

The monetary transmission mechanism in South Africa: A VECM augmented with foreign variables

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Abstract

We develop a structural cointegrated vector autoregressive (VAR) model with weakly exogenous foreign variables, suitable for a small open economy like South Africa. This type of model is known as an augmented vector error correction model (VECM), referred to by VECX*. We compile the foreign variables with trade-weighted three-year moving average data for 32 countries, to account for the significant change in trade shares over time. This model is novel in for South Africa, in two ways: it is the first VECX* developed to analyse the monetary transmission mechanism in the country and the first model that uses time-varying trade weights for the creation of the foreign series. We find three significant long-run economic relations: the augmented purchasing power parity, the uncovered interest parity and the Fisher parity. These long-run relations are imposed on the VECX* to investigate the functioning of the monetary transmission mechanism in South Africa.

JEL Classification: C50, E52

Keywords: South Africa, monetary transmission mechanism, structural cointegrated vector autoregressive model, augmented VECM, VECX*

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1. Introduction

South Africa adopted inflation targeting as its primary tool of monetary policy in 2000. To date the South African Reserve Bank (SARB) remains committed to inflation targeting to ensure long-run price stability. In a letter from Finance Minister Pravin Gordhan to SARB Governor Gill Marcus, dated 16 February 2010, Minister Gordhan states that “the Bank should continue to pursue a target of 3 to 6 per cent for headline CPI inflation” (Gordhan, 2010). He highlights the importance of maintaining low inflation – that it supports sustainable growth and employment, and that it protects the living standards of people in the country.

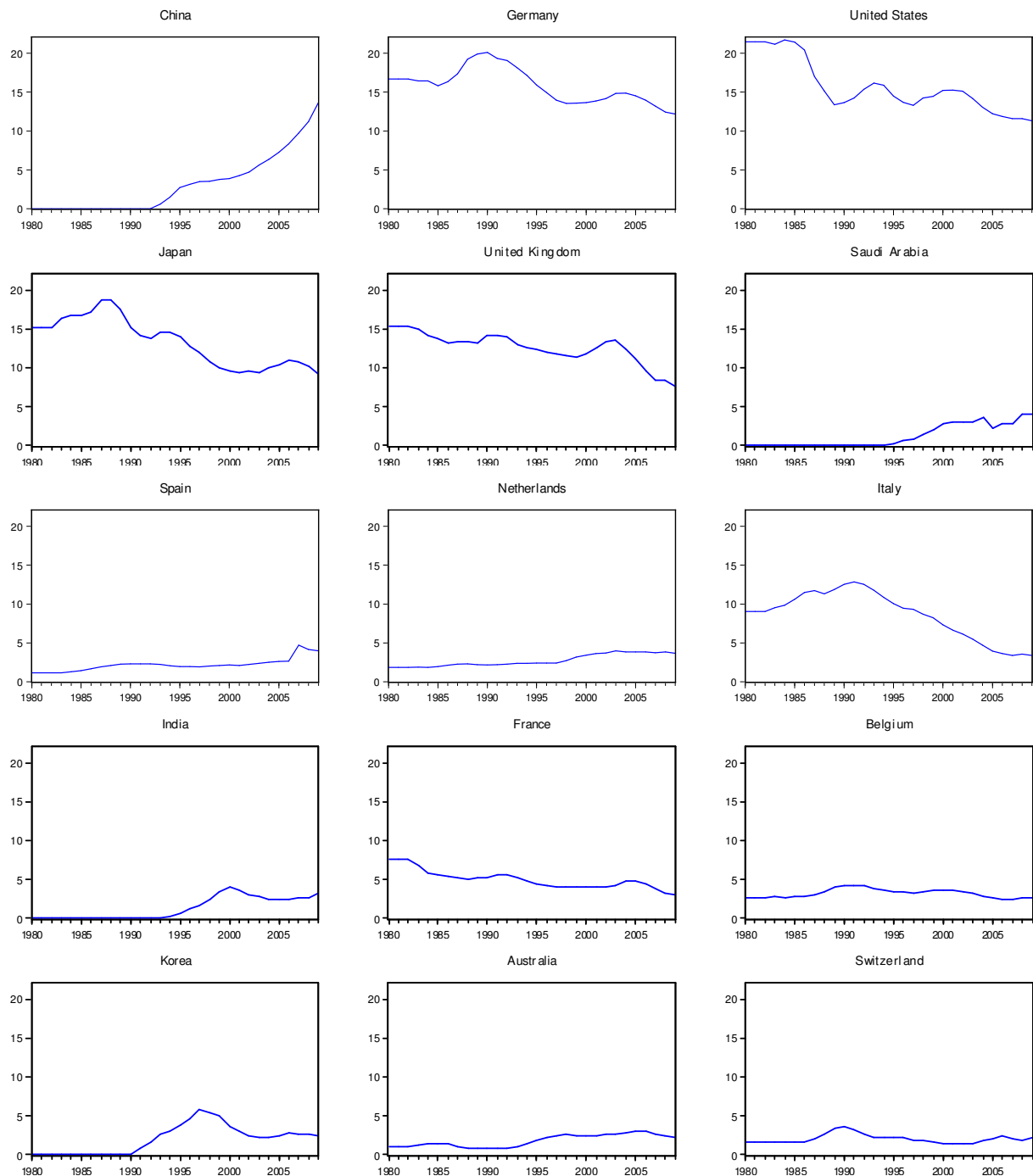
An investigation of the monetary transmission mechanism is thus still important to ensure appropriate policy actions in South Africa. It is not sufficient to know only the direction of change in variables following a change in monetary policy (Bain & Howells, 2003). It is also important that policy makers take into account the time lag between a change in the official interest rate (the repo rate) and its impact on aggregate output and inflation, as well as the magnitude of changes in output and inflation. Mishkin (1995) names these elements the “timing and effect” of monetary policies on the economy.

