

Measuring the Potential Output of South Africa



Nir Klein

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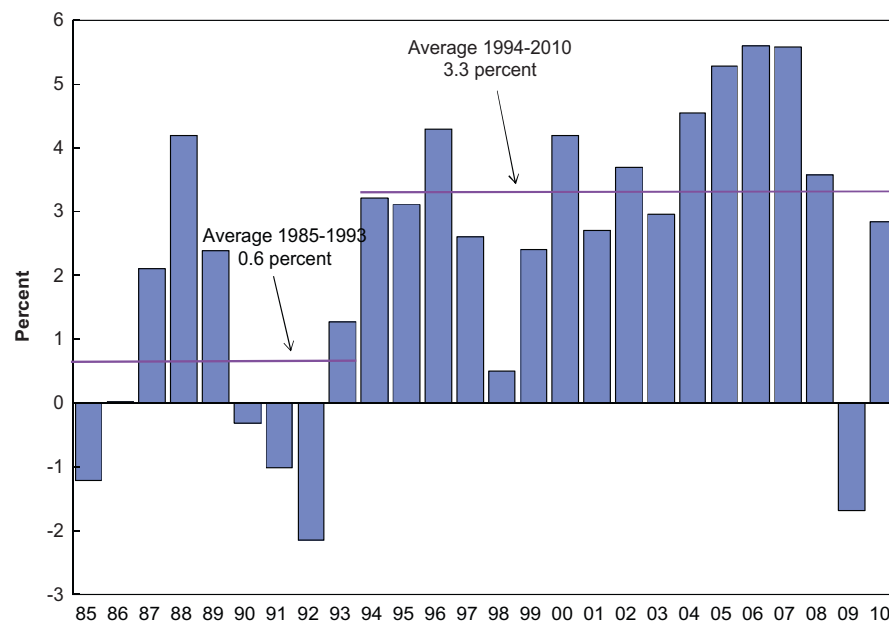
This paper provides an assessment of the South African potential output for the period 1985–2010 by applying both structural and nonstructural estimation techniques. The analysis suggests that, while potential output growth steadily accelerated in the post-apartheid era to about 3½ percent (1994–2008), it has decelerated considerably following the outbreak of the financial crisis, as was observed in other advanced and emerging economies. While this indicates that, at around –1½ percent, the estimated 2010 output gap was lower than previously thought, there is a fair amount of uncertainty regarding its “true” magnitude, reflecting in part the backward looking nature of the estimation methods. Going forward, staff is of the view that the potential growth is likely to gradually revert to its precrisis pace and the output gap to have closed by early 2012.

1 Introduction

The output gap serves as an important indicator for the state of the economy and is widely used by policymakers. However, its measurement involves a high degree of uncertainty as it reflects the movements of potential output, which are not observed. In the context of South Africa, this concept is even more difficult to measure given that the economy has undergone substantial structural changes in recent years, which led to greater global integration and are reflected in a noticeable acceleration of real GDP growth (Figure 1). Furthermore, the recent financial crisis, which led to a massive job shedding that is still continuing in some segments of the economy, a non-negligible contraction of fixed investment, and a protracted decline in the level of exports volume, despite the recovery that was observed in the overall imports of South Africa’s trading partners, add to the uncertainty surrounding the measurement of potential output.¹

¹ There are few definitions to the potential output. Okun (1962) defines it as output that can be produced under full employment (long-term output). Others, such as DeMasi (1997), view it as the maximum output that can be produced without causing inflationary pressures.

Figure 1. South Africa: Real GDP growth, 1985–2010



In order to assess the current output gap and the related potential growth, this note applies a wide range of structural and nonstructural approaches. While some of these methodologies were applied to South Africa in previous studies,² this note also aims to assess the impact of the recent financial crisis and its implications for the prevailing output gap. In this context, the analysis also examines the extent in which output gap is sensitive to the global economic fluctuations and assesses how this sensitivity evolved in recent years.

The remainder of the note is organized as follows: Section 2 reviews the alternative methods that are used to estimate the output gap, Section 3 discusses the estimation results and examines whether the global financial crisis led to a structural break in the potential output growth using the Chow Breakpoint Test, and Section 4 focuses on the recent episode of the global financial crisis from an international perspective and also assesses the impact of the global business cycles on South African's estimated output gap.

2 Review of Estimation Methods

Because estimates of potential output are subjected to considerable uncertainty, we use several alternative estimation techniques. The different approaches can be classified into some of the de-trending statistical methods

² Du Plessis, Smit, and Sturzenegger (2007); Akinboade (2005); Arora and Bhundia (2003); and Du Toit and Moolman (2003).

such as the Hodrick–Prescott filter, Baxter–King band-pass filter, and the unobserved component methods using the Kalman filter. The latter is also extended into a multivariate system that includes structural relationships between economic variables. The more structural approaches for output gap estimation that are being used in this paper are the structural vector autoregression (SVAR) and the production function (PF) methods. The main features of each methodology are described in the following.

A. The Hodrick–Prescott Filter

The Hodrick–Prescott (HP) filter is a simple smoothing procedure and is one of the most common methods to estimate the potential output. The main assumption is that the potential output varies smoothly over time, and, as such, this method minimizes the gap between actual output (y) and potential output \hat{y} subject to a penalty that constrains the second difference of potential output, as follows:

$$\text{Min} \sum_{t=1}^T (y_t - \hat{y}_t)^2 + \lambda \sum_{t=2}^{T-1} (\hat{y}_{t+1} - \hat{y}_t) - (\hat{y}_t - \hat{y}_{t-1})^2 \quad (1)$$

where λ determines the degree of smoothness of the trend. Following the standard practice for quarterly data, we adopt a smoothness parameter equal to 1,600. In addition, to avoid the end-sample bias, we extended the sample to 2016 using the April 2011 *World Economic Outlook* real GDP growth forecast.

B. Baxter–King Band-Pass Filter

Another univariate approach to filter a time series was developed by Baxter and King (1995). The advantage of this approach (compared to the HP filter) is that it isolates the cyclical component of a time series by specifying a range for its duration, thus the business cycles, and the high-frequency components that reflect irregularities or seasonal effects, do not affect the trajectory of potential output. Here, the business cycle duration is set to last between 8 to 32 quarters, though other specifications were tested as well, yet they did not produce results that differed significantly.

C. Unobserved Component Methods Using Kalman Filter

This methodology allows identifying unobserved variables by their link to observed variables and by their underlying statistical process, and it is commonly used to estimate the two unobserved components of GDP: the trend component (potential output) and its cyclical component (the output gap). Here we follow Fuentes and others (2007) and Magud and Medina (2011) with some modifications, and present three alternative models: (1) a univariate model that includes one signal equation, which is close in

its characteristic to an HP filter, though it allows a stochastic variation of potential output; (2) a multivariate filter that includes a Phillips curve; and (3) a multivariate filter that includes both Phillips curve and an IS curve (a technical description of each model is provided in Appendix 1).

