ANALYSIS OF MACROECONOMIC EFFECTS OF OIL PRICE SHOCKS: THE CASE OF SOUTH AFRICA

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Abstract

This paper attempts to capture the role and effects of oil price shocks to an oil-importing economy, South Africa. An adapted version of the dynamic stochastic general equilibrium model (DSGE) of Blanchard and Gali (2008) is calibrated to the South African economy. The results confirm that oil price shocks have had a considerably lesser effect on the South African business cycle over the last four decades. Moreover, real wage rigidities, oil shares in consumption and production, credible monetary policy and a benign macroeconomic environment are all important explanations for dampened pass-through effects of oil prices. In addition, some counterintuitive results were observed for employment. Particularly, evidence suggests that employment is resilient amidst oil price shocks. The theoretical model, in tandem with other research findings, purports that larger than anticipated mark-ups (implying a lower elasticity of substitution between domestic goods) and high employment rigidities (implying lower than expected wage rigidities) are possible sources of the counterintuitive findings. In addition, the initial positive output responses can possibly be attributed to this finding, jointly with the value added effect elucidated from the DSGE model.

Keywords: Monetary policy, Great moderation, credibility, real wage rigidity, New Keynesian

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1. Introduction

This paper attempts to capture the role and effects of oil price shocks to an oil-importing economy, South African. Two main hypotheses characterised in the model are used in explaining the potential transmission areas and the impact of an oil price shock. First, greater flexibility in the labour markets simulated through changes in real wage rigidities are examined. Particularly, reduced wage rigidities in the labour market are postulated to reduce the negative impact of an adverse oil price shock on the macroeconomic variables in the model. Second, the impact of lower oil shares in firm production and household consumption are expected to reduce the impact of an adverse oil shock on the economy.

A large volume of business cycle literature exists examining the global trends on the macroeconomic implications of oil shocks (e.g. Adjemian and Pariés, 2008; Blanchard and Gali, 2008; Edelstein and Kilian, 2007; and Herrera and Pesavento, 2007). However, the emphasis lies heavily on developed countries. This paper will determine whether the South African experience conforms to global developments, particularly with respect to the observed decline in inflation and output volatility over the "Great Moderation" period. Firstly, the literature evidence will be compared to VAR-based impulse response functions of the South African data. Thereafter, a dynamic stochastic general equilibrium (DSGE) model is developed and calibrated to the South African economy. A benchmark model is simulated and the results are compared to those from the VAR. This serves the purpose of giving theoretical underpinnings to observed findings on the South African business cycle. Lastly, a sensitivity analysis is conducted, including an alternatively calibrated model which purports to explain some counterintuitive findings.

This paper finds that the experience of the South African economy is consistent with the literature findings on global developments over the "Great Moderation" period. Moreover, the results from the paper highlight some case specific issues of the South African economy on the business cycle. In particular, the dynamic interaction between employment, real wages and the aggregate mark-up is found to be core to empirically-based South African business cycle fluctuations in the presence of oil price shocks.

2. Literature Review

The work in this paper touches on various areas of research into supply-side shocks. Particularly, built on the seminal work of Bruno and Sachs (1985), analysing the effects of oil price shocks on output and inflation in the 1970's. In addition, and closely related to this paper, is the investigation of the role of wage setting and monetary policy under this scenario.

Well-documented empirical studies show that, for example, every recession in the United States since 1973 was preceded by a sharp increase in the oil price (Hamilton and Herrera, 2004; Hamilton, 2008)[1]. At face value, this suggested an essential role for oil price shocks in economic recessions. However, various subsequent studies have cast doubt on the salience of oil prices in causing recessions (Hooker, 1996; Hamilton, 2008). More recently, Dhawan and Jeske (2008) test the robustness of these findings and conclude that total factor productivity shocks continue to be the impetus behind business cycles, while verifying that energy shocks are responsible for only a small proportion of business cycle fluctuations (see also Kim and Loungani, 1992). However, it is important to note that the majority of these studies focus on industrialised countries and particularly, the U.S. Hence, the effects in a small developing economy, such as South Africa, may differ with respect to the amplification of oil shocks to the business cycle.

Blanchard and Gali (2008) attempt to elucidate three main hypotheses by specifically looking at the determinants of declining output and inflation volatility in a number of developed countries. Declining real wage rigidities, credible monetary policy and decreasing shares of oil in production and consumption are found to be strong determinants for the "Great Moderation". The study emphasises the implications of real wage rigidities and nominal price stickiness,[2] the declining pass-through effect of oil shocks, and structural changes of the global economy. The findings of this paper give similar results. In that oil price shocks have had a considerably lesser effect on the South African business cycle over the last four decades. Moreover, real wage rigidities, oil shares in consumption and production, credible monetary policy and a benign macroeconomic environment are all important explanations for the dampened pass-through effect of oil prices. This implies not just an industrialised country phenomenon, but a global prevalence that envelopes some developing countries. The next section seeks to provide a benchmark for the DSGE comparison. Furthermore, the decreased

[1] 9 out of 10 recessions have been identified as succeeding an oil price spike since World War II (Hamilton and Herrera, 2004; Hamilton, 2008).

[2] Research largely based on the work by Smets & Wouters (2003).

prevalence of oil price shocks in aggregate macroeconomic variables is documented using the VAR approach[3].

3. Estimating the Effects of Oil Price Shocks using a VAR

This section serves to elucidate the macroeconomic effects of an oil price shock using a 7-variable vector autoregression (VAR): the nominal price of oil (in dollars), both CPI and GDP deflator inflation, and four real quantities (output, employment, private consumption of non-durable goods, and remuneration per worker in the non-agricultural sector). It is reasonable to assume that economic developments in South Africa do not significantly affect the world oil price contemporaneously. Therefore, unexpected nominal oil price fluctuations are identified as exogenous relative to the other six macroeconomic variables.

The estimated VAR contains four lags of each variable[4], and the sample period is 1970:02-2010:01. Data are taken from the South African Reserve Bank Quarterly Bulletin. The dollar price of oil is expressed in log differences and also not in real terms to avoid any endogoneity from dividing by the GDP deflator. The two inflation measurements are CPI inflation and GDP deflator inflation, and are expressed in annualised quarterly percentage change terms. The four real quantities are expressed in log differences. This allows the effective comparison of the impulse responses to those from the calibrated DSGE model.

The literature strongly suggests the presence of a structural break in the volatility of output growth at the beginning of 1984 (Kim and Nelson, 1999; and McConnell and Perez-Quiros, 2000). The subsequent period of low inflation and output growth volatility has been coined the "Great Moderation". Although the purpose of this paper is not to examine the differentiating impacts of oil price shocks in the two sub-sample periods of South African business cycle fluctuations, the impulse responses of the two sub-sample periods are analysed. This serves as a benchmark to determine South African data consistency with the literature findings. Moreover, it may serve to highlight any salient features of the South African economy, and mitigates possible misperceptions on business cycle fluctuations from the VAR-based empirical evidence. The VAR is also estimated over the entire

[3] Herrera & Pesavento (2007), Edelstein & Kilian (2007), and Blanchard & Gali (2008) document similar results.
[4] This is consistent with the literature on the effects of an oil price shock. Evidence suggests statistically significant effects on aggregate economic activity tend to arise after one year (see Herrera & Pesavento, 2007; Hamilton, 1983; Hamilton, 2003; and Blanchard & Gali, 2008).

sample period. This gives a preferably longer sample period and focuses on the main discussion with respect to the South African business cycle and oil price shocks.[5]

Figure 1 shows the impulse response functions (IRFs) to a one standard deviation increase in the nominal price of oil price from the full sample period 1970:02 – 2010:01. Interestingly, some counterintuitive results are observed. The expected results would be a decline in output, consumption, wages and employment, while inflation is expected to increase due to supply-side pressures. Output exhibits a double-dip response, the biggest decline lasting 6 quarters from the 11th quarter. Furthermore, output initially declines after the 4th quarter; this is consistent with the literature that suggests statistically significant effects on aggregate economic activity tend to arise one year after an oil price shock (see Herrera & Pesavento, 2007; Hamilton, 1983; Hamilton, 2003; and Blanchard & Gali, 2008). Consumption initially spikes – potentially due to higher inflation expectations, inducing relatively higher pre-emptive consumption[6] – and expectantly decreases quite substantially as inflationary pressures are anticipated and transmitted through the economy and realised after the 4th quarter (e.g. see Springer, 1977; Blinder and Deaton, 1985; Edelstein and Kilian, 2007). However, the pass-through effect is short-lived as consumption patterns stabilise quickly. The result is consistent with macroeconomic literature, in that non-durable consumption is less volatile and persistent than output (Rebelo, 2005). Surprisingly, employment peaks after 5 quarters then steadily declines to negative only *after* 11 quarters, and converges to its steady state in the 18th quarter. This counterintuitive response is puzzling, perhaps indicating a rather resilient labour market (or low wage rigidity) in the presence of supply-side pressures[7]. Wages conform well to the expected results, declining sharply in the 4th quarter and stabilising fairly quickly thereafter. CPI inflation increases in response to the shock; rising significantly after the 6th quarter and persists for more than 20 quarters. The GDP deflator inflation peaks in the 4th quarter, but is not as persistent.

