MASTER'S DISSERTATION SUBMITTED FOR THE FULFILLMENT OF THE REQUIREMENTS FOR M.BUS.SC IN ECONOMICS

DSGE Models for the South African Economy

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Dynamic stochastic modelling is relatively a new exercise in developing countries including South Africa. We use stochastic models to reproduce stylized facts of business cycles in South Africa. The basic neoclassical model and a model with indivisible labour are used to replicate the documented facts from the data. A model with variable capacity utilization and investment specific shocks is also used to reproduce facts about the manufacturing sector in South Africa. The models fair reasonably well in replicating volatilities of certain variables, but investment remains over-volatile in all the models. However, the South African labour market remains the hardest to replicate amidst well documented inflexibility.

Keywords: Business cycles; Dynamic stochastic models; Indivisible labour; Variable capacity utilization; Investment specific shocks

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Introduction

Dynamic stochastic modelling has taken to the fore of economic research in recent times, mainly due to the need to model uncertainty. General economic theories are being updated by adding forms of stochastic shocks to be able to capture much documented theories such as consumption smoothing and risk aversion. Stochastic models are being adopted by a vast number of growing institutions such as central banks, as well as government departments and many private organizations. These models are being used to assess the projected impact of shocks or to forecast anticipated trends to key variables of interest over both the short and long run.

Business cycle research using stochastic modelling has risen to prominence through major contributions by Kydland & Prescott (1982); Greenwood, Hercowitz, and Huffman (1988); Backus, Kehoe, and Kydland (1995); Prescott and Cooley (1995); Aguiar and Gopinath (2007) and many others. These stochastic elements are now being added to various models in order to explain particular features of economies. Greenwood, Hercowitz, and Krusell (2000) assess the impact of investment specific shocks on key economic variables such as hours worked, consumption, output and investment. The calibration of these models allows for different results across countries and hence improves cross-country comparisons and co-movement analyses. Impulse response functions of variables are also quite useful in analyzing not only short term adjustments, but level shifts of variables in the long run.

Stochastic modelling of the business cycle is still in its infancy in developing countries. The South African case has seen contributions by Liu and Gupta (2007) pioneering the cause. Although their paper is more directed at out of sample forecasting ability, it is a step in the right direction. They calibrate a Hansen (1985) model with indivisible labour to assess its forecast accuracy out of sample. Their model, while exaggerating output and hence investment volatility does well in replicating the relative ratios of standard deviation of investment and employment as found in the data.

Aguiar and Gopinath's (2007) contribution highlights the difference between developed and developing countries over the business cycle. Besides finding that investment is more volatile in relation to output in developing economies, they also find that consumption, on average, is more volatile than output in developing economies. In addition, output of developing economies was found to be roughly twice as volatile as in developed economies. Developing economies also had higher correlations of consumption and investment with output. Prescott and Cooley (1995) calibrated a stochastic neoclassical model to try and replicate US business cycle facts from the data. They were able to reasonably replicate the stylized facts about the US business cycle. A significant critique of their paper was the inability of their neoclassical model to capture fluctuations in employment, as well as fully replicate the volatility in total hours worked.

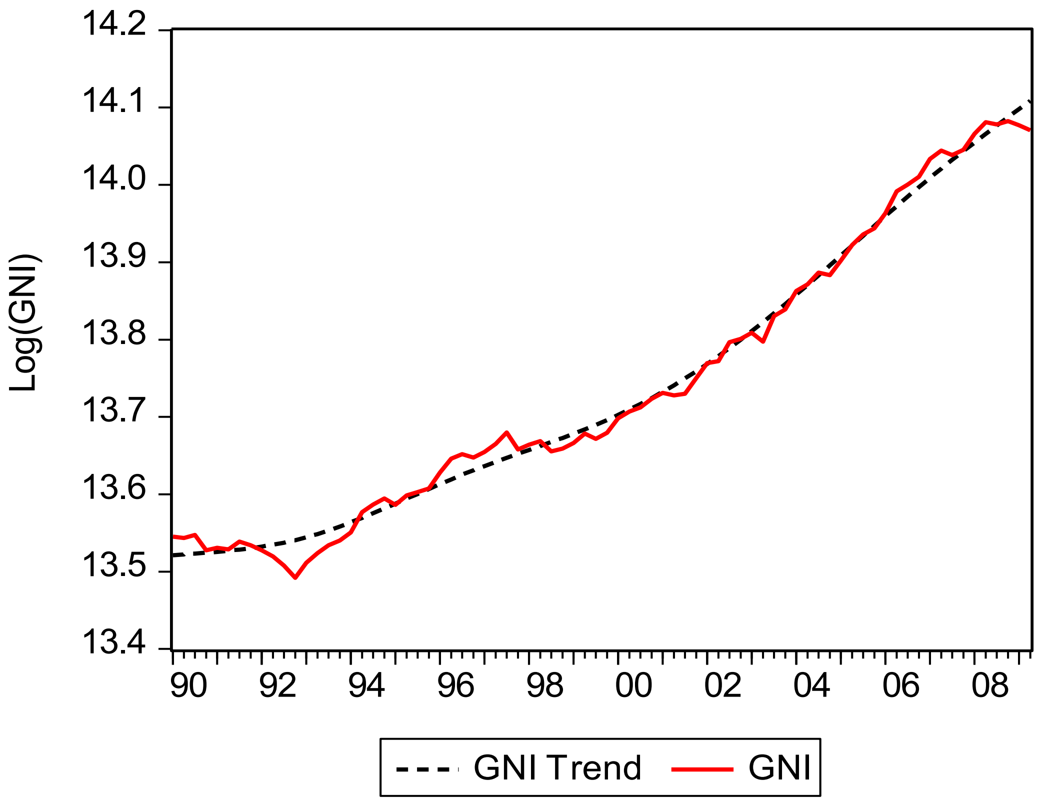

Figure 1: SA Business Cycle

This paper aims to replicate the documented facts and figures of the South African economy by comparing results of various dynamic stochastic models. With various economic models seeking to explain a specific part of a story, the use of multiple models in this paper will enable comparison of results for the various models and allow us to determine which key features of each model are best suited to explain specific segments of South Africa's economic behaviour. The models used in this paper however, are all closed models for reasons of simplicity, and results from simulations along with tabular comparisons between data and model output should be interpreted accordingly.

Figure 1 shows output (GNI) and its trend over the period 1990:1 to 2009:2. The deviations from the trend are the business cycle fluctuations. The South African economy has been hit by a recent recession and the figure highlights the dip in GNI below the trend line. Political instability in the country in the post-Apartheid era attributed to the downturn in the early part of the nineties. With democracy and legislative upheaval came the upswing in the 1996 to 1998 period. Stable economic and political policies have reduced the magnitude of the fluctuations during business cycles. South Africa is currently in a trough below the trend, and the use of stochastic models like these, could aid in estimating future movements in variables of interest.

The neoclassical model and the Hansen (1985) model with indivisible labour are used in attempting to reproduce stylized facts, specifically in the labour market, as this is where most of the stylized facts deviate from economic intuition and theory. An indivisible labour model with investment specific shocks and variable capacity utilization is also used to try and replicate the manufacturing sector. These exercises are all quite useful even in cases when the results are far off from the data. Where the stochastic models fail, it opens a debate as to the cause of the failure in reproducing the facts. This will only aid in adding new elements to the models so as to hopefully be able to reproduce the stylized facts.

DSGE models have their future in forecasting, and this fact is highlighted by Liu, Gupta, & Schaling's (2009) paper that uses a New Keynesian DSGE model to forecast the South African economy. Their results show that in terms of out-of-sample forecasting, the NKDSGE model outperforms both the classical and the Bayesian VARs for inflation, but not for output growth and the nominal short-term interest rate. Gupta & Kabundi (Forthcoming) however show that their Dynamic Factor Model (DFM) outperforms the New Keynesian DSGE in forecasting per capita growth, inflation and the nominal short-term interest rate[1].