D. Structural Vector Autoregression Approach

The SVAR estimation follows Blanchard and Quah (1989), who proposed to impose structural restrictions to breakdown the random disturbances of an unrestricted vector autoregression to demand and supply (productivity) shocks. The underlying assumption is that supply shocks have a long-lasting impact on output while the demand shocks have a temporary one.³

The approach here uses a trivariate vector autoregression system that includes the real GDP growth (ΔY), the change in real exchange rate (ΔRER) and inflation ΔCPI , as used by Clarida and Galí (1994) based on the open economy model that was developed by Obstfeld (1985).⁴ The long-run representation of the system can be written as:

$$\Delta Z = \begin{bmatrix} \Delta Y \\ \Delta RER \\ \Delta CPI \end{bmatrix} = \begin{bmatrix} C_{11}(1) & C_{12}(1) & C_{13}(1) \\ C_{21}(1) & C_{22}(1) & C_{23}(1) \\ C_{31}(1) & C_{32}(1) & C_{33}(1) \end{bmatrix} \begin{bmatrix} \varepsilon_s \\ \varepsilon_d \\ \varepsilon_n \end{bmatrix}$$

where $C(1) = C_0 + C_{1+...}$ is the long-run effect of ε_t on ΔZ .⁵ We follow Clarida and Galí's identifying assumptions, which imply that in the long run, output is not affected by the demand and nominal shocks [$C_{12}(1) = C_{13}(1) = 0$], and that the nominal shock has a permanent impact only on the price level [which also implies that $C_{23}(1) = 0$]. These restrictions will help to recover the structural shocks from the reduced-form innovations. The short-run dynamics were left without restrictions.

E. The Production Function Approach

One of the main structural approaches to the measurement of output gap is the PF method. Here, the PF is assumed to be a Cobb-Douglas type with

³ Blanchard and Quah (1989) acknowledged that demand shocks might have a long-run impact on output while aggregate supply shocks may also affect the business cycles and be short-lived, but they argued that this identification "represents an average of the dynamic effects of the different shocks."

⁴ While the model proposed by Clarida and Galí (1994) includes the relative output, the real exchange rate, and the relative price level; in this estimation, we follow Cerra and Saxena's (2000) approach, which substitutes the relative measures with the domestic output and prices.

⁵ The vector autoregression has a moving average structural representation given by $\Delta Z = C(L)\varepsilon_t$, where L is the lag operator.

constant returns to scale, where the output (Y_t) at time t depends on total factor productivity (A_t), and the production inputs of capital (K_t) and of labor (L_t):

$$Y_t = A_t(Z_t K_t)^{1-\alpha} L_t^\alpha$$

where Z_t represents capital utilization and α is the labor share. We set $\alpha = 0.48$, which is the average labor share in the sample period, and the production function can be shown in log terms as:

$$y_t = a_t + 0.52z_t + 0.52k_t + 0.48l_t$$

In addition, the deviation from potential output (in log terms) is given by the equation:

$$y_t^e = y_t - y_t^p = a_t - a_t^p + 0.52(z_t - z_t^p) + 0.52(k_t - k_t^p) + 0.48(l_t - l_t^p)$$

As in Menashe and Yakhin (2004) and Fuentes and others (2007), we assumed that the total capital stock is potentially available for companies' use (so that $k_t = k_t^p$), thus every deviation from potential use of capital derives from nonutilization. In addition, we omit the cyclical component of productivity as it behaves as a white noise without a clear cycle. Thus, the output gap can be expressed as follows:

$$y_t^e = 0.52z_t^e + 0.48l_t^e$$

For the cyclical utilization rate, we use the cyclical component of an HP filter applied to energy production.⁶ As for the cyclical employment series, given that prior to 2000, the employment data covers only the formal nonagricultural sector, we chose to use this series for the entire sample period to maintain consistency in the output gap calculation. This approach implicitly assumes that the cyclical components (in percentage of the aggregate) of the agricultural, informal, and formal employment are broadly similar.⁷

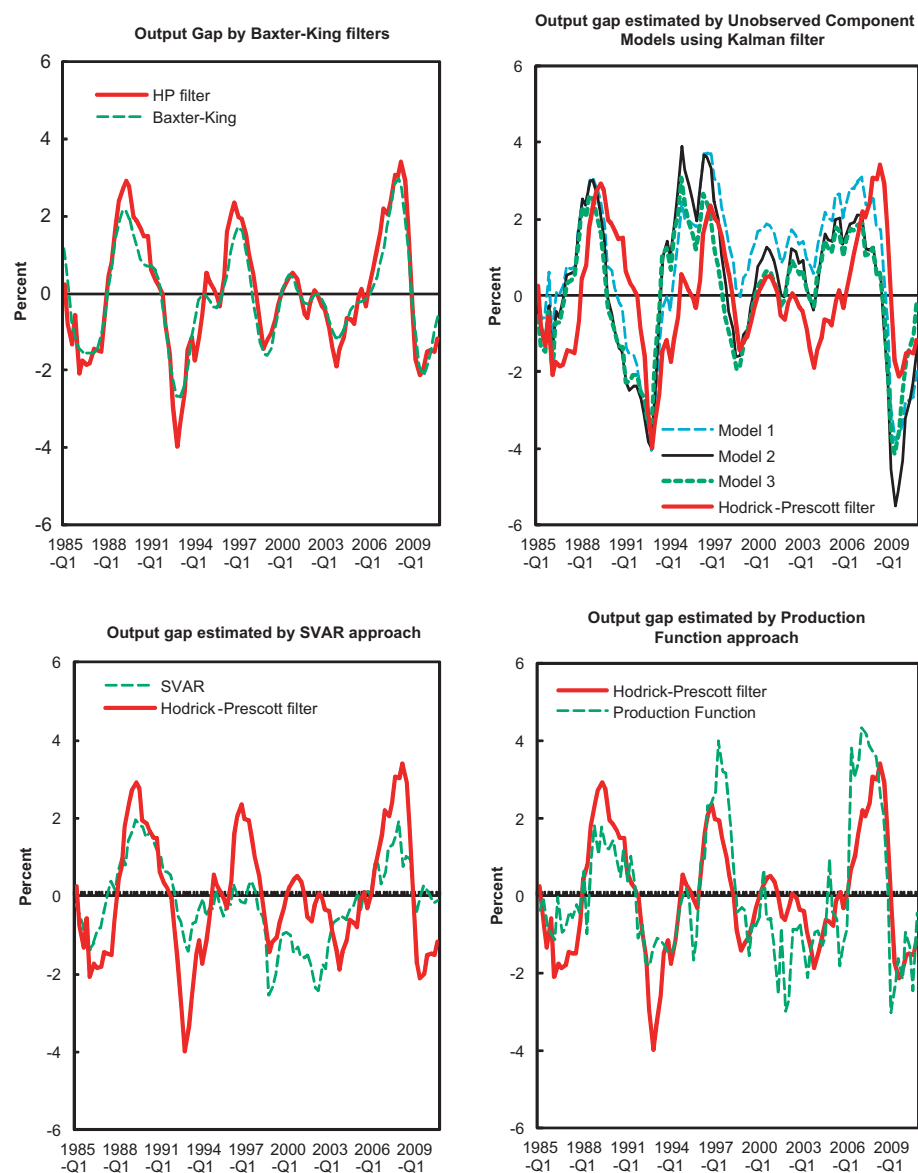
3 Estimation Results

Table 1 presents the estimation results by each methodology divided into several subsamples to identify whether there was a significant shift in potential output growth over the sample's period. The subsamples are (1) the apartheid regime era in which the economic growth was burdened by economic isolation and the international sanctions (1985:Q1–1994:Q1); (2) the post-apartheid regime until the financial crisis adversely affected

⁶ For the output gap estimation, this measure proved to be better than the utilization capacity indicator produced by the South African Central Statistical Service because the latter has been continuously below a 100 percent rate and reached its maximum (86 percent) only two times since 1985.