The observed results merit further analysis, which lead to the investigation of the two sub-sample VARs under the same specifications. Subsequently, the findings for South Africa are more consistent with the bulk of the literature findings, especially the post 1984:01 sub-sample period.

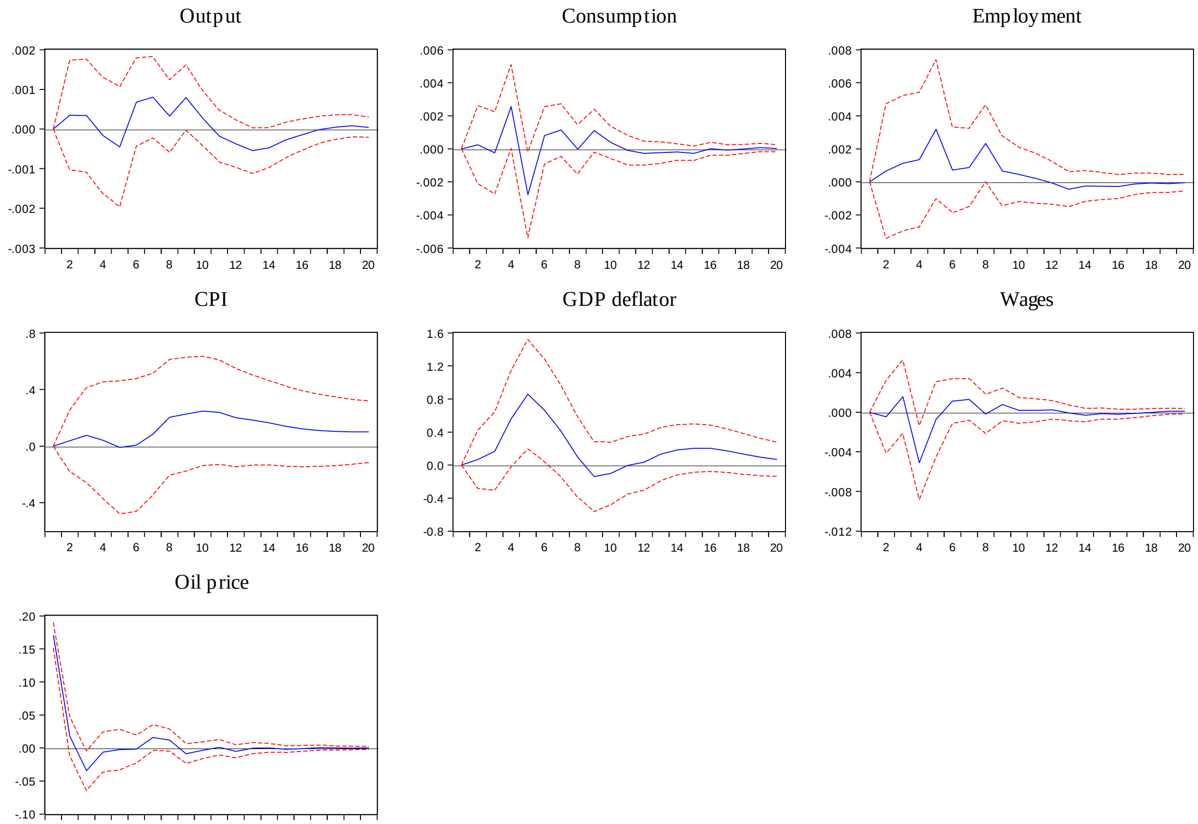
Figure 2 shows the IRFs from the pre-“Great Moderation" era. The findings are closely consistent with those from the full-sample period. Consumption decreases sharply after the 4th quarter and stabilises

[5] It is important to note here that consideration was given to the significant oil shock in 1974q1. However, the impulse responses do no change significantly, and therefore preferably left in the sample.
[6] Households want to purchase goods at the lowest possible prices, which is the immediate present prior to realised inflation.
[7] Granger-causality tests show that employment is the only variable that is not significantly predicted by any of the other variables in the VAR. The counter-intuitive result is discussed in the sensitivity analysis in section 7.

quickly thereafter. Moreover, the decline in consumption and wages is greater in the sub-sample relative to the full sample. Although employment spikes in the 5th quarter, the decline starting in the 10th quarter is larger and more persistent relative to the full sample. Both output and inflation exhibit greater volatility compared to that from the full-sample period. The periods of disinflation observed in CPI and GDP deflator inflation after the 12th quarter and 8th quarter, respectively, are possibly due to the lagged effects of monetary policy or the re-adjustment to overheated prices[8].

The disparity in results between the first sub-sample and the full sample are attributed to the decline in output[9] and inflation volatility during the "Great Moderation" period, as shown in Figure 3. Better technology, better monetary policy and "good luck" have all been suggested as proponents of this identified structural break in the global macro economy (see Blanchard & Gali, 2008; Herrera & Pesavento, 2007).

Figure 1: Impulse Response Functions (full-sample period: 1970:02 - 2010:01)



[8] The theoretical model does show that an increase in the real price of oil has a negative effect on the GDP deflator when prices of domestic output are taken as given, which perhaps explains the observed pattern.
[9] This includes the major components of GDP such as aggregate employment and aggregate consumption (for examples, see McConnell, Mosser, and Perez-Quiros, 1999; Warnock and Warnock, 2000).

Figure 2: Impulse Response Functions (sub-sample period: 1970:02 - 1983:04)