This paper will follow the following structure: Section I will document the stylized facts of the South African economy. Section II introduces the neoclassical model economy features, and then calibrates it to the South African context, before analysing the findings. Sections III and IV do the same for the Hansen (1985) model with indivisible labour and the Greenwood, Hercowitz, and Huffman (1988) model with varying capacity utilization and investment specific shocks respectively. The conclusion will then summarize the findings of the paper.

Section I: South African Business Cycle

In this section we analyze the cyclical fluctuations of certain variables, as well as look at persistence of these variables. The statistics are computed by firstly de-trending the series' using Hodrick and Prescott's (1980) H-P filter. The reported statistics are then based on the filtered data, commonly referred to as the cyclical component of the series. Table 1 shows the standard deviation of the cyclical fluctuations of key variables, standard deviations relative to output as well as cross-correlations of these variables at various lags with output. All data are at a quarterly frequency and were gathered from the South African Reserve Bank (SARB) database. We analyze the data over the period 1990:1 to 2009:2.

The fluctuation of output of the South African economy is on par with the figures documented for OECD countries by Backus, Kehoe, and Kydland (1995). The figure reported here is however

[1] Gupta & Kabundi use the sample period between 1980 and 2006, while Liu, Gupta, & Schaling (2009) use the sample period from 1970 to 2000.

Table 1: Cyclical Behaviour of the SA Economy, 1990:1 - 2009:2

			Cross-Correlation of Output with:										
Variable	SD (%)	SD/SD (GNI)	x(-5)	x(-4)	x(-3)	x(-2)	x(-1)	x(0)	x(1)	x(2)	x(3)	x(4)	x(5)
Output													
GNI	1.58%	1.00	0.12	0.32	0.42	0.58	0.77	1.00	0.77	0.57	0.42	0.31	0.09
Consumption													
Cons	1.87%	1.18	0.17	0.35	0.48	0.60	0.69	0.74	0.73	0.68	0.60	0.46	0.28
ConsD	6.00%	3.79	0.33	0.47	0.55	0.58	0.58	0.57	0.50	0.47	0.38	0.24	0.07
ConsSD	3.37%	2.13	0.10	0.16	0.26	0.33	0.41	0.48	0.51	0.49	0.42	0.33	0.21
ConsND	2.06%	1.30	0.11	0.24	0.39	0.54	0.65	0.72	0.77	0.77	0.71	0.58	0.44
Investment													
Inv	3.93%	2.48	0.07	0.17	0.28	0.41	0.54	0.66	0.74	0.80	0.76	0.67	0.55
InvR	6.20%	3.92	0.30	0.33	0.36	0.39	0.39	0.43	0.42	0.38	0.26	0.10	0.00
InvNR	8.01%	5.06	0.07	0.19	0.29	0.43	0.56	0.60	0.59	0.53	0.42	0.33	0.18
InvF	5.49%	3.47	0.23	0.35	0.43	0.55	0.64	0.68	0.67	0.60	0.46	0.30	0.13
Government Spending													
Govt	1.67%	1.05	-0.12	-0.10	-0.06	0.01	0.09	0.12	0.08	-0.03	-0.12	-0.24	-0.23
Trade													
X	5.53%	3.49	0.09	0.10	0.21	0.18	0.16	0.19	0.35	0.31	0.25	0.09	0.12
M	6.03%	3.81	0.22	0.33	0.43	0.52	0.58	0.66	0.73	0.70	0.61	0.46	0.30
Production Input													
CapUtil	1.85%	1.17	0.31	0.34	0.39	0.50	0.60	0.69	0.69	0.62	0.43	0.23	0.08
Remun	1.86%	1.18	-0.14	-0.10	-0.19	-0.20	-0.18	-0.02	-0.02	0.18	0.24	0.29	0.25
RComp	1.66%	1.05	-0.11	0.01	0.14	0.11	0.15	0.23	0.37	0.37	0.40	0.41	0.49
Emp	0.77%	0.49	0.14	0.14	0.28	0.45	0.58	0.65	0.74	0.66	0.54	0.44	0.31
Prod	0.90%	0.57	0.13	0.38	0.45	0.41	0.44	0.45	0.34	0.33	0.30	0.17	0.01

[2]

less than that calculated by Liu and Gupta (2007).[3] Various theories have been suggested as to why volatility in output has been on the decline recently (see de Hart, 2008). Reforms in the labour and product markets have enabled the smooth shift of resources to more productive sectors during shocks (Kent, Smith, and Holloway, 2005). Technological advances and availability have also allowed for decreased volatility in inventory volatility and in turn reduced

[2] Variable descriptions are available in the Appendix.
[3] Liu and Gupta (2007) use the sample period 1970-2000.

output volatility (see McConnell, Mosser, and Perez-Quiros, 1999). Monetary policy with a stabilization effect has been evident in the post-1990 period according to du Plessis (2006).

However, there still is a difference between the characteristics of business cycles in developed and developing economies. The literature as to the cause of this difference is vast and includes many possible explanations. Rand and Tarp (2002) find that business cycles in developing countries are in general shorter than those in their developed counterparts. Meanwhile, Bejan (2006) found that trade openness in developing economies increases output volatility, while the opposite holds for developed economies. Other explanations available in the literature include discretionary fiscal policy as well as exchange rate regimes.[4]

Cyclical fluctuations in consumption are slightly more volatile than output. This is contrary to the well-documented notion of consumption smoothing of individuals. Liu and Gupta (2007) using data from 1970 to 2000 found that in fact domestic consumption was 14% less volatile than output. The contradictory result in our case indicates the lack of significant domestic savings behaviour in the South African context (especially over the sampled period at least). Personal savings has plunged in South Africa recently attributed particularly to the rapid growth of credit-financed consumption as well as substantial declines in savings by government (Aron and Muellbauer, 2000). This declining savings phenomenon has decreased the ability of individuals to insure against income volatility and thus forces increased volatility in consumption in the face of business cycles. Lewis (2001) adds that the low rate of expansion of deposit facilities to the large low income group is among the reason for the low savings rate. In fact Aron and Muellbauer (2000) go on to point out that it is this enhanced level of consumer credit, coupled with higher interest rates to restrain this spending, that has hampered South Africa's output growth over the post-1990 era.

Linnemayr (forthcoming) finds that the HIV/AIDS pandemic plaguing the country also plays a role in destabilizing the notion of consumption smoothing. He finds that "worn-down safety

[4] See de Hart (2008) for a thorough discussion and analysis of output volatility and growth.

nets make it difficult for non-affected households as well as for those with an HIV-infected member to keep up appropriate consumption levels when experiencing shocks" (Linnemayr, forthcoming). He also finds that households with an infected member, in smoothing food consumption to the detriment of regular expenditures, further undermine their ability to smooth consumption in the face of future shocks. Lack of insuring against shocks in a setting where labour is earning its marginal productivity exposes consumption from labour-income to the volatility of aggregate output (Özbilgin, 2009). This explains the correlation high between consumption and output. Consumption of non-durables is considerably smoother than that of durables, but both still fluctuate more than output. Consumption of non-durables is the most persistent though, with output fluctuations still having a pro-cyclical effect up to five quarters forward with a cross-correlation of 0.44.