⁷ The cyclical component of employment was obtained from the HP filter. To overcome the end-point bias, we extended the series to 2016, assuming that the elasticity of employment with respect to output is around one.

Figure 2. Output gap by different methodologies*



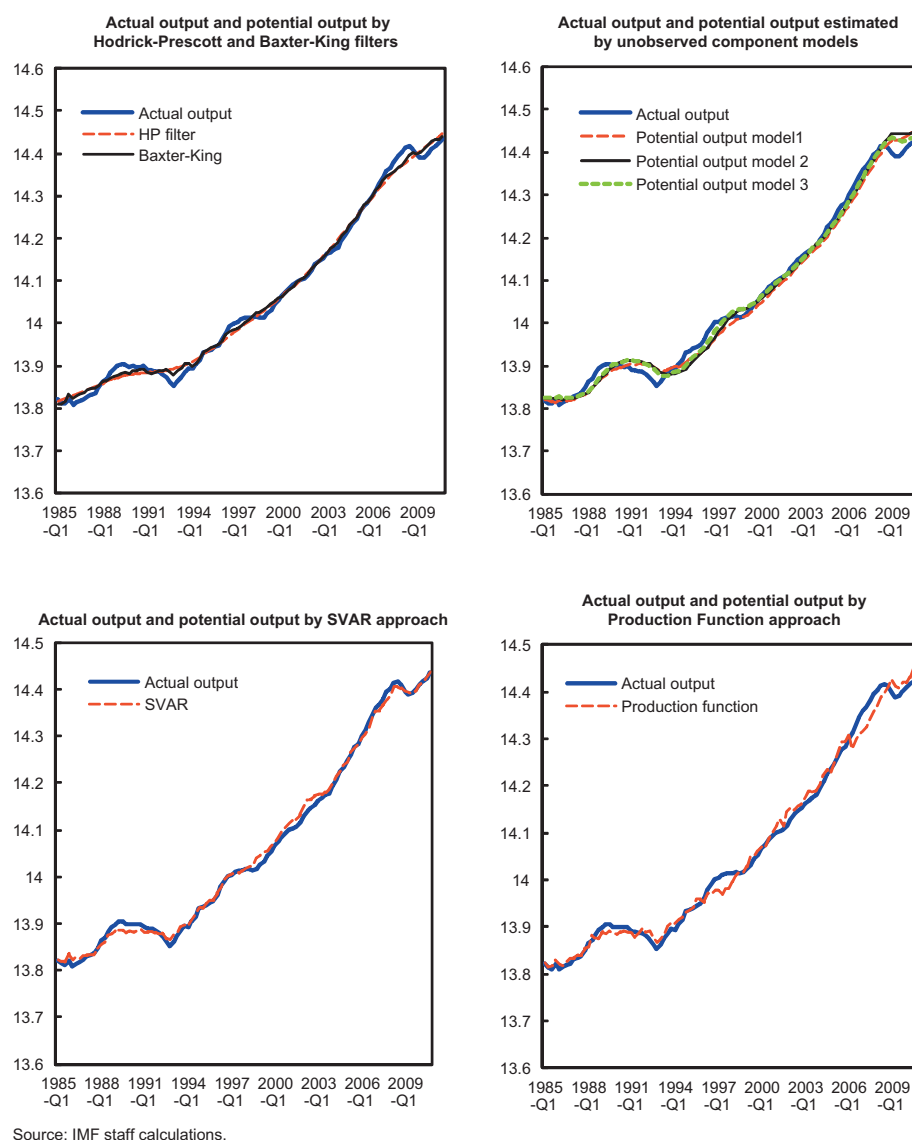
Source: IMF staff calculations.

*The Hodrick-Prescott filter is plotted in all chart for comparison.

South Africa's economic growth (1994:Q2–2008:Q4); (3) the financial crisis period (2009:Q1–2009:Q4), which was reflected in continuous contraction of real GDP (on a year-on-year basis); and (4) the recent period of economic recovery (2010:Q1–2010:Q4).

By and large, the estimated trajectories of the output gap seem to be highly correlated, although the magnitude of the gaps varied in some periods (Table 1 and Figure 2). The only period in which the estimations

Figure 3. Actual and Potential output (in natural log terms)



differ substantially is the 2000–04 cycle. In this period, which includes the deterioration of external conditions in 2001–02 due to the slowdown of the global economy, the SVAR and the PF approaches estimate a negative output gap due to continued strong pace of potential output, while the Kalman filter models estimate a deceleration in potential output growth and therefore yield a positive output gap. The diverging estimations for this period lead to a relatively weak correlation between these three methodologies (Table 2).

The comparison between the subsamples clearly indicates that the potential GDP growth varied significantly over the years. In particular, the estimations

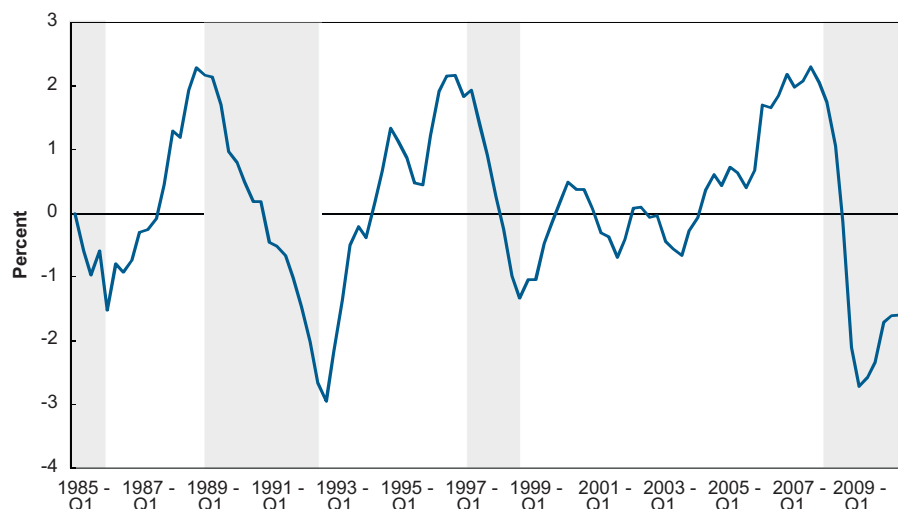
Table 1. The Average of Actual Output, Potential Output, and Output Gap

Period	Potential output growth						
	Actual output growth	Potential output growth	Kalman filter				PF
			Baxter-King	Model 1	Model 2	Model 3	
1985Q1–94Q1	0.633	0.879	1.007	0.996	0.898	0.785	0.766
1994Q2–2010Q4	3.192	3.242	3.171	3.177	3.309	3.375	3.168
1994Q2–2008Q4	3.553	3.431	3.247	3.303	3.458	3.628	3.445
2009Q1–09Q4	–1.696	1.923	2.641	1.835	2.582	2.730	–0.504
2010Q1–10Q4	2.743	1.739	2.584	2.660	1.837	0.284	2.749
Average output gap							
Output gap as a percent of potential output							
1985Q1–94Q1	–0.194	–0.301	–0.292	–0.070	–0.328	–0.401	0.201
1994Q2–2010Q4	0.275	0.142	–0.006	1.205	0.522	0.333	–0.384
1994Q2–2008Q4	0.575	0.363	0.170	1.774	1.086	0.692	–0.430
2009Q1–09Q4	–2.433	–1.547	–1.341	–3.441	–4.872	–3.529	–0.040
2010Q1–10Q4	–1.435	–1.421	–1.259	–2.536	–2.413	–1.090	–0.046