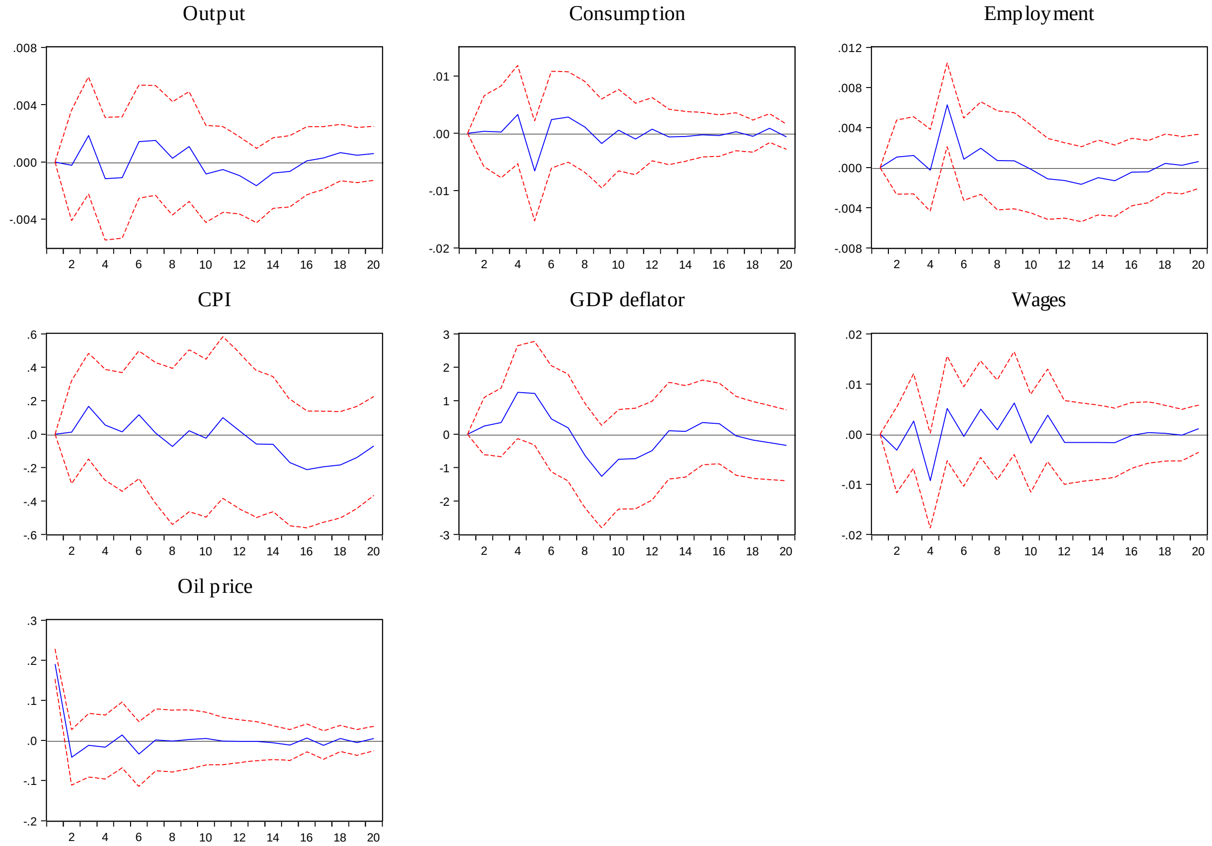
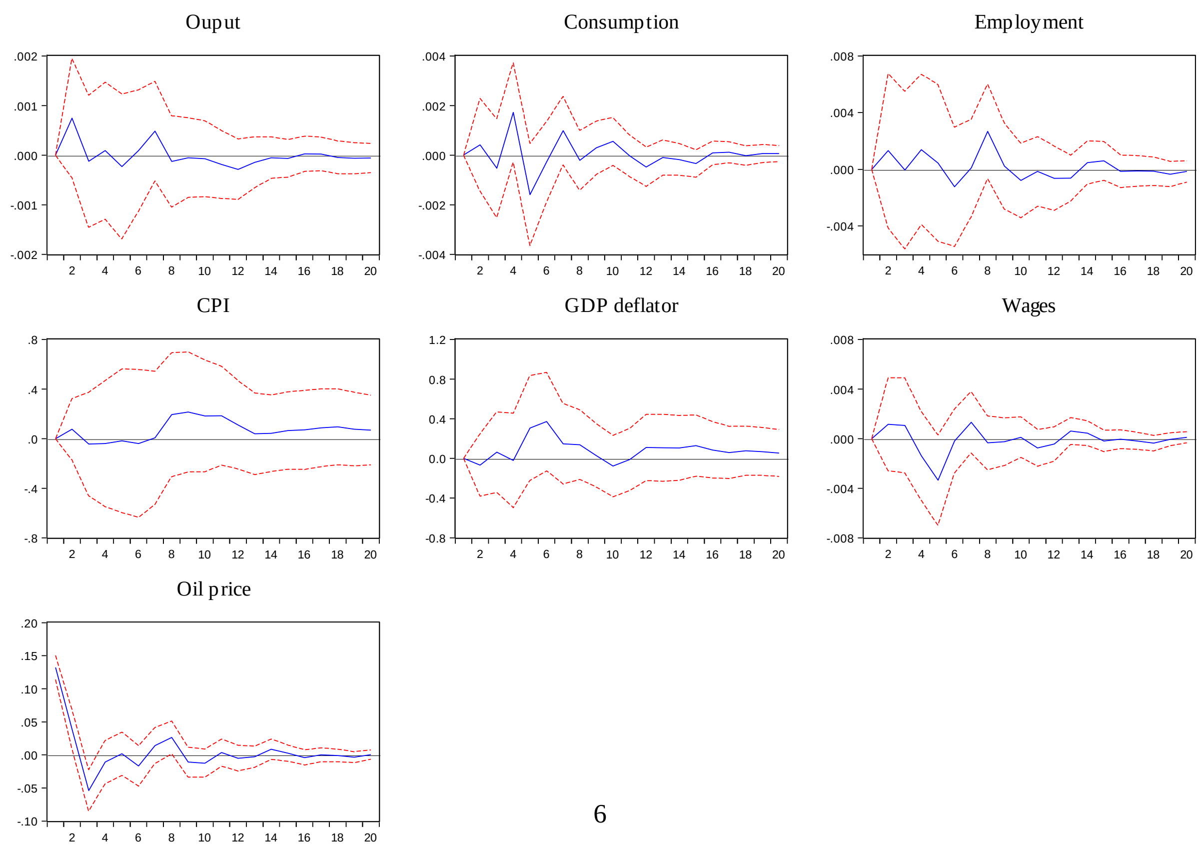


Figure 3: Impulse Response Functions (sub-sample period: 1984:01 - 2010:01))



In summary, the results generally fit conventional wisdom: an oil price shock leads to higher inflation and a decrease in output, wages and consumption. In addition, the significant decline in output and inflation volatility is observed in the post-1984:01 sub-sample. Indeed, the brief counterintuitive results observed in the pre-"Great Moderation" era are puzzling. However, the overall impression from the South African data is consistent with global developments.

Importantly, the indirect effects of monetary policy, technological progress and "luck" as already noted are not extrapolated from the VAR method, neither are there any implicit theoretical underpinnings to directly base the responses on. Therefore, it is the interest of this paper to further examine the potential effects of oil price shocks on South African business cycle fluctuations. Hence, a dynamic stochastic general equilibrium model is used to investigate the macroeconomic dynamics of an oil importing country, in response to supply-side pressures.

4. The Model

This model uses the benchmark dynamic New-Keynesian model, including two further modifications based on Blanchard and Gali (2008). First, oil is characterised as an input in production as well as in household consumption. The country is further assumed to be an importer of oil, with the real price of oil following an exogenous process. Second, real wage rigidities are introduced in the model to examine the impact of an adverse oil shock on labour market flexibility. Lower case letters represent the log-deviations from steady state of the original variables in levels (i.e. capital letters), unless otherwise stated.

The role of oil in firms is characterised in the model by replacing capital as an input used in production, giving the production function[10]

$$q_t = a_t + \alpha_n n_t + \alpha_m m_t \qquad (1)$$

where q_t is (gross) domestic output; a_t an exogenous technology parameter; n_t labour; m_t the quantity of imported oil used in production; with α_m the share of oil in production and α_n the elasticity of output with respect to labour, assuming that $\alpha_n + \alpha_m \leq 1$. In addition, oil is used by consumers in consumption, giving the consumption function

$$c_t \equiv (1-\chi)c_{q,t} + \chi c_{m,t}$$

[10] The Cobb-Douglas production function is maintained by this specification. Capital can be thought of as constant, thus making the analysis more focused on the oil and employment dynamics in the equilibrium model.

where c_t is consumption; $c_{q,t}$ consumption of domestically produced goods; $c_{m,t}$ consumption of imported oil; and χ the share of oil in consumption (in equilibrium). The distinction between the price of domestic output $(p_{q,t})$ and the price of consumption $(p_{c,t})$ is important. Let $p_{m,t}$ be the price of oil and $s_t \equiv p_{m,t} - p_{q,t}$ the real price of oil. By following the consumption definition, it is possible to yield the relationship between the domestic output and consumption prices:

$$p_{c,t} = p_{q,t} + \chi s_t \tag{2}$$

Therefore, real oil price increases indicate increases in the consumption price relative to the price of domestic output.

a. Households

Households are homogenous and infinitely lived, whereby each household maximises the utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, N_t)$$

Where $C_t \equiv \theta_x C_{m,t}^{\chi} C_{q,t}^{1-\chi}$, with $C_{m,t}$ the consumption of (imported) oil; $C_{q,t} \equiv (\int_0^1 C_{q,t}(i)^{1-\frac{1}{\varepsilon}} di)^{\frac{\varepsilon}{\varepsilon-1}}$, is a CES index of domestic goods; N_t employment or hours worked; and $\theta_x \equiv \chi^{-\chi}(1-\chi)^{-(1-\chi)}$ Assume period utility is given by:

$$U(C_t, N_t) \equiv \log C_t - \frac{N_t^{1+\phi}}{1+\phi}$$

The period budget constraint, which is conditional on the (optimal) allocation of expenditures between the different domestic goods, is given by:

$$P_{q,t}C_{q,t} + P_{m,t}C_{m,t} + Q_t^B B_t = W_t N_t + B_{t-1} + \Pi_t \tag{3}$$

Where $P_{m,t}$ is the price of oil in terms of domestic currency; W_t nominal wages; Q_t^B the price of a one-period nominally riskless domestic bond, paying one unit of domestic currency; B_t is the quantity of that bond purchased in period t; and $P_{q,t}$ is a price index for domestic goods given by

$$P_{q,t} \equiv (\int_0^1 P_{q,t}(i)^{1-\varepsilon} di)^{\frac{1}{1-\varepsilon}}$$

Furthermore, the assumption of zero access to international financial markets is maintained (Blanchard & Gali, 2008).