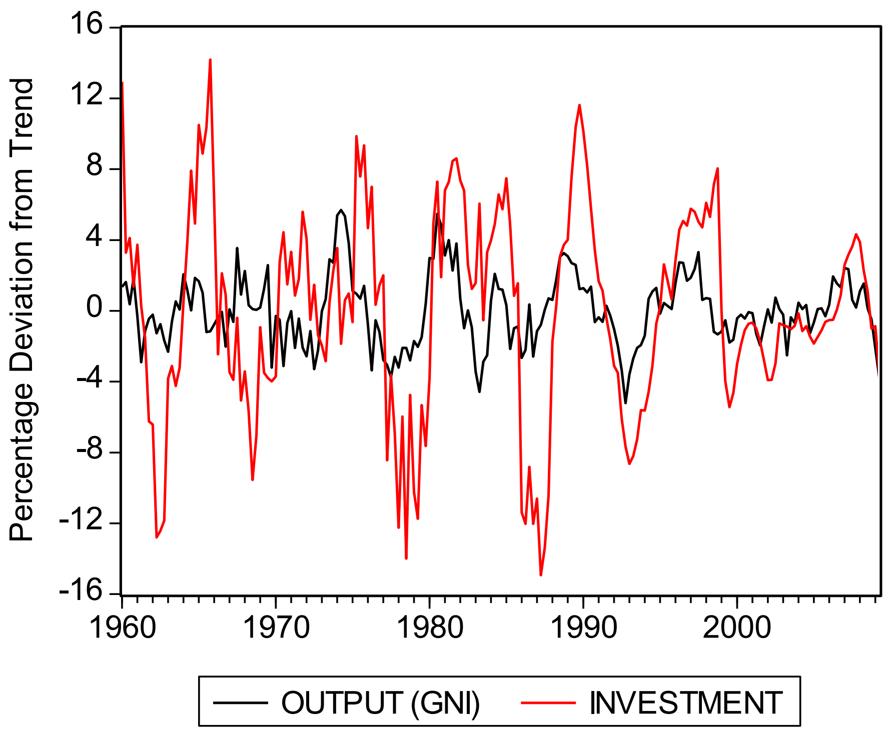

Figure 2: Cyclical fluctuations of investment and output

Total investment is surprisingly less volatile than expected (3.93%). Aguiar and Gopinath (2007) found investment to be roughly four times more volatile than output in contrast to our estimate of 2.48. This difference can be explained from Figure 2 where a marked reduction in investment volatility is observed over the latter democratic phase (post-1994) of our sample period. This could be a consequence of reduced overall savings activity in the country. Domestic savings as a proportion of GDP fell from an average of 24% in the 80's to 14% in 1998, while the equivalent net savings (less depreciation) ratio fell from 8% to 1% (Aron and Muellbauer, 2000). They go on to add that this decline places a larger reliance on foreign capital inflows. Given this train of thought, it is no coincidence then, that the removal of fixed exchange controls have resulted in lesser investment volatility given the reduced misevaluation of the real exchange rate. Volatility in the real rate of exchange have been documented to have a negative impact on investment especially in the case of Sub-Saharan developing economies that are quite dependant on export revenues (Bleaney and Greenaway, 2001). The move to a fully flexible regime at the end of the millennium coupled with aforementioned stabilization policies would have played a large role in the reduced volatility of investment noticed. The correlation of 0.74 between investment and output is still similar to Aguiar and Gopinath's (2007) estimate of 0.72 though. Fixed investment of non-residential nature (i.e. factory buildings etc.) is the most volatile form of investment and fluctuates more than output fivefold. Total investment fluctuations are highly persistent with a cross-correlation of 0.55. This indicates that output shocks today will still significantly affect investment decisions up to five quarters ahead.

Government expenditure fluctuates as much as output but seems to be generally uncorrelated however, which is in line with business cycle literature (Prescott and Cooley, 1995). Exports and imports are relatively similar in magnitude of their fluctuations relative to output. However, imports have a significantly higher correlation with output than exports, 0.66 as opposed to 0.19. This justifies the strong counter-cyclical trade balance of emerging markets documented in Aguiar and Gopinath (2007). Higher incomes lead to more imports, but possible appreciation of domestic currencies hinders export competitiveness, and thus trade deficits widen. Imports are also quite persistent unlike exports. Pro-cyclical import fluctuations are also much more persistent than exports as seen by the cross-correlation statistic of 0.46 of imports four quarters ahead with output.

Looking at factor inputs, wages[5] seem to be more volatile than productivity. Wage proxies also seem to be almost acyclical if anything with the highest cross-correlation with output today occurring about a year later. This seems to imply frictions in the wage setting arena. Furthermore, employment fluctuates about half as much as output. So output shocks seem to be closely followed by similar magnitudinal effects in wages and capacity utilization, while less so in labour productivity, and much less so in labour being employed. There seems to be a suggestion here that labour absorption isn't occurring to the extent of that of the US (see Prescott and Cooley, 1995). Their findings of the US economy show that in fact it is wages that are much less volatile while employment fluctuations seem to be much closer in magnitude to output fluctuations.

So, one can deduce from the findings that during an upswing in output, wages in South Africa would increase much later (about a year) and by far greater than the actual output shock, while actual numbers being employed, while being highly correlated with output, will increase to a much lesser extent. In fact Lewis (2001) finds that based on wage trends categorized by skill level, in addition to category specific unemployment data, seems to definitely point to the assumption that low skilled and unskilled labour are being priced out of the market.[6] Heintz (2000) finds that the widespread unemployment across the country can be in fact attributed, if at least in part, to the insufficient capital accumulation rates that has left many jobless.

Capacity utilization fluctuations are similar to those of output, and have a high correlation of around 0.7. This suggests that capital intensive productivity is in line with the general output of the economy. This is in stark contrast to labour productivity which fluctuates around 40% less than output. This fact, coupled with the larger fluctuations in wage proxies, indicate a strong labour union presence in South Africa. Fallon and Lucas (1998) point to a "large wage differential associated with non-economic characteristics" that are considered too large by

[5] Real compensation of residents and total remuneration per worker used as proxies for wages.
[6] Fallon and Lucas (1998) highlight this fact and point out that the labour market operates much more efficiently for skilled labour as opposed to unskill.

international standards. They highlight the effect of unionization on this differential but also indicate that unionization has reduced wage segmentation such as the gender wage gap. Recent legislature such as the Labour Relations Act (1996) and Basic Conditions of Employment Act (1997) have been installed with the aim to combat the inefficiency of South Africa's overall labour market. Fallon and Lucas (1998) indeed put faith that specifically the Basic Conditions of Employment Act will improve "labour market flexibility". This inflexibility and the unionization effect are well documented by Lewis (2001) who writes:

"Furthermore, within the industrial labour relations system, trade unions have the upper hand, creating a large union effect with wage gains only loosely tied to productivity increases. Industrial or Bargaining Councils enhance union power, by having the authority to extend statutory wages to currently uncovered firms within sectors. Pro-labour legislation also is associated with benefit (e.g., maternity leave, normal working hours, overtime differentials, etc.) and employment security provisions that reduce flexibility."

The latter sections will seek to compare the observed business cycle facts of the South African economy with the model-generated outputs. However, due to the lack of certain data (such as quarterly hours worked) and the simplistic use of closed economy models, some variables will not have direct comparatives in the tables.

Section II: Neoclassical Model

1. Model Economy

The benchmark neoclassical model discussed in this section seeks to capture certain economic phenomena, namely, substitution between consumption and labour (or leisure). This concept is used to explain the procyclicality of total hours worked as in Prescott and Cooley (1995). They found that hours fluctuated almost as much as output along with a very high correlation with output, suggesting that agents worked more hours during economic expansions and less during contractions. In addition to productivity, wages were also found to be much less procyclical and having a smaller correlation with output. The assumption they use to explain these facts is therefore agents' habitual smoothing of consumption by adjusting the labour-leisure trade-off in response to shocks.