Table 2. Output Gap Correlation Matrix

	HP	Baxter-King	Kalman filter, model 1	Kalman filter, model 2	Kalman filter, model 3	SVAR	PF
HP	1.0000	0.9615	0.6400	0.5025	0.4689	0.6321	0.7522
Baxter-King	0.9615	1.0000	0.6067	0.4869	0.4558	0.6298	0.7219
Kalman filter, model 1	0.6400	0.6067	1.0000	0.9286	0.8827	0.1527	0.5253
Kalman filter, model 2	0.5025	0.4869	0.9286	1.0000	0.9767	0.1316	0.3966
Kalman filter, model 3	0.4689	0.4558	0.8827	0.9767	1.0000	0.1780	0.3597
SVAR	0.6321	0.6298	0.1527	0.1316	0.1780	1.0000	0.5883
PF	0.7522	0.7219	0.5253	0.3966	0.3597	0.5883	1.0000

Figure 4. South Africa: The average output gap in percent of potential output by the seven methodologies¹



¹The shaded areas are defined by the Economic Cycle Research Institute (ECRI) as periods of recessions.

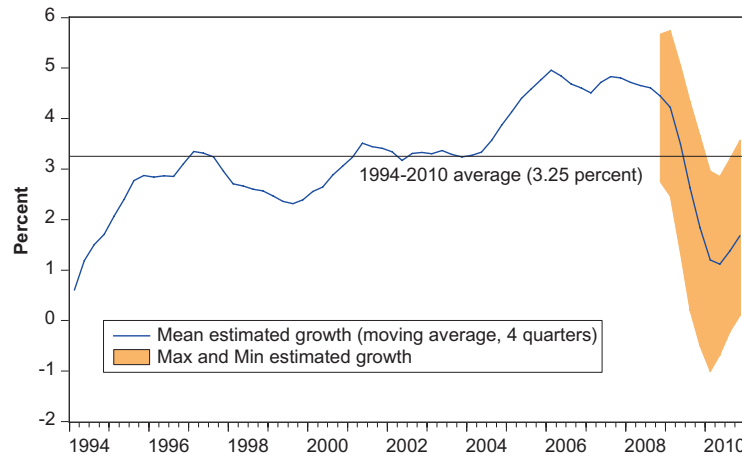
show that in the first period (1985:Q1–1994:Q1), the potential GDP growth was very modest, at slightly below 1 percent, emphasizing the high economic costs associated with isolation of the apartheid regime.⁸ In the second period (1994:Q2–2008:Q4), the potential output growth accelerated to nearly 3½ percent on average, reflecting also the rapid increase in employment and the steep increase in total factor productivity (see Figure A1 in Appendix 1).

While observations are still limited, the estimations also reveal that potential output growth has significantly decelerated to slightly below 2 percent following the global financial crisis, thus suggesting that the prevailing output gap is smaller than previously thought.⁹ In particular, the estimations show that the estimated output gap moved from an average level of 2 percent in 2007:Q1–2008:Q2, to an average level of about –2½ in 2009 (Figure 4). Given that the actual growth was higher than the estimated potential growth in 2010, output gap contracted and on average stood at about –1½ percent.

The breakdown of the potential output by the main three sectors reveals that their cyclical pattern is not identical (see Figure A.3 in Appendix 1). The output gaps of the primary and secondary sectors are significantly more

⁸The low potential growth rate for this period is consistent with the findings of Arora and Bhundia (2003).

⁹While in the previous two subsamples, the estimations on average differ only marginally from each other, it is less so in the third and fourth subsamples. In the period of the financial crisis, the estimations for potential output growth vary in a relatively wide band ranging from 2¾ percent to a contraction of ½ percentage points. The estimated contraction of the potential output is derived from the SVAR methodology, which excludes the public sector's impulse in this period.

Figure 5. South Africa: Estimated potential output growth, 1994-2010

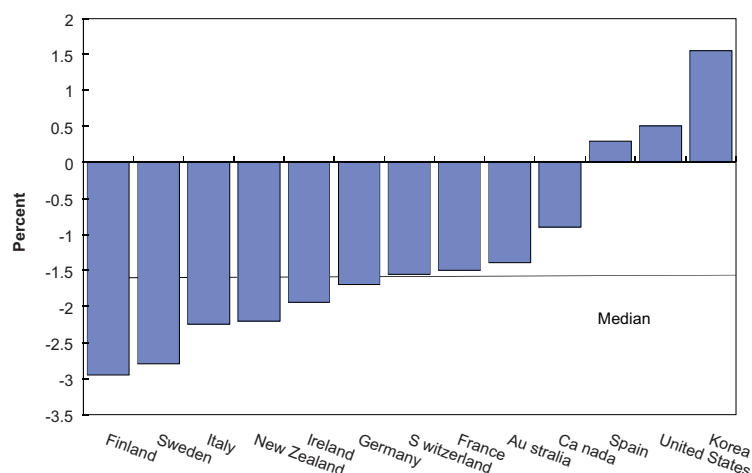
volatile than that of the tertiary sector, which accounts for nearly two-thirds of the total added value. The relatively low volatility of the tertiary sector's output gap, which largely represents the government's services, may reflect the direct impact of the government's countercyclical fiscal policy. Additionally, although the output gap of all the three sectors turned to negative levels with the outbreak of the financial period, the potential output of the primary sector seems to have recovered toward the end of 2010, and its output gap reverted to positive levels. The output gaps of the secondary and tertiary sectors remained negative in 2010, though they show signs of improvement.

The deceleration in potential output growth in 2009–10 reflects the impact of the financial crisis on the multifactor productivity, as well as on the labor and capital factor inputs. More specifically, the decline in innovative activities in advanced economies, which was in part due to the recent tightening in credit conditions and the problems in firms' balance sheets, was reflected in a considerable decline in the multifactor productivity in most advanced economies during the financial crisis episode (Figure 6). This is likely to have an impact on South Africa's productivity growth as well, particularly in industries that are fast adopters of new technologies.

On labor, the nontrivial job shedding of nearly 1 million employees may not be fully reversed in the short-term, not only because of the frictions in the labor market and the relatively long adjustment lags, but also due to the dynamics in the labor force.¹⁰ And indeed, since 2008, the participation rate

¹⁰ The loss of a million jobs reflects a shift from a positive output gap of 2 to 3 percent on the eve of the financial crisis to a negative terrain in 2009–10. Therefore, in the process of returning to potential output, fewer than 1 million jobs are expected to be created.

Figure 6. The average change in multi factor productivity in selected advanced economies, 2008-09*



Source: OECD.