The role of oil in households is incorporated by the optimal allocation of expenditures between domestically produced goods and imported goods, implying

$$P_{q,t}C_{q,t} = (1-\chi)P_{c,t}C_t \tag{4}$$

$$P_{m,t}C_{m,t} = \chi P_{c,t}C_t \tag{5}$$

where $P_{c,t} \equiv P_{m,t}^{\chi} P_{q,t}^{1-\chi}$ is the CPI index. Therefore, $P_{c,t} \equiv P_{q,t}S_t^{\chi}$ where $S_t \equiv \frac{P_{m,t}}{P_{q,t}}$ denotes the real price of oil, which is given in terms of goods that are domestically produced. Therefore, by taking logs

$$p_{c,t} = p_{q,t} + \chi s_t \tag{6}$$

where $s_t \equiv p_{m,t} - p_{q,t}$ is the (log) real price of oil. Additionally, on the condition that an optimal allocation exists between the two types of goods, then:

$$P_{q,t}C_{q,t} + P_{m,t}C_{m,t} = P_{c,t}C_t \qquad [(4) + (5)] \tag{7}$$

Substituting (7) into the budget constraint (3) gives the new budget constraint (9) used to obtain the remaining optimality conditions for households.

Households' optimality conditions are derived by maximising the discounted expected utility function[11]:

$$E_o \sum_{t=0}^{\infty} \beta^t U(C_t, N_t) = E_o \sum_{t=0}^{\infty} \beta^t [\log C_t - \frac{N_t^{1+\phi}}{1+\phi}] \tag{8}$$

Subject to the budget constraint:

$$P_{c,t}C_t + Q_t^B B_t = W_t N_t + B_{t-1} + \Pi_t \tag{9}$$

Therefore, the intertemporal optimality condition is given by:

$$Q_t^B = \beta E_t [\frac{C_t}{C_{t+1}} . \frac{P_{c,t}}{P_{c,t+1}}] \tag{11}$$

Under the assumption of perfect competition in labour markets, the households' intratemporal optimality condition is given by the perfectly competitive labour supply schedule:

$$\frac{W_t}{P_{c,t}} = C_t N^{\phi} \equiv MRS_t \tag{12}$$

The log-linearized versions of the two previous equations give households behaviour. First, the intertemporal condition for consumption from (11):

$$c_t = E_t\{c_{t+1}\} - (i_t - E_t\{\pi_{c,t+1}\}) \tag{13}$$

[11] See calculations in appendix.

Where i_t is the nominal interest rate ($i_t \equiv -\log Q_t^B$) and $\pi_{c,t} \equiv p_{c,t} - p_{c,t-1}$ is the CPI inflation. The second equation characterises labour supply (under perfect competition) from (12), implicitly given by

$$w_t - p_{c,t} = c_t + \phi n_t \equiv MRS_t \tag{14}$$

where w_t is nominal wage and n_t employment. The identity states that the consumption wage (or log real wage, ($w_t - p_{c,t}$)) must equal the marginal rate of substitution (MRS) between consumption and leisure. The coefficient on employment (ϕ) is defined as the inverse of the elasticity of labour supply. Moreover, real wage earnings can be formalised by including a parameter for wage rigidity:

$$w_t - p_{c,t} = (1-\gamma)(c_t + \phi n_t) \tag{15}$$

The wage rigidity variable is included in the model due to its explanatory properties in the attempt to examine the reduced effects of oil shocks to households, while γ lies between zero and one, and is interpreted as the degree of real wage rigidity.

b. Firms

Cost minimization with respect to oil input and labour characterises firms' behaviour in the model economy. Given the production function

$$Q_t(i) = A_t M_t(i)^{\alpha_m} N_t(i)^{\alpha_n} \tag{20}$$

where N_t is employment or hours worked and M_t is oil in production. Each firm produces a differentiated good indexed by $i \in [0,1]$; and $\alpha_m + \alpha_n \leq 1$.

Given that prices are set independently[12], and assuming that both input prices are taken as given, the firm's cost minimization implies that firm *i*'s nominal marginal cost is[13]:

$$\psi_t(i) = \frac{W_t}{\alpha_n (Q_t(i)/N_t(i))} = \frac{P_{m,t}}{\alpha_m (Q_t(i)/M_t(i))} \tag{21}$$

Therefore letting $\mathcal{M}_t^p(i) \equiv P_{q,t}(i)/\psi_t(i)$ denote firm *i*'s gross mark-up (over marginal cost) and using the cost minimisation of oil in (21) we have:

$$\mathcal{M}_t^p(i).S_t M_t(i) = \alpha_m Q_t(i) \frac{P_{q,t}(i)}{P_{q,t}} \qquad \text{, if } \; S_t \equiv \frac{P_{m,t}}{P_{q,t}} \tag{24}$$

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[12] Prices are set by firms in a monopolistic competitive market, implying some market power and a mark-up over marginal cost.
[13] From (23) & (22) calculated in Appendix

Letting $Q_t \equiv (\int_0^1 Q_t(i)^{1-\frac{1}{\varepsilon}} di)^{\frac{\varepsilon}{1-\varepsilon}}$ denote aggregate gross output, it follows that

$$M_t = \frac{\alpha_m Q_t}{\mathcal{M}_t^p S_t} \tag{25}$$

where $\mathcal{M}_t^p$ is defined as the average gross mark-up, weighted by firms input shares, and $Q_t(i) = (P_{q,t}(i)/P_{q,t})^{-\varepsilon} Q_t$ is the demand schedule facing firm *i*. Log-linearizing equation (25) gives the firm's demand for oil (ignoring constants):

$$m_t = -\mu_t^p - s_t + q_t \tag{26}$$

Equation (26) can be substituted into the (log-linearized) aggregate production function (1) in order to give the reduced form gross output equation, which is then dependent on technology, employment, the real oil price, and the mark-up:

$$q_t = \frac{1}{1-\alpha_m}(a_t + \alpha_n n_t - \alpha_m s_t - \alpha_m \mu_t^p) \tag{27}$$

Therefore output is a decreasing function of the real price of oil s_t, given employment n_t and technology a_t.Where, $\mu_t^p \equiv \log \mathcal{M}_t^p$.

Similarly, from the cost minimization of labour in (21), logs-linearization yields:

$$q_t = w_t - p_{c,t} + \mu_t^p + n_t + \chi s_t \tag{29}$$

Substituting (29) into the aggregate production function (27) yields the factor price frontier:

$$(1-\alpha_m)(w_t - p_{c,t}) + (\alpha_m + (1-\alpha_m)\chi)s_t + (1-\alpha_m - \alpha_n)n_t - a_t + \mu_t^p = 0 \tag{28}$$

where $1 \geq \alpha_m + \alpha_n \geq 0$.

Therefore, an increase in the real price of oil (s_t), given productivity (a_t), must cause an adjustment in at least one of the following variables: lower real wage $(w_t - p_{c,t})$, lower employment (n_t), and/or a lower mark-up (μ_t^p).

Blanchard & Gali (2008) show that under their assumed functional forms and using flexible prices and wages, mark-up and employment do not change with an increase in s_t. Rather, the adjustment is manifested entirely in real wages. The calibration in this paper gives a similar result. However, when mark-up is allowed to fluctuate and inefficient markets give rise to wage rigidities, different results are found[14].

Following Calvo-type price setting for firms gives the log-linearized equation for domestic inflation

$$\pi_{q,t} = \beta E_t\{\pi_{q,t+1}\} - \lambda_p \mu_t^p \tag{30}$$

where $\lambda_p \equiv [(1-\theta)(1-\beta\theta)/\theta][(\alpha_m + \alpha_n)/(1+(1-\alpha_m+\alpha_n)(\varepsilon-1))]$; θ is the fraction of firms that leave prices unchanged; β the discount factor of households; and ε the elasticity of substitution between domestic goods in consumption. Blanchard & Gali (2008) note the assumption of a constant desired mark-up is implied by the above specification.

c. Domestic Inflation, Output and the GDP deflator

Equation (15) gives the real wage that is consistent with household choices, while (28) gives the real wage consistent the factor price frontier (both relating to real wage rigidities). Therefore, looking at (15) and (28) together implies the mark-up is a function of consumption, employment, and the real price of oil.

Substituting (33) into the real wage equation (15) and then replacing the real wage in the factor price frontier (28) gives the following description of the mark-up[15]:

$$\mu_t^p = -\Gamma_n n_t - \Gamma_s s_t + \Gamma_a a_t \tag{34}$$

Where:

$$\Gamma_n \equiv \frac{(1-\alpha_n-\alpha_m)\gamma + (1-\alpha_m)(1-\gamma)(1+\phi)}{1-(1-\gamma)(\alpha_m-(1-\alpha_m)\eta)} \geq 0$$

$$\Gamma_a \equiv \frac{\gamma}{1-(1-\gamma)(\alpha_m-(1-\alpha_m)\eta)} \geq 0$$

$$\Gamma_s \equiv \frac{\gamma(\alpha_m+(1-\alpha_m)\chi)}{1-(1-\gamma)(\alpha_m-(1-\alpha_m)\eta)} \geq 0$$

Substituting (34) for the mark-up into equation (30) gives the following characterization of domestic inflation in terms of expected inflation, employment, the real oil price, and technology gives:

$$\pi_{q,t} = \beta E_t\{\pi_{q,t+1}\} + \lambda_p\Gamma_n n_t + \lambda_p\Gamma_s s_t - \lambda_p\Gamma_a a_t \tag{35}$$

[14] This issue is addressed in section 7.
[15] See derivation in Appendix.