The model economy we start off with here is the basic neoclassical real business cycle model used in Prescott and Cooley (1995), with utility function as follows:

$$u(c_t, l_t) = \frac{\left({c_t}^{1-\alpha} {l_t}^{\alpha}\right)^{1-\sigma} - 1}{1-\sigma}, \qquad 0 < \alpha < 1, \quad \sigma > 1, \tag{1}$$

where c_t and l_t are the consumption and the amount of leisure at time t. α is the share parameter of leisure and $1/\sigma$ is defined as the inter-temporal elasticity of substitution. Here however, we will only consider the case where $\sigma = 1$. Households' utility is a function of stochastic consumption and leisure sequences and is optimized by maximizing the following function:

$$U[c(\cdot), h(\cdot)] = E\{\sum_{t=0}^{\infty} \beta^t u(c_t, 1 - h_t)\}, \qquad 0 < \beta < 1, \tag{2}$$

Where β is the period discount rate, and h_t is the labour supply (or work hours). Households' time is normalized to unity such that $h_t + l_t = 1$. Output is determined by the following Cobb-Douglas production function:

$$Y_t = z_t {K_{t-1}}^{\theta} {H_t}^{1-\theta}, \qquad 0 < \theta < 1, \tag{3}$$

where θ is the capital share of output, and $1 - \theta$ is the labour share. K_{t-1} is capital stock at beginning of period t that is to be used in production. H_t is the total amount of hours worked by workers in the economy. z_t is a random productivity parameter that is the source of uncertainty in this model economy. This technological productivity parameter follows the following law of motion:

$$logz_{t+1} = (1-\rho)log\bar{z} + \rho logz_t + \varepsilon_t, \qquad 0 < \rho < 1\,, \tag{4}$$

where ε_t is a well behaved error term following a $N(0\,,\,\sigma^2{}_{\varepsilon})$ distribution. Capital in this economy depreciates at a constant rate δ, and households invest a portion of their income each period in productive capital stock to be utilized the following period. The law of capital accumulation is thus:

$$K_t = (1-\delta)K_{t-1} + X_t\,, \qquad 0 < \delta < 1\,, \tag{5}$$

where X_t is the amount invested by agents in period t. In this baseline model we also introduce η and γ, the population growth rate and the rate of growth of output per capita. We include these features because the neoclassical model is first and foremost a growth model. We are however only interested in the cyclical component, and thus it is important to include parameters that determine the balanced growth path so as to correctly capture the only the cycle around the trend. Taking all the prior information, the social planner problem is to maximize household utility given by:

$$\max E[\![\textstyle\sum_{t=0}^{\infty} \beta^t (1+\eta)^t [(1-\alpha)\log c_t + \alpha \log l_t]]\!], \tag{6}$$

subject to the following resource constraints:

$$c_t + x_t = z_t {k_{t-1}}^{\theta}(1-l_t)^{1-\theta} \tag{7}$$

$$(1+\gamma)(1+\eta)k_{t+1} = (1-\delta)k_t + x_t \tag{8}$$

$$logz_{t+1} = (1-\rho)log\bar{z} + \rho logz_t + \varepsilon_t, \tag{9}$$

where all variables are now in per capita terms.

2. Model Calibration

We now set out to calibrate and assign numerical values to the following parameters: $\delta, \gamma, \eta, \beta, \theta, \alpha, \rho$ and σ_ε. The first order equations as well as the capital stock law of motion are used to determine parameter values for calibration purposes. We first determine a value for β using the average real rate of interest over the period 1994 – 2008. We subtract annualized inflation from the end of period discount rate.[7] The average of the real rate over this period is 5.9%. We thus obtain β to be 0.9443 (or a quarterly rate of 0.9858). The capital stock law of motion on a balanced growth path implies:

$$\delta = \frac{x}{k} + 1 - (1+\gamma)(1+\eta) \tag{10}$$

We can therefore calculate δ by obtaining γ and η from the data.[8] An annual depreciation rate of 4.4% (or 1.1% quarterly) is obtained. The first order equation for capital in balanced growth implies:

$$\frac{(1+\gamma)}{\beta} + \delta - 1 = \theta * \frac{y}{k} \tag{11}$$

We use this equation to obtain the capital share, θ, given that the average capital output ratio over the period is 2.14. This yields a value of 0.26 for θ. Labour's share of income is therefore 0.74. The next step involves finding an estimate for h, the allocation of discretionary time to market-based activities. Due to the lack of micro-studies for South Africa analyzing labour related time allocations, we use Prescott and Cooley's (1995) estimate of 0.31. Then using the first order condition for labour (or leisure) on a balanced growth path implies:

[7] All data are monthly statistics from the SARB.

[8] Population growth rate was calculated from population data obtained from the IMF's International Financial Statistics (IFS) database.

$$(1-\theta)\frac{y}{c} = \frac{\alpha}{1-\alpha} * \frac{h}{1-h} \quad (12)$$

Using an output to consumption[9] ratio of 1.2 allows us to determine $\frac{\alpha}{1-\alpha}$ to be 1.96. Hence α is calculated to be 0.66. The final step is to calibrate the parameters ρ and σ_ε that determines the process that generates technological shocks from the following equation:

$$logz_{t+1} = (1-\rho)log\bar{z} + \rho logz_t + \varepsilon_t \quad (13)$$

We first set $\bar{z}$ equal to one in steady state. This simplifies the technological process law of motion to evolve according to:

$$logz_{t+1} = \rho logz_t + \varepsilon_t \quad (14)$$

Prescott and Cooley (1995) compute the following equation to generate a series for the Solow residuals (Solow, 1957):

$$lnz_t - lnz_{t-1} = (lnY_t - lnY_{t-1}) - \theta(lnK_{t-1} - lnK_{t-2}) - (1-\theta)(lnH_t - lnH_{t-1}) \quad (15)$$

The aim of this exercise is to extract a series of technological factor changes that influence output. Growth accounting has never been a direct science, and Nelson (1973) writes "early studies recognized quite explicitly the difficulties, perhaps even the theoretical impossibility, of distinguishing between alternative explanations of observed growth patterns without rather strong a priori assumptions." The exercise can be fruitful when the fundamental determinants of factor growths are "substantially independent" from the determinants of technological change (Barro, 1999). However, Fedderke (2002) highlights the significant labour market

[9] Consumption here is final consumption expenditure by both households and government as defined by the model specifications.

segmentation in South Africa directly affects factor input quality and if this is not de-composed, then this simple form of growth accounting has its limitations.[10]

In addition to the arguments above in addition to the lack of consistent data availability[11], we choose to assign these parameters values that are consistent with the literature. We are however aware that this reduces the credibility of the calibration exercise, but face no clear alternative to this end. We thus set ρ to 0.95 in the technological progress equation (Prescott and Cooley, 1995; Liu and Gupta, 2007). We then adopt a set of innovations to technology that have a standard deviation (σ_ε) of 0.0083 from Liu and Gupta (2007). They estimate this value of σ_ε using the Solow residual equation without capital.[12] They argue that because capital has relatively no cyclical volatility at business cycle frequencies, it can be eliminated from the equation. Thus any volatility in output would be attributed to the labour market. Table 2 summarizes the calibrated parameter values.

Table 2: Model Economy Parameters

θ	δ	ρ	σ_ε	γ	β	σ	α	η
0.26	0.011	0.95	0.009	0.0195	0.9858	1	0.66	0.015

3. Model Simulation

Table 3: Simulation Results for Calibrated Economy

Neoclassical Model Economy				South Africa Data			
Variable	SD%	SD/SD(GNI)	Corr.	Variable	SD%	SD/SD(GNI)	Corr.
GNI	1.45%	1.00	1.00	GNI	1.58%	1.00	1.00
Consumption	0.51%	0.35	0.92	Consumption	1.87%	1.18	0.74
Investment	11.07%	7.63	0.99	Investment	3.93%	2.48	0.66
Hours	0.50%	0.34	0.98	Employment	0.77%	0.49	0.65
Wages	0.97%	0.67	0.99	Compensation	1.66%	1.05	0.23

[10] Fedderke (2002) also mentions the shortcomings of the assumption of constant returns to scale on growth accounting.
[11] Capital stock data is not available quarterly; no consistent quarterly series on hours worked.
[12] Prescott and Cooley (1995) estimate a value of 0.007 for the US economy.