*For Australia, and New Zealand the figures refer to 2008 only.

has declined by some 4 percentage points and resulted in a growing number of discouraged work-seekers (see Figure A.4 in Appendix 1).¹¹

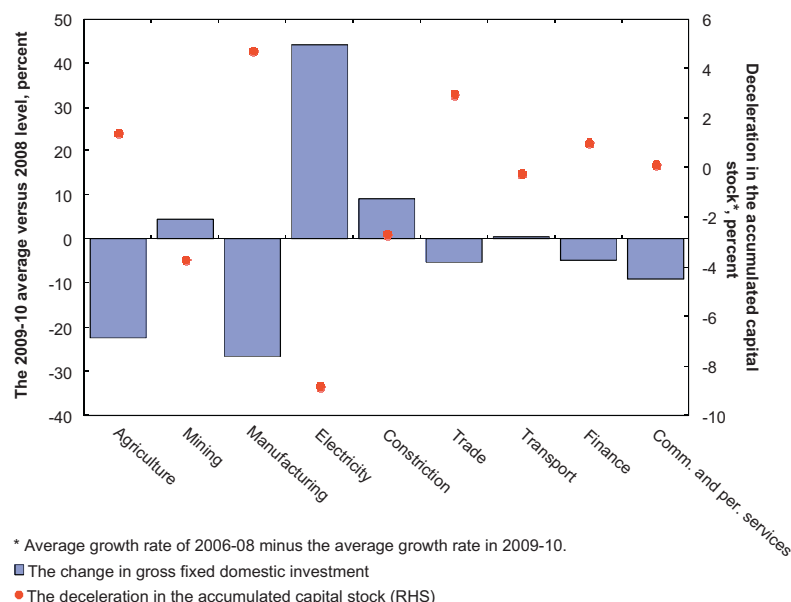
The deceleration of potential growth also stems from the sharp drop of investment, which affected the pace of the accumulation of capital stock. The overall gross fixed domestic investment declined by 3½ percent of GDP since 2008, largely reflecting the contraction of the private sector's investment, particularly in the manufacturing and agriculture sectors (Figure 7). Given that labor and capital are often viewed as complementary input factors, the decline in capital stock is likely to affect job creation in the near future.

External Demand and the Potential Output Growth

A possible explanation for the continued contraction of employment and private investment in 2010 is the substantial and sharp decline in external demand for South African exports in the past two years (Figure 8). During 2009, the South African exports volume fell by 20 percent, and registered only modest recovery in 2010 despite the relatively strong global economic recovery. Consistent with this explanation, the breakdown of the nonagricultural employment to tradable and nontradable sectors indeed confirms that the recent employment loss is exclusively concentrated on the exporting sectors, most notably manufacturing (Figure 9).

¹¹ Since 2008, the number of discouraged work-seekers has increased by 1.1 million to 2.2 million. This may lead to a permanent destruction in human capital, provoking further loss in the level of potential output.

Figure 7. South Africa: The change in gross fixed domestic investment and capital stock by sectors (constant prices)



The fact that South African exports volume failed to recover despite the relatively strong demand of its trading partners may suggest that the decline in external demand is not entirely cyclical and may partly reflect structural factors, including low competitiveness. In this regard, at some 30 percent, the appreciation of South Africa's real effective exchange rate since the eve of the financial crisis is the highest among South Africa's peers, is not entirely explained by fundamentals, and significantly reduces South Africa's ability to compete in the international markets (see Figure A.5 in Appendix 1). Additionally, the sluggish economic recovery in advanced economies and the expectation that it will continue over the medium-term add to South Africa's weak external demand. The latter was also reflected in the decline in the share of exports of goods to Europe, which until 2008 was South Africa's largest trading partner, to 28 percent in 2009–10 from a share of 32 percent in 2008 (see Figure A.6 in Appendix 1).

Has the Financial Crisis Led to a Structural Break in Potential Output Growth?

In view of the substantial differences in potential output growth between the examined subsamples, this section evaluates, using Chow Breakpoint test, whether there was a structural break around 2008:Q4 or if it was part of the “normal” volatility of the estimated series. Because the exact timing of the shift in growth is unclear, we also examine the possibility of a structural break two quarters before and after these points. To exclude the impact of

Figure 8. South Africa: Real GDP, employment and exports volume (1999=100)

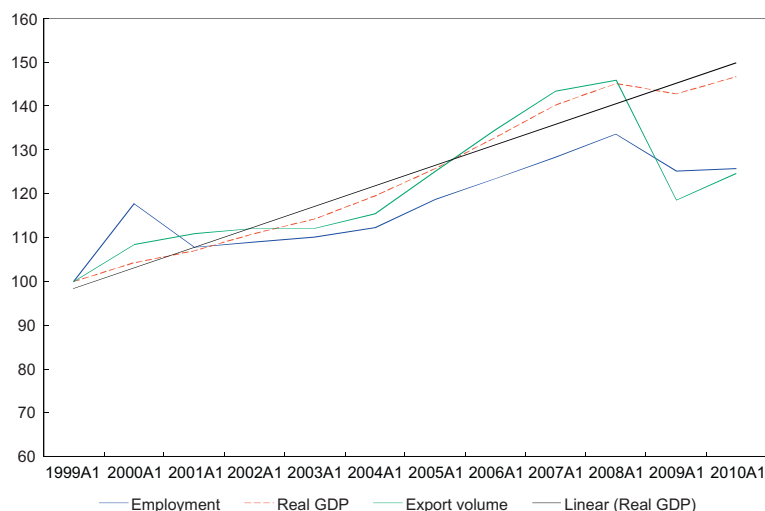
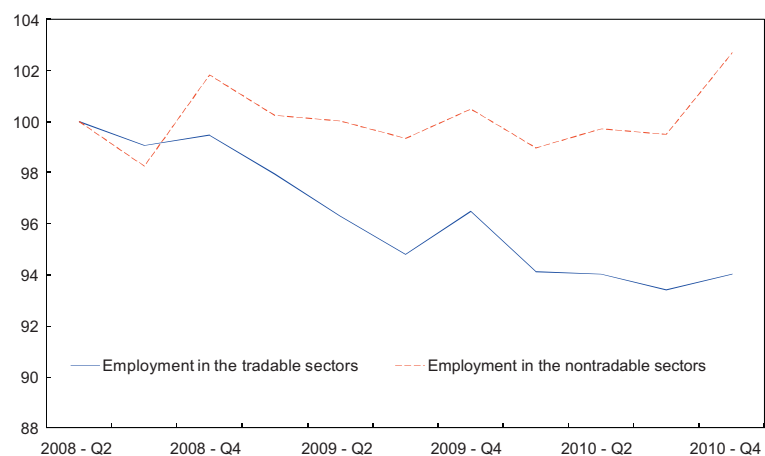


Figure 9. South Africa: Nonagricultural employment (2008:Q2=100)



the apartheid regime era, the regressions were estimated for the 1994:Q2–2010:Q4 period using the lagged dependent variable as explanatory variables. The probability values of the Chow Breakpoint Test are presented in Table 3.

The results point to a structural break in potential output growth following the outbreak of the global financial crisis as, apart from the potential output that was estimated by the PF approach, the null hypothesis can be rejected in at least one of the examined quarters. The results also point out that the structural break probably took place in 2008Q4 or 2009Q1 given that the null hypothesis can be rejected in four out of the seven estimated series.