Time lags tend to differ from country to country due to differences in economic and financial market structures (Casteleijn, 2001). Bain and Howells (2003) note that for industrialised countries, the lag between a change in the official interest rate and its full impact on demand and production is normally about 12 months. The lag between the interest rate change and the full impact on inflation is 24 months, thus a further 12 months. Research by the SARB, performed more than a decade ago, confirmed these time lags for South Africa (Smal & De Jager, 2001). As far as we know, this is the only complete study of the transmission of monetary policy for South Africa. The authors do not provide details to replicate their small macroeconomic model.

Our objective is to develop a suitable topical model for analysing the monetary transmission mechanism in South Africa. The model must include a foreign component, since South Africa is a small open economy. Previous macroeconomic models for South African use either United States data as a proxy for the rest of the world or they use fixed trade weights to weigh data of the main trading partners. Due to substantial changes in the trade shares of South Africa’s key trading partners, we argue that the incorporation of foreign variables created using time-varying trade-weighted data is more accurate.

Figure 1 illustrates the considerable change in the trade shares of South Africa's 15 most important trading partners between 1980 and 2009¹. Trade with China increased from none before 1993 to a three-year moving average of 14 per cent in 2009. China became the largest trading partner of South Africa in 2009 (overtaking Germany's position). Trade with the UK, USA, Japan and the Euro area generally decreased in the last few decades.

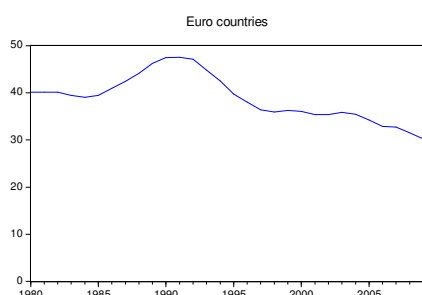
Figure 1: Three-year moving average trade weights (%) for 15 main trading partners (1980 - 2009)



¹ The data are from the Global VAR (GVAR) Toolbox 1.1 dataset (Smith & Galesi, 2011).

Figure 2 shows the combined trade share of the eight Euro countries included in the model (Austria, Belgium, Finland, France, Germany, Italy, Netherlands and Spain) with South Africa, highlighting the declining trade of with these countries.