Capital	0.43%	0.30	0.35	Productivity	0.90%	0.57	0.45
Technology	1.08%	0.74	1.00				

In this section we analyze the moments of our baseline neoclassical economy model, with the stylized facts from the actual data from Section I. With σ_ε calibrated to match output volatility of the model to that of the actual data, we find that investment volatility is greatly overestimated at (11.07% vs. 3.93%). Moreover, given the unusual high consumption volatility in the data, the volatility from the model is clearly understated (0.51% vs. 1.87%) and is significantly less than output. This is down to the model assuming consumption smoothing behaviour. Productivity shocks entice workers to invest more today, so that the same unit of capital invested will now return more in terms of output (income) in the next period. However, as discussed earlier, the significant low levels of saving in South Africa would therefore underestimate the effects of output shocks on investment volatility. Hence, the model would generate exaggerated results; much higher investment volatility; much lower consumption volatility, higher investment correlation with output, and lower correlation of consumption with output; than the data implies.

Given that the baseline economy here is in a perfectly competitive setting, fluctuations in wages also reflect fluctuations in the productivity of labour. Productivity fluctuations from the data are closely matched by that of the model (0.97% vs. 0.90%), whereas wage volatility are underestimated in the model (0.97% vs. 1.66%). The model also shows that fluctuations in output are comprised of mainly labour productivity variations as opposed to variation in hours worked by agents. This is where Hansen (1985) critiqued inability of a neoclassical model to replicate the actual fluctuations of hours worked in the data. There is also a large disparity in the correlation between productivity (wages) in the model and productivity in the data (0.99 vs. 0.45). This suggests that there is a relatively large portion of labour market behaviour that is not captured by the baseline model. In other words, certain cyclical labour market features that are not being explained by shocks to total factor productivity.

Section III: Indivisible Labour

1. Model Economy

The economy described in this section is based on Hansen's (1985) real business cycle model with indivisible labour. Here, individuals do not choose how many hours to work, but rather whether to work or not. The model assumes that the variability in total hours worked is a result of numbers being employed and not as an agent's choice between labour and leisure. The neoclassical model fails to capture certain crucial labour market elements like unemployment, as well as fluctuation in the unemployment rate (Hansen, 1985). Hansen (1985) argues that micro-studies using panel data have failed to capture the inter-temporal substitution required to explain the large fluctuations in hours worked. So the argument follows that these fluctuations are thus a result of fluctuations of labour moving in and out of the production and not necessarily fluctuations in agents' resource allocation between leisure and labour.

Prasad (1996) added to the debate by suggesting that the composition of employment through the business cycle will shed light on cyclical labour market dynamics. He argued that "the differences in employment cyclicality for workers of different skill levels have implications for measurements of wage cyclicality". He mentions that the average skill level (and thus average wage) should be countercyclical. In times of a recession, low-skilled workers are laid off, thus raising both the average skill level being employed, and also the average wage. Prasad's (1996) rationale is in line with the documented facts of the US in Prescott and Cooley's (1995) findings where aggregated wages and productivity are not as procyclical as hours or employment, while not accentuating Prasad's argument, seem to at least provide a measure of credibility. Hence Hansen (1985) focused on the movement of labour in and out of the market by assuming indivisibility. This indivisibility would imply that for a given output, productivity should rise when labour moves out of the market during a contraction, therefore implying counter-cyclicality of average wages and productivity as Prasad (1996) suggested.

In this model economy, only the utility function changes where the infinitely-lived households now maximize the following lifetime utility function:

$$U[c_t, N_t] = E\left\{\sum_{t=0}^{\infty} \beta^t \left(\frac{{c_t}^{1-\sigma}}{1-\sigma} - AN_t\right)\right\} \qquad 0 < \beta < 1 \quad \sigma > 1 \tag{16}$$

$N_t \in \{0, \bar{N}\}$ is labour employed that is subsequently used in production.[13] Labour here is not specified over a range, but rather a set of two extremes. Agents that choose not to work will take on a value of 0, while those who choose to work will work $\bar{N}$, no more and no less. Once again, we will only consider the case where σ is set to 1. The production function, capital law of motion and simplified technology law of motion are similar to that in the previous section.

2. Model Calibration

The parameters to be calibrated in this section are θ, δ, ρ, σ_ε, β and A. We assume the same value of β as in the previous section (0.9858). We start by noting that in balanced growth the capital law of motion implies:

$$\delta = X/K \tag{17}$$

This yields an annual depreciation rate of 7.9% or a quarterly rate of 1.9%. This is the same value calibrated by Liu and Gupta (2007). The balanced growth first order condition for capital implies:

$$\frac{1}{\beta} - (1 - \delta) = \theta\left(\frac{Y}{K}\right) \tag{18}$$

[13] N_t is normalized to 1 for solving purposes.

We can then solve for the capital share, θ, which equates to 0.29 which is close to Smit and Burrows' (2002) estimate of 0.31. Labour's share, $1-\theta$, is thus 0.71. Next we calibrate A from the first order equation for N_t. Again, in balanced growth this condition is:

$$A = \frac{1}{N}(1-\theta)\frac{Y}{C} \tag{19}$$

This implies a value for A of 2.17. [14] The remaining parameters are those associated with the law of motion of technology, ρ and σ_ε. After setting ρ to 0.95 again as per the literature, we set σ_ε equal to 0.0083 as per Liu and Gupta (2007). The table of calibrated values is shown in Table 4.

Table 4: Calibrated Parameters

θ	δ	ρ	σ_ε	β	A	σ
0.29	0.019	0.9 9	0.0058	0.985 8	2.1 7	1

3. Model Simulation

Table 5 compare the moments from the calibrated baseline Hansen (1985) model with the moments and stylized facts from the actual data. A major difference from the neoclassical economy in Section I is the reduced volatility in investment. Investment is 4.77 times more volatile than output in this model, in line with the empirical findings of Aguiar and Gopinath

Table 5: Simulation Results for Model Economy

Hansen Model Economy				South Africa Data			
Variable	SD%	SD/SD(GNI)	Corr.	Variable	SD%	SD/SD(GNI)	Corr.
GNI	2.28%	1.00	1.00	GNI	1.58%	1.00	1.00
Consumption	0.70%	0.31	0.88	Consumption	1.87%	1.18	0.74
Investment	10.88%	4.77	0.99	Investment	3.93%	2.48	0.66
Employment	1.70%	0.75	0.98	Employment	0.77%	0.49	0.65
Wages	0.70%	0.31	0.88	Compensation	1.66%	1.05	0.23

[14] N is calculated as the ratio of employment to labour force (annual average from 1999 to 2008). This yields a value of 0.39. Data is from International Financial Statistics, *IMF*.

Capital	0.71%	0.31	0.36	Productivity	0.90%	0.57	0.45
Technology	1.08%	0.47	1.00				

(2007).[15] The ratio of investment volatility to that of output in our model economy is similar to the ratio found in Liu and Gupta (2007).[16] The reason for the reduced volatility is the assumption that workers in this economy cannot choose between labour and leisure. This thus does not allow for as much savings ability as in the neoclassical case. The incentive for increased savings in light of a productivity shock arises from the slight increase in wage, due to higher output. Whereas in the neoclassical case, additional incentive for investment arose when any productivity boosts would imply the increased output (income) to de distributed among everyone already being employed (no unemployment assumption). In this model however, there is additional labour being hired, hence the output (income) boost is to be diluted prior to being distributed through wages. Hence wages will also be much less procyclical than in the neoclassical case.

Employment volatility of the model economy is more accentuated than in the data (1.70% vs. 0.77%). This is expected as this is the only labour adjustment mechanism in the model. Consumption's correlation with output is less than in the neoclassical model and is closer to the correlation in the actual data (0.88 vs. 0.74). This is down to the fact that reduced wage cyclicality imply reduced consumption volatility, and hence a lesser correlation with output than in the neoclassical setting. The ratio of consumption volatility to output volatility is therefore also less in this model economy than in the neoclassical economy (0.31 vs. 0.35). However, consumption in this economy is still way below the actual observed consumption volatility in the data.