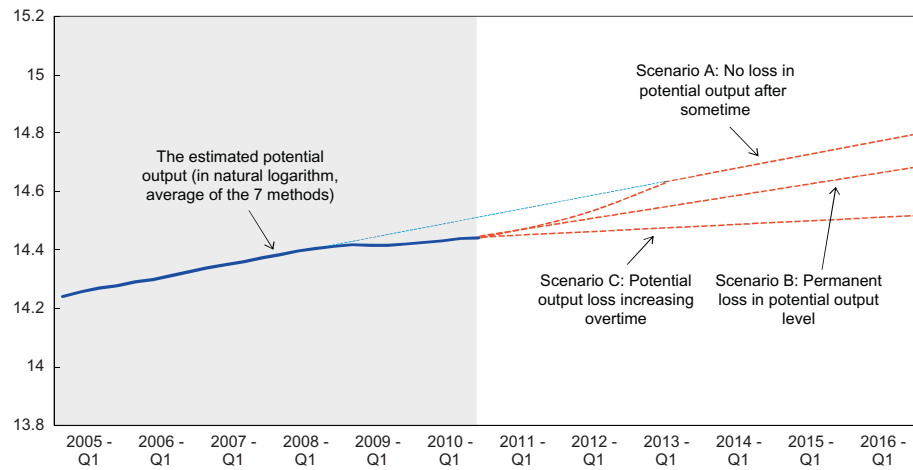
Table 3. Chow Breakpoint Test^{1,2}

	2008Q2	08Q3	08Q4	09Q1	09Q2
HP (5)	0.013	0.009	0.009	0.031	0.034
Baxter-King (6)	0.632	0.207	0.146	0.101	0.947
Kalman filter, model 1 (1)	0.041	0.081	0.004	0.016	0.103
Kalman filter, model 2 (6)	0.169	0.154	0.013	0.024	0.032
Kalman filter, model 3 (6)	0.274	0.212	0.181	0.170	0.069
SVAR (1)	0.276	0.034	0.008	0.004	0.272
PF (1)	0.805	0.593	0.569	0.402	0.204
Average potential growth (5)	0.155	0.011	0.013	0.008	0.013

¹The null hypothesis is that there is no break at the specified breakpoint.

²Figures in parentheses reflect the chosen lag structure by the Akaike information criterion.

Figure 10. South Africa: Alternative scenarios for potential output



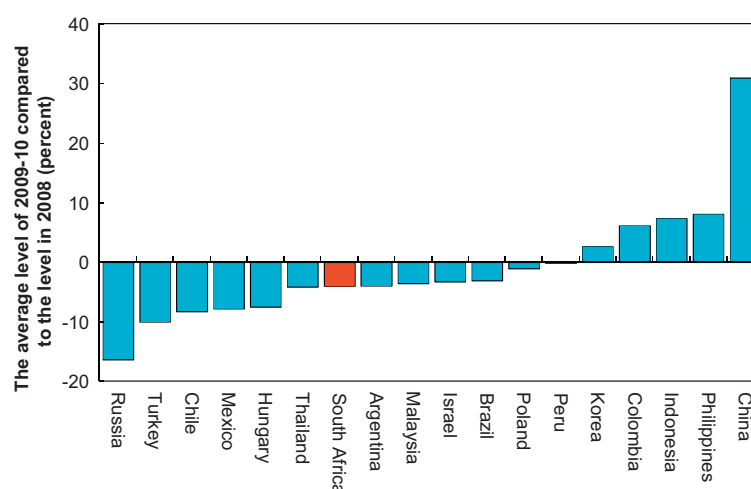
But going forward, it is not clear whether the slower pace of potential growth reflects a transitional phase, in which the level of potential output will revert back to the precrisis trajectory as demonstrated in Scenario A in Figure 10, or remain below that level for a protracted period. Scenario A implies a sharp acceleration of potential growth to around 5 to 6 percent over the medium-term, before returning to its precrisis pace. Alternatively, if potential growth resumes its precrisis pace of around 4 percent or continues at the current pace of below 2 percent, this will result in a permanent loss of potential output as illustrated in Scenario B and Scenario C, respectively. This said, based on the pace of recovery and the dynamics in the labor market thus far, it is most likely that Scenario B will prevail.¹²

¹² Empirical evidence suggests that previous financial/debt crises were associated with large and permanent output loss in other emerging and developing economies (Cerra and Saxena, 2008).

4 Potential Growth and Output Gap in the Aftermath of the Financial Crisis: An International Perspective

The sharp deceleration in the potential output growth is well reflected in the developments in labor and capital inputs. As shown in Figures 11 and 12, South Africa is among the few countries that experienced a non-negligible contraction in both employment and fixed capital formation in 2009–10. In particular, South Africa experienced the largest loss of employment following the financial crisis (2010 average compared to the 2008 average), among its comparable group of emerging markets even though the level of economic activity expanded in real terms since the crisis unfolded, while gross fixed domestic investment continued to decline in both 2009 and 2010 (in constant prices).

Figure 11. The change in gross fixed capital formation in selected economics, 2008-2010

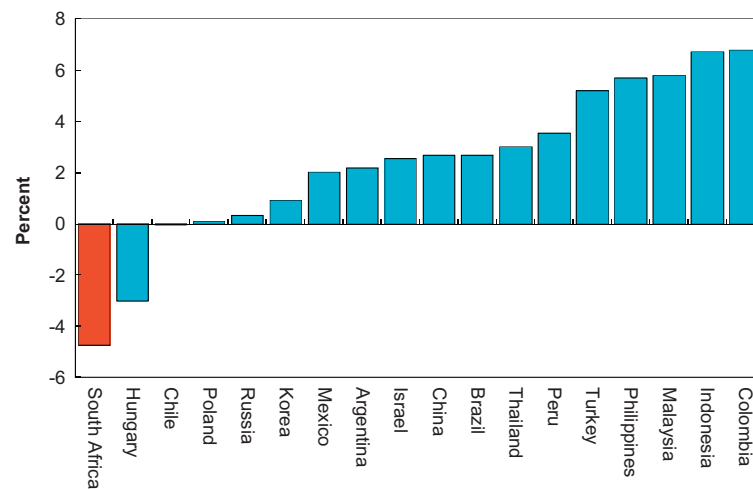


Source: World Economic Outlook database and staff calculations.

An international comparison reveals that the financial crisis has led to a deceleration in potential growth in advanced economies, as a group, as well as in a number of emerging economies. The magnitude of the deceleration seems to vary, reflecting in part the various degrees of financial and trade openness and other country-specific factors such as the rigidities in the labor market (Figure 13). The deceleration in South Africa seems to be among the highest in this group, with a deceleration of about 3 percent—second only to Russia (nearly 4 percent).¹³ The confluence of the considerable deceleration of potential output growth and the relatively shallow trough in 2009 places

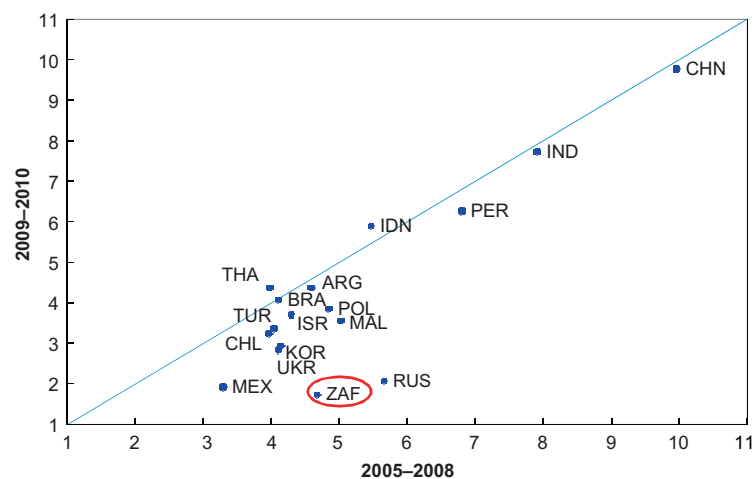
¹³ Given that every estimation technique has its pros and cons, this section uses a simple average of the estimated output gap and potential output growth.

Figure 12. The change in employment in selected economies, 2008-2010



Source: World Economic Outlook database and staff calculations.