Figure 2: Three-year moving average trade weight (%) for Euro area (1980 - 2009)



To account for the significant changes in trade shares, we use time-varying trade weights for 32 countries² to create the foreign variables in our model.

We develop a structural vector error correction model (VECM) with weakly exogenous (X) foreign (*) variables (Pesaran, Shin & Smith, 2000; Pesaran & Shin, 2002; Garratt, Lee, Pesaran & Shin, 2003; Garratt, Lee, Pesaran & Shin, 2006). This type of model, which is suitable for a small open economy such as South Africa, is referred to by VECX*. Applications of VECX* in the literature include models for the UK (Garratt *et al.*, 2003), Thailand (Akusuwan, 2005), Indonesia (Affandi, 2007) and Switzerland (Assenmacher-Wesche & Pesaran, 2008; 2009).

To our knowledge, this is the first VECX* developed to analyse the monetary transmission mechanism in the country. De Wet, Van Eyden and Gupta (2009) developed a VECM model for South Africa using part of the framework suggested in earlier Global VAR (GVAR) studies. Their model has a different purpose of investigating portfolio risk and it is not comparable to the VECX* models listed below since it did not utilise the Garratt *et al.* (2006) framework.

The next section provides more information on the literature consulted, while Section 3 briefly outlines the VECX* methodology. Sections 4, 5 and 6 respectively provide information on the data used, analysis of the data and the VECX* model results. We conclude with a summary and a discussion of further research.

² The 32 countries account for 77 per cent of South Africa's average trade between 2006 and 2010. These countries were included to align the model with the 33 countries (South Africa and 32 other countries) included in the Global VAR (GVAR) Toolbox 1.1 dataset (Smith & Galesi, 2011).

2. Literature review

VECX* models are also classified as cointegrating VARX or cointegrating VARX* models (Affandi, 2007; Garratt *et al.*, 2006). These models were introduced and further developed by Pesaran *et al.* (2000), Pesaran and Shin (2002) and Garratt *et al.* (2003), with a detailed explanation of the methodology in Garratt *et al.* (2006). Pesaran *et al.* (2000) explain that the models are particularly suitable for small open economies due to the handling of foreign variables as weakly exogenous. Pesaran and Smith (2006) further illustrate that this type of model can be derived as the solution to an open macro economy New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model, thereby underpinning the long-run relations considered in the VECX* model.

Therefore, the advantage of using a VECX* approach for South Africa is that the model accounts for both long-run theoretical relations and short-run properties, which are both important in the analysis of the monetary transmission mechanism and the impact of shocks on the system. Secondly, the inclusion of weakly exogenous foreign variables, which is relevant for a small open economy such as South Africa, is possible in a VECX* model. The inclusion of foreign variables also enables analysis of the impact of a global shock on the transmission of monetary policy in South Africa. Another advantage of developing a VECX* model for South Africa is that it can be incorporated directly into a GVAR model, where all the foreign variables are determined endogenously. Pesaran, Schuermann and Weiner (2004) first suggested the GVAR framework.

Finally, the VECX* model for South Africa and its inclusion into a GVAR model could be a useful addition to the suite of econometric models of the SARB. The models currently used by the SARB include a core model (SARB, 2007), a small-scale macroeconomic model, VAR models, VECMs, Phillips-curve models, indicator models and structural VAR models (Casteleijn, 2001). More recently, the SARB has developed quarterly projection models (QPMs) and dynamic stochastic general equilibrium (DSGE) models, including a steady state QPM for the country (De Jager, 2007), a New Keynesian DSGE model for South Africa (Steinbach, Mathuloe & Smit, 2009) and a Small Open Economy New Keynesian DSGE-VAR (SOENKDSGE-VAR) model for South Africa (Gupta & Steinbach, 2010). The SARB draws on these models for various purposes, including forecasting and simulations. None of these models includes time-varying trade-weighted foreign variables. We showed in Section 1 that the incorporation of time-varying

weights in an open economy model for South Africa (as in our VECX* model) is important due to substantial changes in the trade weights of South Africa's main trading partners over time.

