA Press.

Nell, K. S., and L. Delfim Santos. 2008. "The Feldstein-Horioka Hypothesis Versus the Long-run Solvency Constraint Model: A Critical Assessment." *Economics Letters*, 98(1): 66-70.

Nell, K.S. 2015. "The Complementary Nature between Technological Progress and Capital Accumulation in India's Long-Run Growth Transitions." *Metroeconomica*, 64(4): 565-605.

Ng, S. and P. Perron. 2001. “Lag Length Selection and the Construction of Unit Root Tests with Good Size and Power.” *Econometrica*, 69(6): 1519-1554.

Odhiambo, N.M. 2007. “Saving and Economic Growth in South Africa: A Multivariate Causality Test.” *Journal of Policy Modeling*, 31(5): 708-718.

Pesaran, M. H., and B. Pesaran. 1997. *Working with Microfit 4.0: Interactive Econometric Analysis.* Oxford: Oxford University Press.

Pesaran, M. H., and Y. Shin. 2002. “Long-Run Structural Modelling.” *Econometric Reviews*, 21(1): 49-87.

Pesaran, M. H., Y. Shin, and R. Smith. 2000. “Structural Analysis of Vector Error Correction Models with Exogenous I(1) Variables.” *Journal of Econometrics*, 97(2): 293-344.

Phillips, P.C.B. and P. Perron. 1988. “Testing for a Unit Root in Time Series Regression, *Biometrika*, 75(2): 335-346.

Pritchett, L. 2000. “Understanding Patterns of Economic Growth: Searching for Hills Among Plateaus, Mountains, and Plains.” *World Bank Economic Review*, 14(2): 221-250.

Rodrik, D. 2000. “Saving Transitions.” *World Bank Economic Review*, 14(3): 481-507.

Romm, A.T. 2005. “The Relationship between Saving and Growth in South Africa: A Time Series Analysis.” *South African Journal of Economics*, 73(2): 171-189.

Schwarz, G. 1978. “Estimating the Dimensions of a Model.” *Annals of Statistics*, 6(2): 461-464.

Smit, B., C. Grobler, and C. Nel. 2014. “Sudden Stops and Current Account Reversals: Potential Macroeconomic Consequences for South Africa.” *South African Journal of Economics*, 82(4): 616-627.

Solow, R. M. 1956. “A Contribution to the Theory of Economic Growth.” *Quarterly Journal of Economics*, 70(1): 65-94.

Sørensen, P.B. and H.J. Whitta Jacobsen. 2010. *Introducing Advanced Macroeconomics: growth and business cycles*, second edition. London: McGraw-Hill.

Tang, C.F. and B.W. Tan. 2014. “A Revalidation of the Savings-Growth Nexus in Pakistan.” *Economic Modelling*, 36(C): 370-377.

Vogelsang, T.J. and P Perron. 1998. “Additional Test for a Unit Root Allowing for a Break in the Trend Function at an Unknown Time.” *International Economic Review*, 39(4): 1073–1100.

APPENDIX A, Table A1 – VARIABLE DEFINITIONS AND DATA SOURCE

Variable	Description	Source
$\ln(y_{p/c})_t$	Natural logarithm of real GDP per capita at market prices (constant 2005 prices).	South African Reserve Bank
$\Delta\ln(y_{p/c})_t$	Per capita income growth rate.	$\Delta\ln(y_{p/c})_t = \ln(y_{p/c})_t - \ln(y_{p/c})_{t-1}$
$\ln(s)_t$	Natural logarithm of total gross domestic saving as a share of nominal GDP at market prices.	South African Reserve Bank
$\Delta\ln(s)_t$	Growth rate of domestic saving rate	$\Delta\ln(s)_t = \ln(s)_t - \ln(s)_{t-1}$
Total Investment Rate	Total gross domestic investment as a share of nominal GDP at market prices.	South African Reserve Bank
Fixed Investment Rate	Gross domestic fixed investment as a share of nominal GDP at market prices.	South African Reserve Bank
Machinery & Equipment Investment rate	Total machinery and equipment investment (excluding transport) as a share of nominal GDP at market prices.	South African Reserve Bank
Dummy: $D_{(60-61)}$	Equals 1 in 1960 and 1961; zero otherwise.	Captures the slowdown in growth following the Sharpeville massacre in March 1960 (see Figure 1). For more details, see Lodge (2011).
Dummy: $D_{(80-84)}$	Equals 1 during 1980-1984; zero otherwise.	Models the growth surge associated with the high dollar gold price during the early 1980s (see Figure 1) together with the downward shift in the saving rate (see Figure 3).
Dummy: D_{92}	Equals 1 in 1992; zero otherwise.	A proxy for the negative per capita income growth rate of -4.24% in 1992, following the global recession during the early 1990s and more restrictive monetary policy measures at home (see Figure 1).
Dummy: $D_{(04-12)}$	Equals 1 during 2004-2012; zero otherwise.	Captures super fast growth over the period 2004-2007 and the global financial crisis years during 2008-2012 (see Figure 1).

Note: The data cover the period 1949-2012. Due to lagged and differenced variables the effective sample period is 1952-2012. For more information on the sample period used, consult footnote 5.