Figure 13. Potential output real growth in selected economies



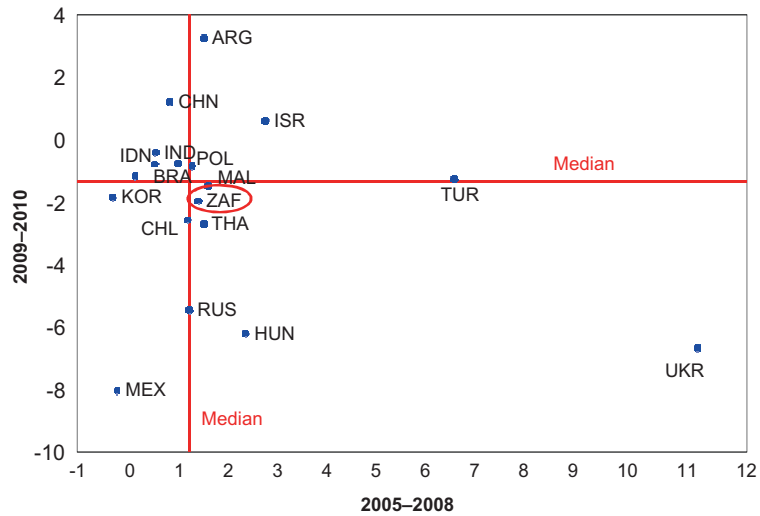
Source: WEO database.

South Africa's output gap in the postcrisis period close to the sample's median, despite the anemic recovery that was registered in 2010 (Figure 14).

The Impact of Global Economic Fluctuations on South African Output Gap

Given the impact of the global financial crisis on the South African output gap, this section aims to quantify the extent to which the South

Figure 14. Output gap in selected countries (in percent of potential output)



Source: WEO database.

Table 4. Dependent Variable: South African Estimated Output Gap, 1985Q1–2010Q41

	Reg. 1	Reg. 2	Reg. 3	Reg. 4
<i>C</i>	0.295***	0.285***	0.375**	0.266
<i>Gap (-1)</i>	1.286*	1.298*	1.265*	1.221*
<i>Gap (-2)</i>	-0.208	-0.227	-0.245	-0.244
<i>Gap (-3)</i>	-0.228**	-0.217**	-0.224**	-0.183
<i>Real Rate(-8)</i>	-0.026***	-0.025***	-0.032**	-0.023
<i>D(G_Y(-3))</i>		0.047	0.110***	0.117***
<i>Global business cycles</i>			0.079***	0.103***
<i>Global inflation cycles</i>				-0.158*

Significance level: * Significant at 1 percent.

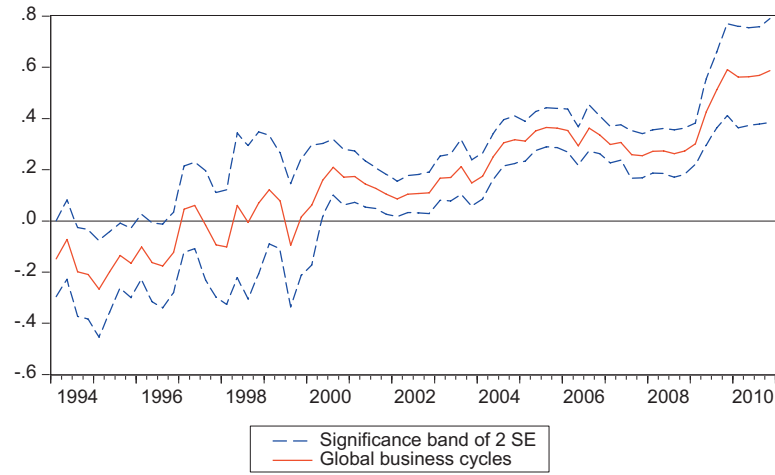
** Significant at 5 percent.

*** Significant at 10 percent.

¹The regressions were estimated by ordinary least squares (OLS). Autocorrelation in the residuals was corrected by Newey-West estimator.

African output gap is sensitive to external shocks. This is done by regressing the global business cycles (the deviations of the world output from its HP filter) together with other variables on the estimated output gap (average of all the methods). The other explanatory variables include the yield on 3-month Treasury bills adjusted for inflation (real rate), the

Figure 15. Rolling regression, the coefficient of global business cycles



global inflation cycles (world's consumer price index, weighted by trade imports from advanced economies) to control for sharp movements in the prices of commodities, and $D(G_Y)$, which reflects the change in public consumption as a share of GDP. The explanatory variables also include the output gap (GAP) with lags. The various specifications of the estimations appear in Table 4.

Although the estimated output gap is highly correlated with its level in the previous quarter, the estimations reveal that other external and internal factors do play a role. As expected, an increase in the short-term real rate contributes to the contraction of output gap with a lag of eight quarters, while an increase in public consumption (as a share in GDP) has a positive impact on the output gap with a lag of three quarters. Additionally, the estimations show that the output gap is indeed sensitive to external shocks measured by both fluctuations in the global output and inflation.

Although the estimation indicates that the size of the coefficient of global business cycles was on average around 0.1 in the sample period, a rolling regression, which is based on the *Reg. 4* specification, shows that it varied significantly over time.¹⁴ In particular, this exercise shows that the coefficient has become significantly different from zero at around 2000 and its size has increased steadily since then (Figure 13). This result points to South Africa's increasing integration into the global economy in recent years, and as a corollary, the growing sensitivity of the economy to global economic shocks.

¹⁴ The rolling regression is based on a fixed window of 30 observations, in which all explanatory variables were allowed to change.

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Appendix 1. Unobserved Component Models using Kalman Filter

Model 1

The state space form of the univariate filter can be presented as follows:

$$y_t = \hat{y}_t + y_t^c \quad (2)$$

$$\hat{y}_t = \hat{y}_{t-1} + g_{t-1} \quad (3)$$

$$g_t = g_{t-1} + \varepsilon_t^g \quad (4)$$

$$y_t^c = \theta y_{t-1}^c + \varepsilon_t^c \quad \theta < 1 \quad (5)$$

The variables y_t^c and g_t represent the cyclical component of y_t (the output gap) and the trend growth, respectively. ε_t^c and ε_t^g are residual terms of mean 0 and variances σ_c^2 and σ_g^2 , respectively. The cyclical component of output follows an autoregressive process, and θ is lower than 1 to ensure a stationary process. The smoothness of the trend component is controlled by constraining the relative variance (σ_c^2 / σ_g^2) to be equal to 1,600, as in the HP filter. The system can be estimated by Kalman filter, using equation (2) as a signal equation and equations (3) to (5) as the transitional equations.

Model 2

In this model, we add a backward-looking Phillips curve as a second signal equation in the system presented previously, which implies that inflation path is affected by past inflation rates as well as current and past output gaps, as follows:

$$\pi_t = \sum_{p=1}^P \alpha_p^\pi \pi_{t-p} + \sum_{q=1}^Q \alpha_q^y y_{t-q}^c + \varepsilon_t^\pi \quad (6)$$

Where π_t is the inflation rate and ε_t^π is a white noise process of mean 0 and variance σ_π^2 . The parameters p and q refer to the lags of inflation and output gap, respectively.