The first VECX* model was developed by Garratt *et al.* (2003) for the UK economy. Further VECX* models followed for Thailand (Akusuwan, 2005), Indonesia (Affandi, 2007) and Switzerland (Assenmacher-Wesche & Pesaran, 2008; 2009). The countries considered in these papers are small open economies such as South Africa. In addition, the UK and Thailand are full-fledged inflation-targeting countries like South Africa. Indonesia is categorised as an inflation-targeting "lite" country, while Switzerland follows implicit inflation targeting. Due to the similarities, all the above studies are relevant to this VECX* model for South Africa. Since South Africa is an emerging market economy, we pay particular attention to the models developed for Thailand and Indonesia. Each of the previous VECX* studies effectively explores the monetary policy transmission process in the country considered, which is the objective of this paper. In addition, the models are successful in forecasting inflation.

Regarding our aim to investigate the monetary transmission mechanism in South Africa, to our knowledge the only complete published investigation of the transmission of monetary policy in South Africa is by Smal and De Jager (2001) from the SARB. The authors analyse the monetary transmission mechanism in South Africa with a small-scale macroeconomic model. They discuss monetary policy in the country since the 1980s, before investigating the various transmission mechanisms, or channels, through which changes in monetary policy affect the real economy and inflation in a country. The channels, as classified by Mishkin (1995), are the interest rate channel, other asset price channels (exchange rate and equity prices) and the credit channel (bank-lending channel and balance-sheet channel). Their model incorporates these channels to explore the lags involved in the transmission of monetary policy in South Africa. The authors provide no specific details of the model used, but they do clarify the two scenarios used to shock the system to determine the lags involved. These scenarios are an increase in the repo rate (providing for the real exchange rate to be affected by the interest rate differential and purchasing power parity) and a change in the repo rate with a Taylor-type monetary policy reaction function added to the model (which will further allow the repo rate to adjust to domestic output and inflation). Smal and De Jager (2001) confirm the time lag between a change in the official interest rate and the full impact on demand and production, which is real economic activity, as approximately 12 months. The authors verify the lag between a change in monetary

policy and the full impact on domestic inflation as approximately 24 months, thus a further 12 months, but they caution that the lags are dependent on the prevailing factors.

For the SARB, the core model [“a medium-sized Type II hybrid model”, (2007)], the QPM model (De Jager, 2007) and the New Keynesian DSGE model (Steinbach *et al.*, 2009) all include monetary policy transmission channels. The authors note that the models’ responses to shocks illustrate the correct functioning of the monetary transmission mechanism in South Africa, but they do not provide a clear indication of the time lags and magnitude of changes following a monetary policy shock.

This paper thus adds to the literature by developing a VECX* for South Africa that includes time-varying trade-weighted foreign variables to account for the substantial change in the trade shares of the key trading partners over time. In addition, due to the focus of the model on monetary policy, it provides a more recent view of the monetary transmission mechanism in South Africa.

3. VECX* methodology

The VECX* approach is documented in Garratt *et al.* (2006). We provide a brief summary of the methodology here.

Hendry and Richard (1983) refer to weakly exogenous explanatory variables as regressors that are uncorrelated with the stochastic error term. The definition of weakly exogenous variables in the VECX* framework is different. The sub-system VECM models (named marginal models) for the weakly exogenous foreign variables do not contain the cointegrating vectors of the overall VECX* model (Pesaran *et al.*, 2000). This assumption is necessary for modelling a small open economy, such as South Africa.

A vector of endogenous and exogenous $I(1)$ variables, \mathbf{z}_t , can be written as $\mathbf{z}_t = (\mathbf{y}'_t, \mathbf{x}'_t)$, with \mathbf{y}_t a vector of endogenous $I(1)$ variables (the domestic variables) and \mathbf{x}_t a vector of exogenous $I(1)$ variables (the foreign variables). Assume now that \mathbf{x}_t is weakly exogenous (also known as long-run forcing for \mathbf{y}_t) in the long-run multiplier matrix $\mathbf{\Pi}$ of a normal VECM. This assumption corresponds to $\mathbf{\Pi}_x = 0$, where $\mathbf{\Pi}$ is separated as $\mathbf{\Pi}' = (\mathbf{\Pi}'_x, \mathbf{\Pi}'_y)$. This means

that the domestic endogenous variables do not have an impact on the foreign exogenous variables in the long term, since the domestic economy is small and open.