[15] Aguiar and Gopinath (2007) found developing economies to have an average relative standard deviation of investment of 3.93, while that of developed economies to be 3.41.
[16] Liu and Gupta (2007) calibrated model has investment 4.66 times as volatile as output.

Section IV: Investment Specific Shocks and Variable Capacity Utilization

1. Model Economy

Here we describe the model economy described in Greenwood, Hercowitz, and Huffman (1988) (henceforth called GHH) which incorporates investment shocks induced by increased capacity utilization that in turn leads to a higher depreciation rate of this capital in the next period through elements such as wear and tear. These are in addition to the standard output (productivity) shocks that have been dealt with in previous sections. The authors adopt Keynes' (1936) view that "it is shocks to the marginal efficiency of investment that are important for generating output fluctuations" (Greenwood, Hercowitz, and Huffman, 1988). These shocks in turn accelerate the depreciation of old capital (Greenwood, Hercowitz, and Huffman, 1988). They argue changes in the marginal efficiency of investment directly affects aggregate investment, aggregate demand and thus employment and output. The shifts in these variables are deemed to be the cause of the business cycle.

Wang (2001) discusses another aspect of variable capacity utilization; that within firms' financing uncertainty and production smoothing. He found that in the face of financing uncertainty (bank loan availability etc.) via monetary policy for example, by varying capacity utilization, firms are able to smooth production and therefore reduce variability in their capital stocks, and also in their outputs. When firms foresee lower stocks, through possible reduced borrowing ability, then reducing capacity utilization today will conserve capital for future use. When the financing difficulty arises, "firms increase their utilization rates in order to smooth the flow of capital services" (Wang, 2001). He found that varying capacity utilization not only plays a role in the inter-temporal substitution of capital, but also in the intra-temporal substitution between capital and investment. The long-run acyclicality of capital stocks during business cycles can be explained in Wang's (2001) framework.

We however believe that the GHH framework would be best suited to model the manufacturing sector in South Africa as opposed to the economy as a whole. Manufacturing is a sector where variable capacity utilization plays an important role, and where advances to technological efficiency impact greatly on investment within the sector. We thus set out to attempt to replicate the cyclical properties or variables indicative to the manufacturing sector in South Africa.

We use a model including indivisible labour as it seems more applicable to the South African context. We also note the fact that the manufacturing sector, being crucial to the industrialization of the economy is quite reasonably unionised. This justifies our use of indivisible labour. The utility function is the same as the previous section. Production is the economy is again of a Cobb-Douglas form:

$$Y_t = z_t(u_t K_{t-1})^{\theta} {N_t}^{1-\theta}, \qquad 0 < u\ ,\ \theta < 1, \tag{20}$$

where u_t is the capacity utilization rate of capital, K_{t-1}, to be used in production. The more productive the capital, the more depreciation through wear and tear will occur. The capital stock law of motion therefore differs from before:

$$K_t = (1 - \delta u_t^{\omega})K_{t-1} + X_t q_t\ , \qquad \delta > 0, \quad 0 < u < 1, \quad \omega > 1, \tag{21}$$

With q_t being the investment specific shock which follows the law of motion:

$$log q_{t+1} = (1 - \varphi)\ log\bar{q} + \varphi\ log q_t + \mu_t, \qquad 0 < \varphi < 1\ , \tag{22}$$

with μ_t following a normal distribution with mean zero and standard deviation σ_{μ}. In steady state we set $\bar{q}$ to one, so the law of motion simplifies to:

$$log q_{t+1} = \varphi\ log q_t + \mu_t \tag{23}$$

The law of motion for technology in total production follows from the previous models. Finally, the closed economy setting is fulfilled by the following resource constraint:

$$Y_t = C_t + X_t \tag{24}$$

2. Model Calibration

We set out to calibrate the following parameters: $\beta, \theta, A, \delta, \omega, \varphi, \sigma_\mu, \rho$ and σ_ε. We begin the calibration of parameters in this manufacturing economy by adopting previously calibrated parameters from our previous models. β is set to 0.9858; θ is set to 0.29; and A is set to 2.17.[17] The next step is to calibrate δ and ω from the investment capital ratio on a balanced growth path:

$$\delta u^\omega = X/K, \qquad \delta > 0, \quad 0 < u < 1, \quad \omega > 1, \tag{25}$$

The steady state value for u is set at 0.9, and the investment capital ratio is 0.076 as per the data.[18] This enables us to simultaneously calibrate the aforementioned parameters given their restrictions, as well as general closeness to real economic observations. We estimate δ to be around 9.4% annually (or 2.3% quarterly), which is close to the average depreciation rate from 2000 to 2008 according to the data.[19] This therefore results in an estimate of 2.0 for ω.[20] ρ and σ_ε are assigned their previous values, 0.95 and 0.0083, respectively. We then proceed to assign values to the parameters that describe the evolution of technological progress in investment, φ and σ_μ. We adopt values from Greenwood, Hercowitz, and Huffman (1988); φ is therefore 0.83 and σ_μ is set to 0.0035.[21] Table 6 summarizes the calibrated parameters:

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[17] The same parameter values assigned to the model with indivisible labour in the previous section.
[18] The average capacity utilization over the 1990 – 2008 period was around 82% in the data.
[19] SARB database: Consumption of Fixed Capital (KBP6002J).
[20] Greenwood, Hercowitz, and Huffman (1988) set ω to 1.42.
[21] φ is an annual value of 0.47 in Greenwood, Hercowitz, and Huffman (1988). This implies 0.83 at qaurterly intervals.

Table 6: Summary of Calibrated GHH parameters

β	A	θ	ω	δ	ρ	σ_ε	φ	σ_μ
0.9858	2.17	0.29	2.0	0.023	0.95	0.0083	0.83	0.0035

3. Model Simulation

In this section, we simulate the GHH model and compare the results to the cyclical properties of some manufacturing variables from the data.

Table 7: Baseline Model vs. Manufacturing Data

Model Simulation				SA Manufacturing Data			
Variable	SD(%)	SD/SD(Output)	Corr.	Variable	SD(%)	SD/SD(Vol)	Corr.
Output	4.29%	1.00	1.00	Production Volume	3.36%	1.00	1.00
Employment	3.82%	0.89	0.99	Employment	2.39%	0.71	0.47
Investment	26.75%	6.24	0.99	Investment	6.50%	1.93	0.73
Wages	0.84%	0.20	0.63	Productivity	2.66%	0.79	0.88
Capacity Utilization	2.24%	0.52	0.97	Capacity Utilization	1.85%	0.55	0.69
Output Technology	1.08%	0.25	0.93	Unit Labour Cost	3.61%	1.07	-0.89
Investment Technology	0.43%	0.10	0.34				

From the table, one prominent feature is the significantly higher investment volatility that the model generates. This is down to the fact that there are two shocks operating simultaneously in the model. This significantly amplifies the investment decision. When an agent in the model experiences a positive shock to output, the overall productivity in the economy would rise. This raises the equilibrium wage for workers who hence save more. Now, when there is a simultaneous rise in efficiency of investment, this effect is multiplied. The agent now not only faces an incentive to invest (from the output productivity shock), but additional incentives knowing that a single unit invested today will yield a higher return in the next period than before. The use of GHH preferences where “labour effort is determined independently of the inter-temporal consumption savings choice” could drastically reduce investment volatility in the model (Greenwood, Hercowitz, and Huffman, 1988).