Therefore, under perfect competition employment is not affected by the real price of oil (or the mark-up, because $\mu_t^p = 0$), due to the cancelling out of the income and substitution effects. That is, if there are no real wage rigidities ($\gamma = 0$) then Γ_a and Γ_s are both equal to zero, and domestic inflation only depends on expected future domestic inflation and employment. To what Blanchard & Gali (2008) refer to as the "divine coincidence", these two equations imply that "stabilising domestic inflation is equivalent to stabilising the distance of employment from first best". On the other hand, positive values of γ give positive values for Γ_a and Γ_s. For an increase in either γ or $(\alpha_m + (1-\alpha_m)\chi)$, there is an increase in the trade-off between the stabilisation of employment and the stabilisation of domestic inflation in the presence of oil price shocks, *ceteris paribus* (Blanchard & Gali, 2008: 43).

The variables for value added (GDP) and the GDP deflator are required in the equilibrium calibration in order to compare the characteristics of the data to the model. The GDP deflator $p_{y,t}$ is defined implicitly by $p_{q,t} \equiv (1-\alpha_m) p_{y,t} + \alpha_m p_{m,t}$ and rearranging the terms gives:

$$p_{y,t} = p_{q,t} - \frac{\alpha_m}{1-\alpha_m} s_t \tag{36}$$

An increase in the real price of oil has a negative effect on the GDP deflator when prices of domestic output are taken as given. The definition of GDP (combined with the demand for oil) gives the relationship between value added and firm output[16]:

$$y_t = q_t + \frac{\alpha_m}{1-\alpha_m} s_t + \eta \mu_t^p \tag{37}$$

Substituting (37) in the reduced form production function (27) gives the relationship between GDP and employment[17]:

$$y_t = \frac{1}{1-\alpha_m} (a_t + \alpha_n n_t) \tag{38}$$

The above approximation implies that the relationship between GDP and employment is independent of the real price of oil.

Combining the equations for GDP (38) and consumption (33) gives the relation

[16] See Appendix for calculations. Furthermore, it is important to note the distinction between value added output and firm output.

[17] Using the same assumption as above, i.e. $(\eta - \frac{\alpha_m}{1-\alpha_m})\mu_t^p \approx 0$.

$$c_t = y_t - (\frac{\alpha_m}{1-\alpha_m} + \chi)s_t \tag{39}$$

Given output, an increase in the price of oil leads to a decrease in consumption because imported oil has an input share in production and consumption.

5. Quantifying the Effects of Oil Price Shocks

The equations below are used in describing the equilibrium dynamics of the linearized system. In the goods market, market clearing requires that:

$Y_t(i) = C_t(i)$, for all $i \in [0,1]$ and time t

Letting aggregate output be defined as:

$$Y_t(i) \equiv (\int_0^1 Y_t(i)^{1-\frac{1}{\varepsilon}} di)^{\frac{\varepsilon}{\varepsilon-1}}$$

It follows that $Y_t = C_t$, which must hold for all time *t*. This condition is used to substitute into the consumer Euler equation (13) to yield the equilibrium condition for output.

$\pi_{q,t}$ denotes core CPI inflation, which is the variable that numerous central banks focus on as the source for interest rate policy decisions and is therefore used to determine the *ad hoc* interest rate rule: $i_t = \kappa_i i_{t-1} + (1-\kappa_i)(\varphi_\pi \pi_{q,t} + \kappa_y y) + \upsilon_t$. This monetary policy rule implies full central bank credibility and is a function of the previous period nominal interest rate, inflation and output deviations, including an autoregressive exogenous process υ_t .

The equilibrium dynamics of prices and quantities is described by equations (2), (13), (35), (40), and (38). Allowing for exogenous processes for the real price of oil and technology, and giving a description of the real oil price and nominal interest rate determination, gives the conditions required to characterise the economy's response to an oil price shock. Assume that a_t is equal to zero for all *t* to abstract from technology shocks. It follows from equation (38) that the efficient level of GDP is constant.

$$y_t = \frac{1}{1-\alpha_m}(a_t + \alpha_n n_t) = \frac{\alpha_n}{1-\alpha_m} n_t \tag{41}$$

Assume that the (log) real price of oil follows an AR(1) process:

$$s_t = \rho_s s_{t-1} + \varepsilon_{s,t} \tag{42}$$

The equilibrium dynamics of GDP is given by using the market clearing conditions, and equations (13) and (40):

$$y_t = E_t\{y_{t+1}\} - (i_t - E_t\{\pi_{q,t+1}\}) + \frac{\alpha_m(1-\rho_s)}{1-\alpha_m} s_t \tag{44}$$

Domestic inflation can be summarized through the system, using (41) and (35):

$$\pi_{q,t} = \beta E_t\{\pi_{q,t+1}\} + \kappa y_t + \lambda_p \Gamma_s s_t \tag{43}$$

Where:

$$\lambda_p \Gamma_n n_t = \lambda_p \Gamma_n [\frac{1-\alpha_m}{\alpha_n} y_t] = \frac{\lambda_p \Gamma_n (1-\alpha_m)}{\alpha_n} y_t = \kappa y_t$$

The equations in calibration are summarised below in the complete linearized system[18].

Variables: $c_t, i_t, (w_t - p_{c,t}), \pi_{c,t}, \pi_{q,t}, y_t, n_t, s_t, \mu_t^p$

1. Consumption:

$$c_t = y_t - (\frac{\alpha_m}{1-\alpha_m} + \chi) s_t \tag{39}$$

2. Monetary Policy Rule (Interest Rate Rule):

$$i_t = \kappa_i i_{t-1} + (1-\kappa_i)(\varphi_\pi \pi_{q,t} + \kappa_y y) + \upsilon_t$$

As mentioned above, domestic inflation is core CPI inflation and is used in the interest rate rule. The AR(1) process υ_t is described by $\upsilon_t = \rho_i \upsilon_{t-1} + \varepsilon_{i,t}$.

3. Real Wages:

$$w_t - p_{c,t} = (1-\gamma)(c_t + \phi n_t) \tag{15}$$

4. Domestic Inflation:

$$\pi_{q,t} = \beta E_t\{\pi_{q,t+1}\} + \kappa y_t + \lambda_p \Gamma_s s_t - \lambda_p \Gamma_n \kappa_m \mu_t^p$$

(43)

5. Consumer Inflation (CPI Inflation):

$$\pi_{c,t} = \pi_{q,t} + \chi \Delta s_t$$

[18] Note: the model has been slightly revised to allow the mark-up to vary. This makes the results more robust with respect to the hump-shaped dynamics documented in the literature.

6. Value Added/GDP[19]:

$$y_t = E_t\{y_{t+1}\} - (i_t - E_t\{\pi_{q,t+1}\}) + \frac{\alpha_m(1-\rho_s)}{1-\alpha_m} s_t \quad (44)$$

7. Employment:

$$n_t = \frac{(1-\alpha_m)}{(1-\alpha_n)} y_t - \kappa_m \mu_t^p$$

Using equation (38) and where: $a_t = 0$

8. Oil Shock:

$$s_t = \rho_s s_{t-1} + \varepsilon_{s,t} \quad (42)$$

9. Mark-up:

$$\mu_t^p = -(1-\alpha_m)(w_t - p_t) - (\alpha_m + (1-\alpha_m)\chi)s_t - (1-\alpha_n-\alpha_m)n_t \quad (43)$$

Derived from equation (28).

6. Results

a. Calibration

The model is calibrated using the parameter values assumed and derived above. This is needed to quantitatively assess the potential and dynamic impacts of oil price shocks in the defined macroeconomic variables.

θ	β	α_m	α_n	ϕ	ϕ_π	χ	ρ_s	γ	$\mathcal{M}^\rho$	κ_i	κ_y	ρ_i
0.75	0.99	0.05	0.7	1	2	0.076	0.94	0.7	1.17	0.65	0.3	0.75

θ is the fraction of firms that leave prices unchanged (Calvo parameter); β the discount factor of households; α_m the share of oil in production; α_n the elasticity of output with regards to labour; ϕ is a unitary Frisch labour supply elasticity; ϕ_π determines the degree of response of monetary policy to domestic inflation, and similarly κ_y for output; χ is the share of oil in consumption; ρ_s is the persistence of the oil shock process and ρ_i the persistence of the monetary policy shock process; γ equals 0 for fully flexible labour market, 0.7 for reduced wage rigidity, and 0.9 for high wage rigidity; and $\mathcal{M}^\rho$ is gross mark-up in steady state.