Model 3

In this third model, we add the following standard backward-looking IS curve to the second model, such that the system includes three signal equations:

$$(y_t - \hat{y}_t) = \sum_{s=1}^S \beta_s^y (y_{t-s} - \hat{y}_{t-s}) + \sum_{v=1}^V \beta_v^r (r_{t-v} - \hat{r}_{t-v}) + \varepsilon_t^y \quad (7)$$

Where r_t is the real short-term rate and ε_t^r is the white process of mean 0 and variance σ_r^2 . The parameter \hat{r}_t reflects the unobserved natural real rate, which is affected by the trend growth, as follows:

$$\hat{r}_t = \gamma + \delta g_t + \varepsilon_t^r$$

The smoothness of \hat{r}_t is controlled by constraining the relative variance of ε_t^y and ε_t^r (σ_y^2/σ_r^2) to λ

Figure A1. The estimated total factor productivity (in natural logarithm), 1985-2009

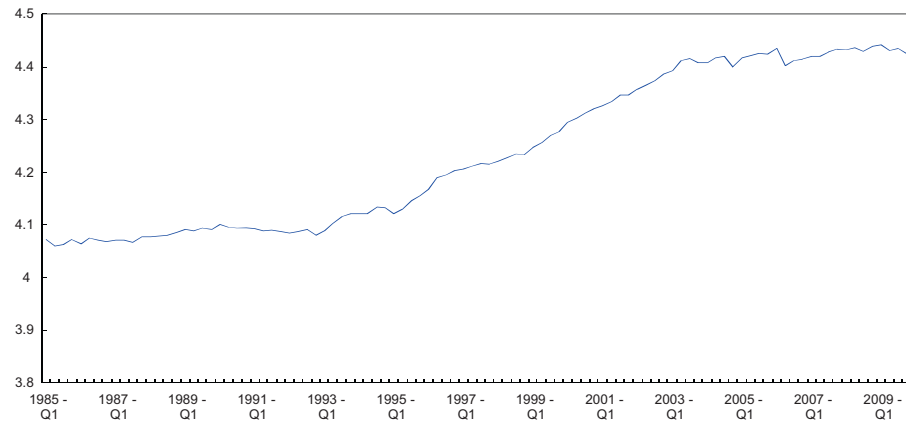


Figure A2. The cyclical components of energy production and employment, 1985-2010

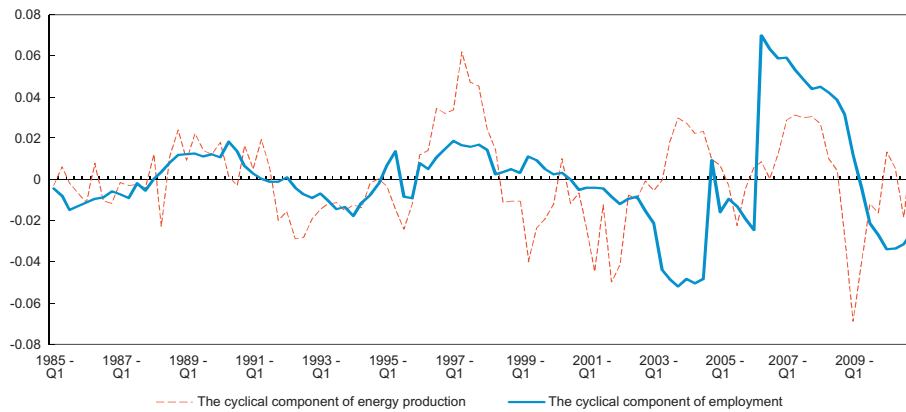


Figure A3. South Africa's output gap by main sectors

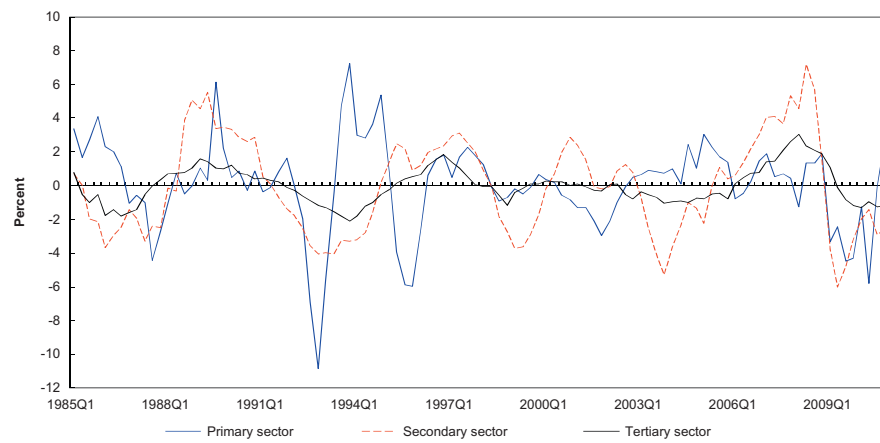
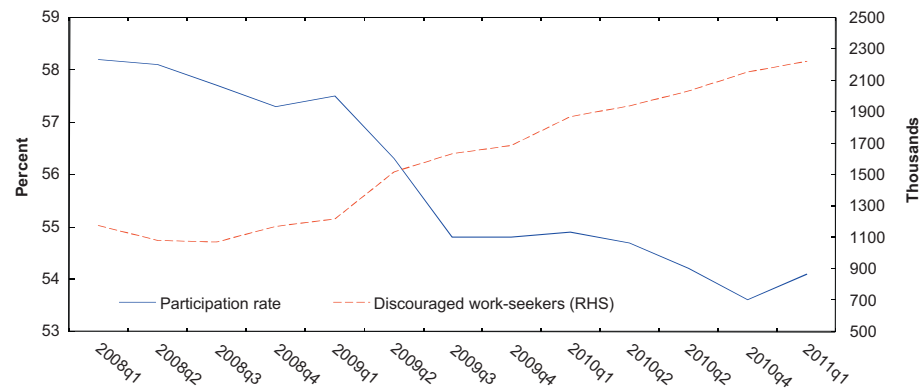
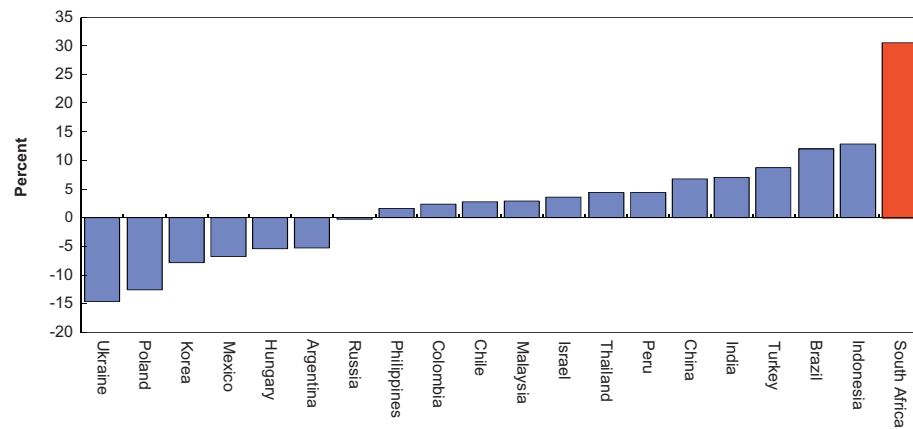


Figure A4. South Africa: Participation rate and discouraged work-seekers



Source: Quarterly Labor Force Survey, SASTAT.

Figure A5. REER change in selected EMs, 2008Q2-2010Q4



Source: INS database.

Figure A6. The share of South Africa's exports of goods by regions