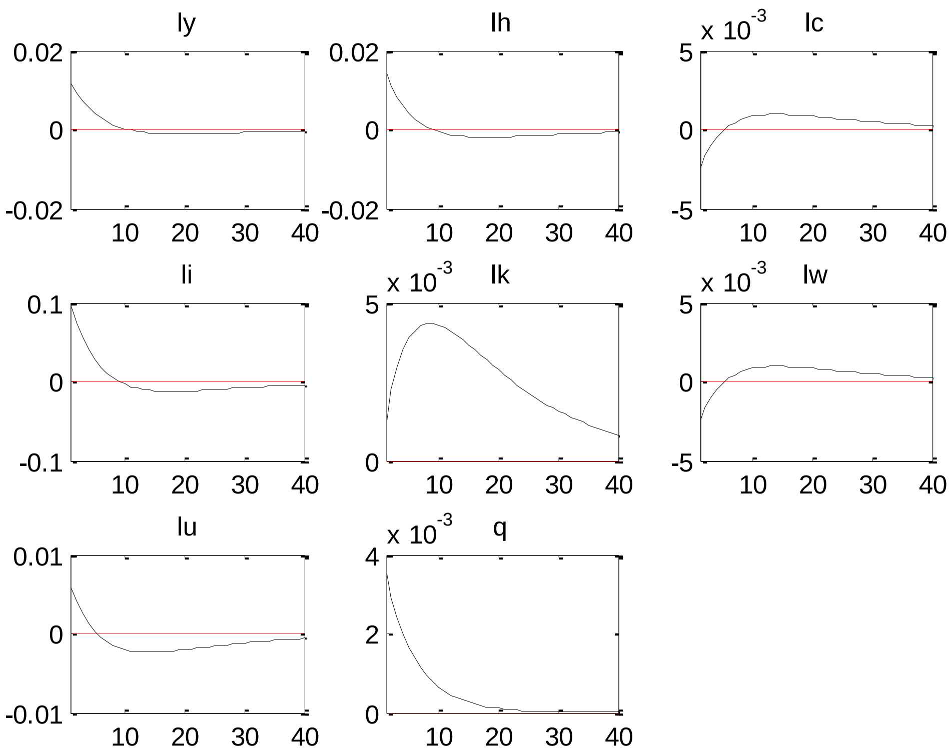

Figure 3: Impulse response functions for orthogonalized shock to investment efficiency

Figure 3 depicts how each variable deviates from its steady state following a shock only to investment efficiency.[22] The vertical axis depicts the percentage deviation (divided by 100) from steady state (red line). Investment increases by roughly around 10% from steady state. Although labour increases, its productivity is less, and thus wages decrease. Therefore, consumption decreases, but because output has increased through investment productivity, the agent in the model is able to save (invest) more.

[22] See Appendix for variable labels.

Output, employment and capacity utilization however are captured reasonably well in the model. The model slightly exaggerates output volatility by around 1%, but the ratios of employment and capacity utilization to output are very close to that reported in the data. The frictions of the labour market discussed in previous sections could possibly explain why employment in the model is slightly more procyclical than in the data (3.82% vs. 2.39%). This implies that there is more at work in the real economy during output booms than merely hiring more labour to produce.

Productivity is significantly more procyclical in the data than wages (or productivity) in the model (0.84% vs. 2.66%). In fact, wages seem to be almost acyclical in the model given the relatively low correlation with output. This could explain why employment is not as procyclical as the model implies. Aside from hiring more labour, employees seem to be putting in more productive hours (higher productivity) than the model suggests. This is backed up by the higher correlation of productivity with output in the data than in the model (0.63 vs. 0.88). In the model however, this is not necessarily the case. So in a production boom with investment shock, more workers would choose to work so as to earn and earn higher investment returns. This increase in labour reduces the productivity, hence the lower correlation of output and productivity.

Conclusion

This paper aimed document stylized facts about the South African economy and relate the findings to those of various dynamic stochastic models. The stylized facts about the South African economy were not as intuitive as first thought. Labour market inflexibility, new legislature, newly-found democratic stability and shifts in economic policies are just some of the forces affecting aggregate economic activities. While output and investment are relatively less volatile than first thought, the labour market in South Africa has shown remarked deviations from both economic theory and documented findings such as those in Prescott and Cooley (1995) and Hansen (1985).

In attempting to document the labour market in different ways, both a neoclassical model and a Hansen (1985) model with indivisible labour were calibrated to try and replicate the findings from the data. The Hansen model was a much closer fit with regards to labour market features such productivity and employment, seemed to overestimate output. The neoclassical model captured output quite well but significantly overestimated investment volatility. We then introduced a GHH model with variable capacity utilization and investment specific shocks. We used this model in a manufacturing sector setting given that this would be the environment that is strongly linked to investment efficiency shocks and variable capacity utilization of capital. The model replicates the sector relatively well with capacity utilization, output and even employment volatilities matching the data reasonably closely.

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Appendix

1. Data Descriptions

The data used in documenting the business cycle facts are all collected from the SARB database. The data was collected at quarterly frequencies for the period 1990:1 to 2009:2. All series were collected at constant prices and seasonally adjusted where possible. The following table lists the data with their codes.

Variable	Description	Code
GNI	Gross National Product (Income)	KBP 6016
Cons	Total Personal Consumption Expenditure	KBP 6007
ConsND	Consumption of Non-Durables	KBP 6061
ConsD	Consumption of Durables	KBP 6050
ConsSD	Consumption of Semi-Durables	KBP 6055
Inv	Gross Fixed Capital Formation	KBP 6009
InvR	Gross Fixed Capital Formation - Residential Buildings	KBP 6110
InvNR	Gross Fixed Capital Formation - Non-Residential Buildings	KBP 6114
Govt	Government Purchases	KBP 6008
X	Exports of Goods and Services	KBP 6013
M	Imports of Goods and Services	KBP 6014
CapUtil	Percentage Utilisation of Production Capacity (Manufacturing)	KBP 7078
Remun	Total Remuneration per Worker in the Non-Agricultural Sector	KBP 7013
RComp	Compensation of residents	KBP 6240
Emp	Total Employment in the Non-Agricultural Sector	KBP 7009
Productivity	Labour Productivity	KBP 7014

RComp was obtained as a nominal figure and so had to be deflated. This was done by deflating the series by dividing through the 19999BIRZF...GDP Deflator series from the IFS database. Employment and productivity volatilities were only calculated over the 1990:1 to 2002:2 period as there were several structural shifts in the series thereafter due to new and expanded surveys. InvF in Table 1 was calculated as the sum of InvR and InvNR and then logged and H-P filtered accordingly.

Data used in calibration was all at an annual frequency. They were collected from either the SARB database or the International Monetary Fund's IFS database. The data were collected for the period 1990 to 2008 (where the data is available) and at constant prices. The following table lists the data, their source, and codes. The calibration process however was done using the data from 1994 due to South Africa's strong economic contraction during the early part of that decade. The contraction strongly distorted some data averages, even over the longer period.

Variable	**Description**	**Source**	**Code**	
Consumption	Final Consumption Expenditure	SARB	KBP	6620
Investment	Gross Fixed Capital Formation	SARB	KBP	6009
GNI	Gross National Product (Income)	SARB	KBP	6016
GNI/cap Growth	Gross National Product (Income) per Capita Growth	SARB	KBP	6271
Depreciation	Consumption of Fixed Capital	SARB	KBP	6002
Capital	Capital Stock	SARB	KBP	6149
Employment	Total Employment	IFS	19967E..ZF...	
Population	Total Population	IFS	19999Z..ZF...	
Labour Force	Total Labour Force	IFS	19967D..ZF...	

The manufacturing sector specific data used were all obtained at quarterly frequencies for the period 1990:1 to 2009:2 (at constant prices) from the SARB's database. Where available, the seasonally adjusted series were used. The following table lists the data and their codes.

Variable	Description	Frequency	Code	
Investment	Gross Fixed Capital Formation: Manufacturing (Investment)	Quarterly	KBP	6082
Employment	Employment in the Private Sector: Manufacturing	Quarterly	KBP	7004
CapUtil	Manufacturing: Percentage Utilisation of Production Capacity of Total Goods	Quarterly	KBP	7078
Productivity	Manufacturing: Labour Productivity	Quarterly	KBP	7079
Labour Cost	Manufacturing: Unit Labour Costs	Quarterly	KBP	7080
Volume	Manufacturing: Total Volume of Production	Monthly	KBP	7085

The volume series was converted from a monthly frequency to a quarterly frequency by adopting the average method. Each quarter was assigned the average value of the monthly statistics of that quarter. The quarterly series was then H-P filtered to obtain the cyclical volatility.