[19]The last term in (44) differs slightly in our calculation, but after substituting the parameter values in, the coefficient values are approximately the same. Therefore, we adopt the equation used by Blanchard & Gali (2008) to maintain consistency.

$$\mathcal{M}^{\rho} = \frac{\varepsilon}{\varepsilon - 1}$$; ε is the elasticity of substitution between domestic goods in consumption

$$\lambda_{\rho} \equiv [(1-\theta)(1-\beta\theta)/\theta][(\alpha_m + \alpha_n)/(1+(1-\alpha_m+\alpha_n)(\varepsilon-1))]$$

$$\kappa \equiv \lambda_{\rho}\Gamma_n(1-\alpha_m)/\alpha_n;$$

$$\Gamma_n \equiv \frac{(1-\alpha_n-\alpha_m)\gamma + (1-\alpha_m(1-\gamma)(1+\phi)}{1-(1-\lambda)(\alpha_m-(1-\alpha_m)\eta)} \geq 0;$$

$$\Gamma_s \equiv \frac{\gamma(\alpha_m + (1-\alpha_m)\chi)}{1-(1-\gamma)(\alpha_m-(1-\alpha_m)\eta)} \geq 0; \text{ and}$$

$$\eta = \frac{\alpha_m}{\mathcal{M}^{\rho} - \alpha_m}$$

$$\kappa_m = \frac{\alpha_m(1-\mathcal{M}^p)}{(\mathcal{M}^p - \alpha_m)\alpha_n}$$

Time periods are quarterly, with the discount factor β made equal to 0.99. The fraction of firms that leave prices unchanged θ is assumed to be 0.75 and the elasticity of output with respect to labour α_n is equal to 0.7. ϕ is assumed to be 1, implying a unitary labour supply elasticity. The above parameters are consistent with conventional wisdom and are necessary to maintain comparability with Gali and Blanchard's (2008) values. The aggregate gross mark-up in South Africa is assumed to be 17% across all firms (Edwards and Winkel, 2003).[20]

The share of oil in production is derived from the weighting of petroleum and coal in the producer price index (PPI), which is a proxy for the share of crude oil in the total cost of production of goods and services. Similarly, the share of oil in consumption is proxied by the weighting of transport fuel and household energy consumption in the consumer price index (CPI) (Wakeford, 2008).

Gali and Blanchard (2008) emphasise the low probability of changes in real oil price volatility to be the determining factor to changes in the size of the effects of oil shocks. Therefore, the oil shock process is assumed to be unchanged and the standard deviation of the real price of oil over the sample period is calculated to be 0.148.[21] ρ_s is calculated as 0.94, implying the oil price is close to non-stationarity.

[20] The average mark-up between 1970 and 2002 for the entire economy equals 17% when including intermediate inputs, therefore $\mathcal{M}^{\rho}$ = 1.17 (Edwards and Winkel, 2003).

[21] In this calculation, the 1974q1 oil shock is not included due to the excessive distorting magnitude of the shock in calculating the standard deviation.

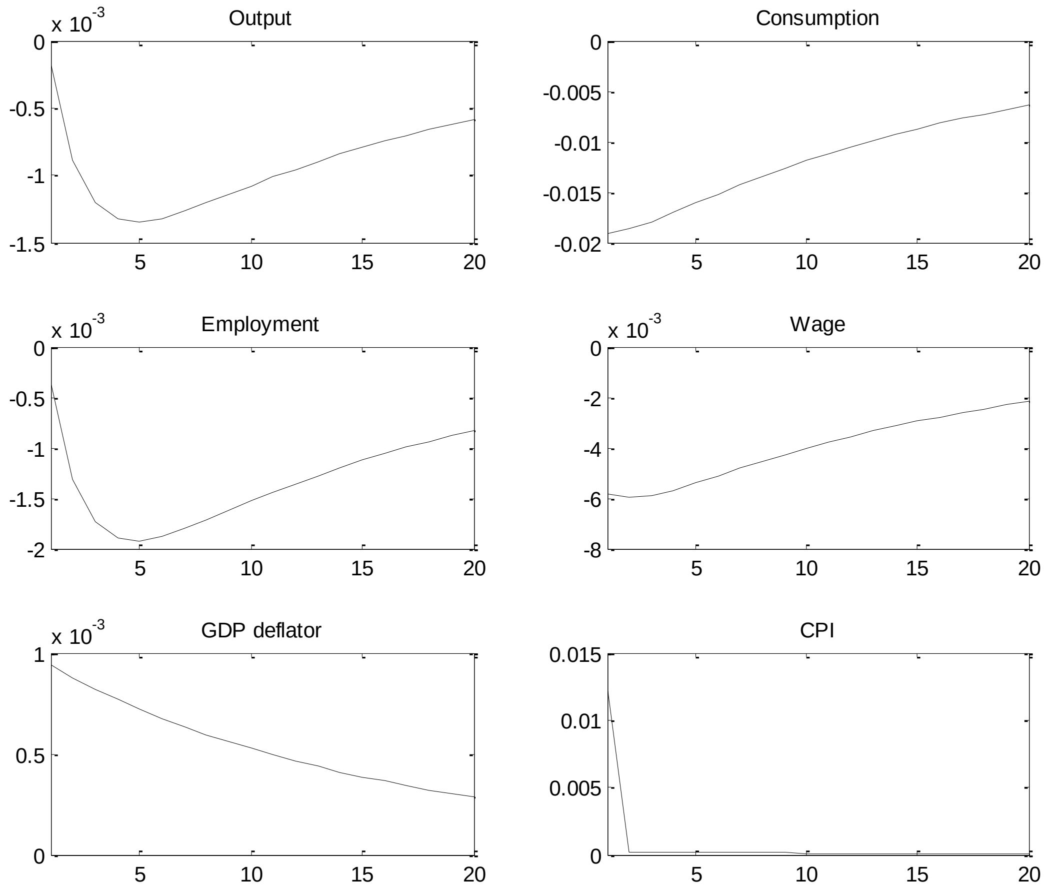
The above parameters remain constant through-out the analysis. However, wage flexibility and the parameters for oil share in production and consumption are changed to assess the macroeconomic impact of oil shocks under different scenarios. The sensitivity analysis will be discussed at the end.

b. DSGE model results

Figure 4 below shows the impulse response to an oil shock for the benchmark model described. The results are consistent with the theory. Output, consumption[22], employment and real wages are all negative, and the GDP deflator and CPI inflation are positive. CPI inflation reverts to steady state within two quarters, while GDP deflator inflation persists for more than 20 quarters. The impact on output and employment reaches its peak by the 5th quarter and then reverts to steady state gradually. Real wages and consumption revert gradually before four quarters. The magnitude of the oil shock is greatest for consumption and real wages. Employment is affected to a lesser extent, while the impact on output is relatively small. The intuition from the model seems correct. If a central bank is fully credible CPI inflation will not persist as higher future inflation expectations are short-lived. Moreover, if there is relatively mild wage flexibility (i.e. $\gamma = 0.7$) then real wages only partly absorb the burden of the oil shock, which then spills over into lower employment and consumption expenditure; ultimately decreasing output. The persistence of GDP deflator inflation is important here as it exacerbates the prolonged negative effect on the real variables in the economy.

[22] Note: given output, an increase in the price of oil leads to a decrease in consumption because imported oil has an input share in production and consumption. This impact is in addition to the value added on purchased domestic output.

Figure 4: IRFs to an oil price shock: Benchmark model



Checking the robustness and compatibility of the results requires a comparison of the DSGE results with VAR-based empirical evidence (Figures 1 and 3). Although, the strong inertia of the real variables in the model is not as strongly replicated in the VAR, all the variables except employment exhibit similar directional qualities. As noted, this is significantly related to the persistence of the GDP deflator. Both real wages and consumption are the most significantly affected in each method. GDP deflator inflation is more significant compared to CPI inflation in both results.

The GDP deflator has a dual impact specified in the DSGE model. An increase in the real price of oil has a negative effect on the GDP deflator when prices of domestic output are taken as given. The VAR results possibly show this negative impact more strongly after 5 quarters. The theoretical model does not capture the delayed and slightly persistent CPI inflation shown after 6 quarters in the VAR-based results. This is due to the nature of the shock in the theoretical model (i.e. an AR(1) process), which allows the real price of oil to persist with a once-off oil shock. Conversely, the VAR-based empirical evidence cannot extrapolate any underlying theoretical motivation for this. The initial positive output response from the VAR can possibly be attributed to the increased value added from higher oil prices on domestic products purchased by households. This would be consistent with the specifications of the theoretical model (see equation (44)). In addition and already noted in section 3, the initial positive consumption response from the VAR is characterised in the literature by inflation expectation theory (e.g. Springer, 1977), which also partially explains the initial increase in aggregate demand.