2. Additional Figures

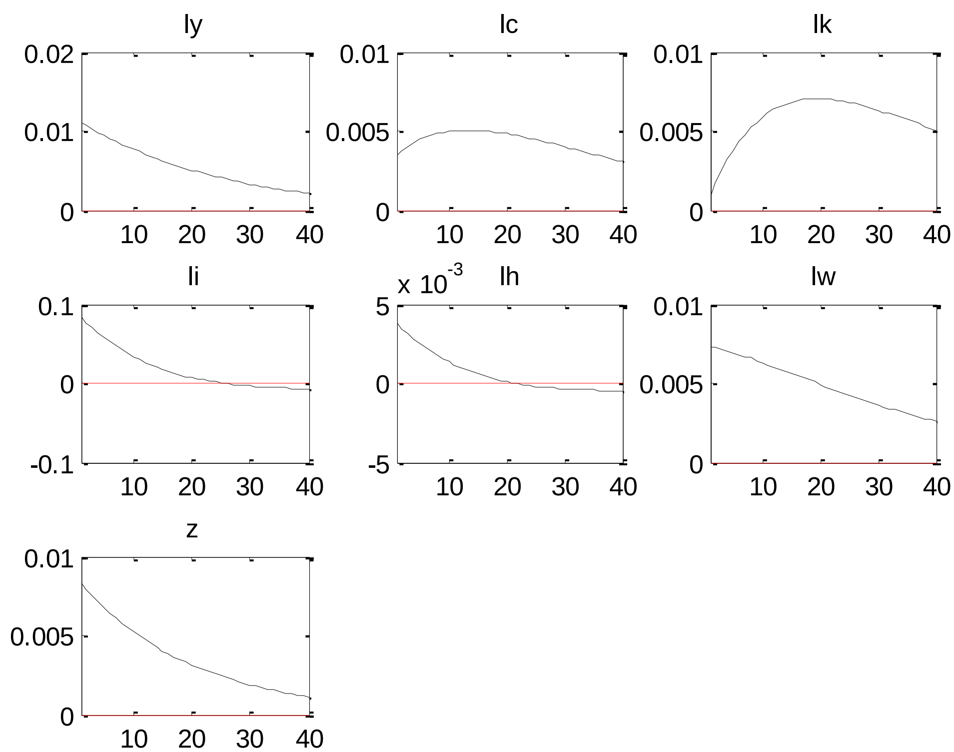

Figure 4: Impulse response function for neoclassical model economy

Variable	Legend
ly	LN(Output)
lh	LN(Hours)
lc	LN(Consumption)
li	LN(Investment)
lk	LN(Capital)
lw	LN(Wages)
z	LN(Z)

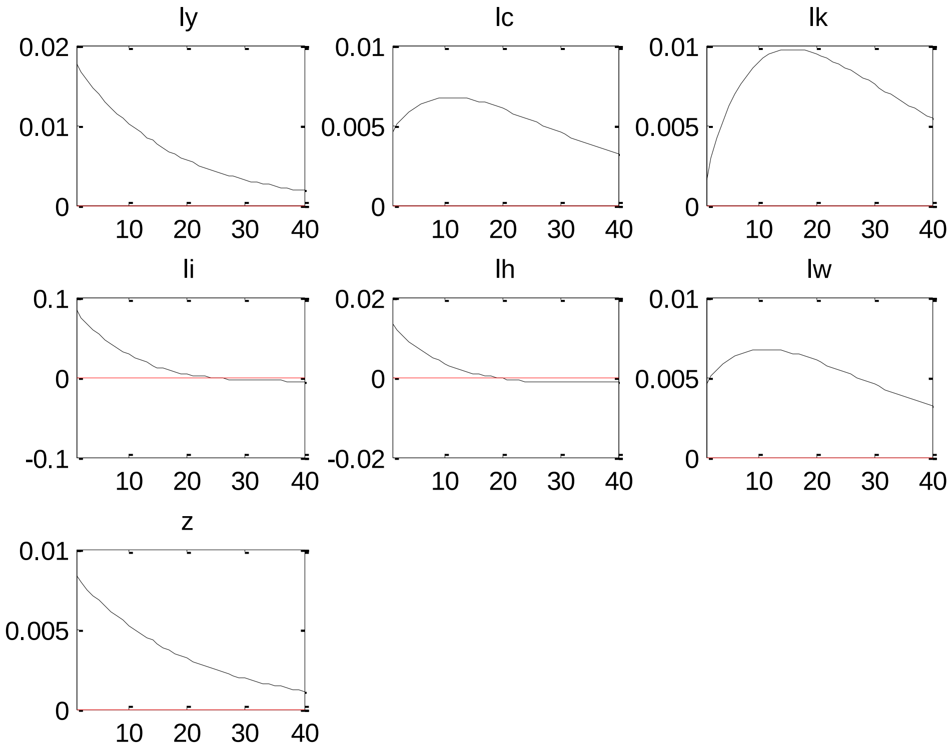

Figure 5: Impulse response function for model economy with indivisible labour

Variable	Legend
ly	LN(Output)
lc	LN(Consumption)
lk	LN(Capital)
li	LN(Investment)
lh	LN(Labour)
lw	LN(Wages)
z	LN(Z)

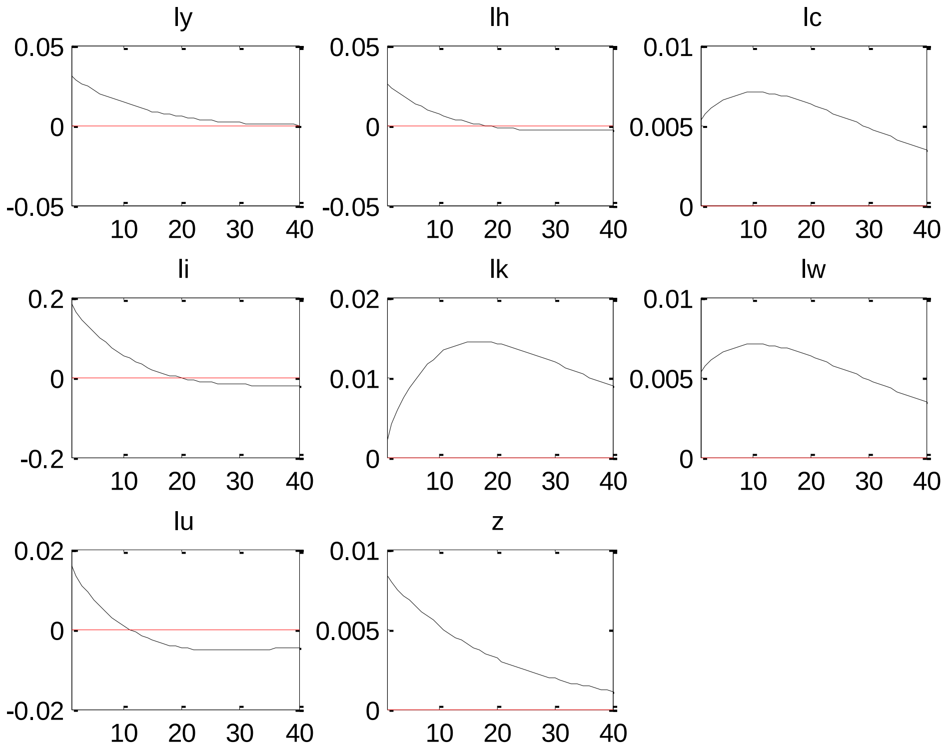

Figure 6: Impulse response functions for orthogonalized shock to output technology in GHH model

Variable	Legend
ly	LN(Output)
lh	LN(Hours)
lc	LN(Consumption)
li	LN(Investment)
lk	LN(Capital)
lw	LN(Wages)
lu	LN(CapUtil)
z	LN(Z)