Employment is best assessed by comparing the DSGE results to the post-1983 sub-sample in Figure 3. Both results show employment is the least affected real variable other than output. This is intuitively correct and consistent with labour market rigidities in South Africa (e.g. see Burger and von Fintel, 2009). Moreover, Granger-causality tests show that employment is the only variable that is not significantly predicted by any of the other variables in the VAR. Additionally, the theoretical model implies that the relationship between GDP and employment is independent of the real price of oil. Interestingly, the significant decline in wages accompanied by resilient employment in the VAR results indicates greater wage flexibility than expected. A study by Kingdon and Knight (2005) found that wage elasticity curves are no weaker than in OECD countries. This effect is captured in the sensitivity analysis of the theoretical model (section 7).

7. Sensitivity Analysis

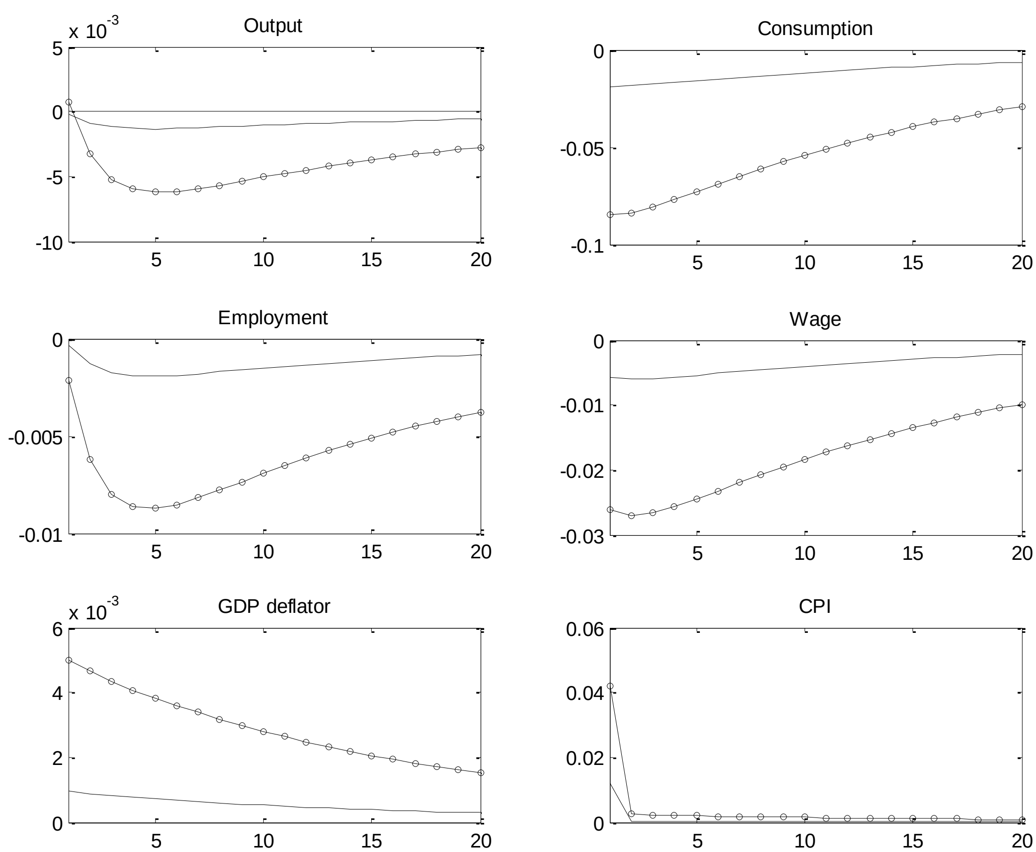
The impulse response results from the DSGE model provide a benchmark for theoretical comparability to the impulse response functions from the VAR, strengthening the argument above. That said, the model elucidates the dynamics between real wages, employment and the mark-up. Specifically, an increase in the real price of oil must be realised through at least a decline in one of these variables. Moreover, the constant mark-up specification raises some concerns for counter-cyclicality and underestimation tendencies found in the literature on business cycle behaviour of mark-ups (e.g. see Barro and Tenreyro, 2004: 3 and Fedderke et al, 2005: 7)[23]. First, we determine the sensitivity of the model with respect to oil shares in consumption and production. Gali and Blanchard (2008) emphasise declining oil shares as an important factor explaining lower output and inflation volatility observed in the "Great Moderation". Secondly, the changing macroeconomic affects under high and low wage flexibility are examined, another causal factor identified in the "Great Moderation". Lastly, an

[23] Note: the benchmark model results include variable mark-up in this updated version.

alternative result is proposed with respect to alternative literature findings indicating low wage rigidity and a higher aggregate mark-up.[24]

Figure 5 below shows how a decline in the share of oil in consumption and production closely exhibits the decline in output and inflation volatility observed throughout the "Great Moderation" era. α_m and χ are changed from 5% and 7.8% to 25% and 25%, respectively, and the circle marker line shows the alternative paths of impulse responses. The high shares are used to determine the sensitivity of the model to these parameters and to highlight the changing patterns of the variables. All the variables are affected by higher shares of oil in production and consumption. The results are consistent with other literature findings. Declining oil shares are largely attributed to technological and productivity increases, shedding light on the fact that the pass-through effects of oil price fluctuations have decreased substantially over time. (Blanchard & Gali, 2008)

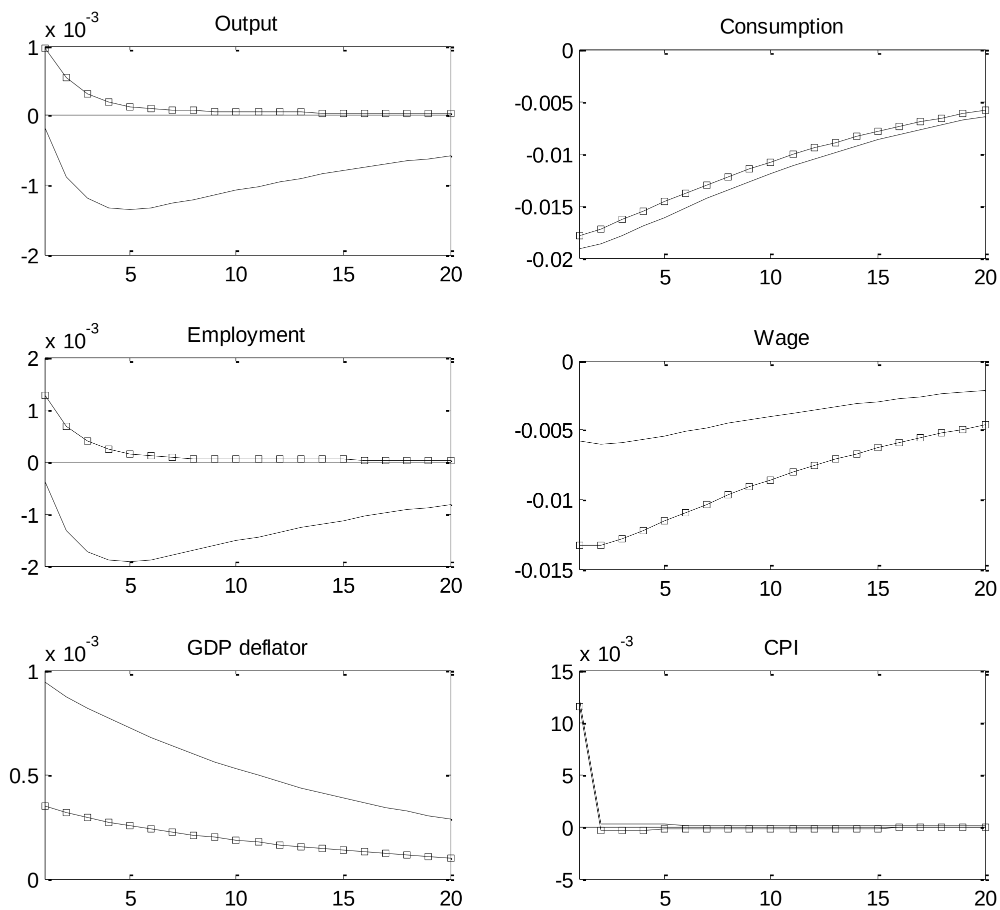
Figure 5: IRFs to an oil price shock: share of oil: small (solid) vs large (circle marker)



[24] Based on aggregate mining mark-up estimations and the aggregate mark-up for the South African economy excluding intermediate goods (both for the period 1970 – 2002).

Figure 6 below deals with the second hypothesis that low wage rigidity also dampens the effect of an oil shock in the economy. γ is changed from 0.7 to 0.2, implying low wage rigidity and is indicated by the square marker line. As a result and consistent with economic theory, real wages absorb the brunt of the oil price shock because of the direct income effect and because firms can adjust wages rapidly (with negligible costs). Interestingly, high wage flexibility actually induces a brief spike in output and a slight positive increase in employment. This perhaps sheds light on the VAR results where increases in employment and output are observed. The counterintuitive response could indicate that real wage adjustment plays a part in the resilience of output and employment to oil shocks in the South African economy. However, such a drastic reaction to an oil price shock is unlikely, although it does show that reduced real wage rigidity has a role in the observed decline in oil price pass-through effects. It is important to note that consumption expenditure does not change much and CPI inflation is not affected. This is consistent with the relatively minor differences in the two sub-sample period VAR estimates for consumption and CPI.

Figure 6: IRFs to an oil price shock: high wage rigidity (solid line) vs low wage rigidity (square marker)



A paper by Rotemberg and Woodford (1999) surveyed a branch of macroeconomic literature, highlighting the importance of mark-up ratios in business cycles. Particularly, shifting mark-up ratios, in response to changing degrees of competition, can be a significant source of aggregate business cycle fluctuations. Using the real business cycle (RBC) framework Barro and Tenreyro (2004) confirm that mark-ups tend to be more counter-cyclical in less competitive markets, implying that economic booms reduce mark-ups due to greater efficiency and competition. Moreover, estimated mark-ups have a tendency of being underestimated, implying unrealistically large elasticities of substitution between domestic goods (Basu and Fernald, 1997). Conversely, Broda and Weinstein (2005) find relatively small elasticities of substitution, implying large mark-ups.[25] That said, a paper by Fedderke et al (2005) on mark-up pricing in South African industry discover this ambiguity on mark-up behaviour over the business cycle. Their main findings suggest that the South African manufacturing sector mark-up is counter-cyclical and relatively higher than US industries, which implies high industry concentration and low competitiveness. Moreover, as long as the supply or demand of product variety is pro-cyclical, the mark-up will be counter-cyclical.

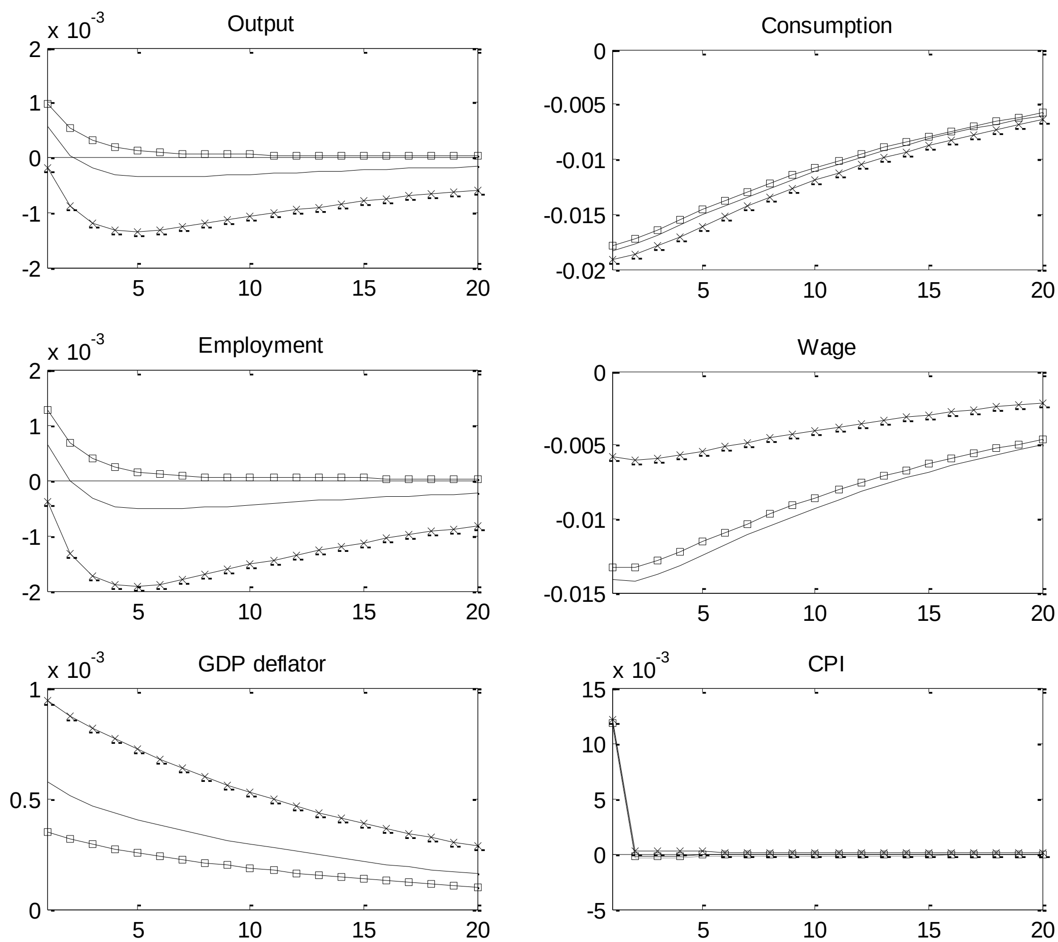
Therefore, taking cognisance of this finding with respect to aggregate mark-up behaviour, and the evidence suggested from Figure 3 and Figure 6 – including a study from Kingdon and Knight (2005) – suggest evidence of lower wage rigidity in South Africa. Moreover, Burger and von Fintel (2009: 25) find evidence of strong labour market rigidities in South Africa, while participation rates in downswings tend to go up for the black population due to a strong added worker effect. These findings reflect the results and intuition of this paper on the business cycle effects of supply side shocks. Particularly, oil price shocks have a tendency to pre-empt economic downswings (Hooker, 1996; Hamilton, 2008). In this context we examine the impulse responses of the model calibrated to a higher aggregate mark-up (consistent with lower competitiveness and declining product variety in downswings of the business cycle) and lower wage rigidity. The elasticity of substitution between domestic goods in consumption (ε) is 3.04 (down from 6.88) conforming to the aggregate mark-up in the economy excluding intermediate goods, equal to 49% (Edward and Winkel, 2003). For lower wage rigidity γ equals 0.2.

Figure 7 below gives an alternative result (solid line) to the benchmark model used (x marker line) and perhaps sheds light on the South African business cycle. The square marker line is the low wage rigidity analysis in Figure 6 and is included so that the effects of the higher mark-up can be isolated.

[25] See the equation for the gross mark-up in section 6 for the inverse relationship.

Due to existing employment rigidities evidence suggests that wage rigidities are in actual fact relatively low, implying that real wages tend to absorb the brunt of the cost-push shock, while employment is more resilient in the face of shocks to the business cycle. In addition, the lower elasticity of substitution (and the higher aggregate mark-up) will significantly affect the dynamics of real wages, employment and output. This effect was observed in the VAR-based empirical impulse responses, and more persuasively explained by the above results. Output is initially positive, showing the results of the value added effect of consumption. Importantly, the variation from the original benchmark model (x marker line) shows that consumption and CPI inflation are unaffected by the changed calibration, while employment, wages and output conform more closely to the VAR-based results and the research evidence highlighted above.

Figure 7: IRFs to an oil price shock: Alternative (solid), Original (x marker) and Lower mark-up (square marker)



8. Conclusion

Two main hypotheses postulated in the paper for sources of reduced pass-through effects of oil price shocks were modelled and examined. Specifically, reduced wage rigidities and lower shares of oil in firm production and household consumption over the “Great Moderation” period. Consequently, oil price shocks have had a considerably lesser effect on the South African business cycle over the last four decades. Moreover, real wage rigidities, oil shares in consumption and production, credible monetary policy and a benign macroeconomic environment are all important explanations for dampened pass-through effects of oil prices.

The evidence from the South African calibrated theoretical model and VAR-based results conform to the bulk of literature studies. However, some counterintuitive results were observed for employment. Particularly, evidence suggests that employment is resilient amidst oil price shocks. The theoretical model, in tandem with other research findings, purports that larger than anticipated mark-ups (implying a lower elasticity of substitution between domestic goods) and high employment rigidities (implying lower than expected wage rigidities) are possible sources of the counterintuitive findings. In addition, the initial positive output responses can possibly be attributed to this finding, jointly with the value added effect elucidated from the DSGE model.

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