The VECX* model can be represented by

$$\Delta \mathbf{y}_t = -\Pi_y \mathbf{z}_{t-1} + \Lambda \Delta \mathbf{x}_t + \sum_{i=1}^{p-1} \Psi_i \Delta \mathbf{z}_{t-i} + \mathbf{c}_0 + \mathbf{c}_1 t + \mathbf{v}_t,$$

with the marginal equations for the weakly exogenous variables identified as

$$\Delta \mathbf{x}_t = \sum_{i=1}^{p-1} \Gamma_{xi} \Delta \mathbf{z}_{t-i} + \mathbf{a}_{x0} + \mathbf{u}_{xt}.$$

4. Data

The VECX* model for South Africa incorporates quarterly domestic and time-varying trade-weighted foreign data from 1979 Q2 to 2009 Q4. Except for domestic broad money supply (M3), the data used is from the GVAR Toolbox 1.1 dataset (Smith & Galesi, 2011), which includes data for 33 countries accounting for about 90 per cent of world output. Appendix A describes the data sources and it provides information regarding the creation of the domestic and foreign variables.

5. Data analysis

In the remainder of this paper, we follow the modelling approach used by Assenmacher-Wesche and Pesaran (2009) in their development of a VECX* model for Switzerland.

The long-run economic relations that we consider for South Africa are the purchasing power parity (PPP), the uncovered interest parity that relates domestic and foreign interest rates (UIP), the Fisher parity that links the domestic interest rate to domestic inflation (LIR), a money demand relationship (MD) and a connection between domestic and foreign output (GAP). These long-run relations are included in the VECX* literature. Table 1 shows which of these five long-run relations hold in the cases of Switzerland (Assenmacher-Wesche & Pesaran, 2009), Thailand (Akusuwan, 2005) and Indonesia (Affandi, 2007), based on the autoregressive distributed lag (ARDL) or bounds testing approach to cointegration (Pesaran & Shin, 1999;

Pesaran, Shin & Smith, 2001). One of the advantages of the ARDL approach is that it is not necessary to know whether variables are $I(0)$ or $I(1)$, i.e. stationary or non-stationary.

Table 1: Long-term economic relationships in previous VECX* studies

	Switzerland	Thailand	Indonesia
PPP^a	✓	✗	✓
UIP^b	✓	✓	✓
LIR^c	✓	✓	✓
MD^d	✓	✓	✗
GAP^e	✓	✗	✗

^a PPP: Purchasing power parity ($p - p^* - e$) or PPP^A: Augmented purchasing power parity ($e - (p - p^*) - \beta_1(y - y^*)$)

^b UIP: Uncovered interest parity ($r - r^*$)

^c LIR: Fisher parity ($r - \pi$) or Modified Fisher parity ($r - \beta_2\pi$)

^d MD: Money demand relationship ($m - \beta_3y - \beta_4r$)

^e GAP: Relation between domestic output and foreign output ($y - y^*$)

The domestic variables needed to test these relationships are the nominal effective exchange rate (e), prices (p), the repo rate (r), the quarterly inflation rate (π), real M3 ($m3$) and real output (y). The foreign variables used are foreign prices (p^*), foreign real output (y^*) and the foreign short-term interest rate (r^*).

We first investigate the potential long-term relations graphically. Theoretically, the PPP suggests that domestic and foreign prices calculated in the same currency will be in equilibrium in the long term due to global trade. Due to the large correlation between the exchange rate (e) and the output gap ($y - y^*$), observed in Table 7 in Appendix A, we explore both PPP ($p - p^* - e$) and PPP^A, augmented purchasing power parity, ($e - (p - p^*) - \beta_1(y - y^*)$). Figure 3 and Figure 4 show the movement in exchange rates against the ratio of domestic and foreign prices and the ratio of domestic and foreign output respectively, both in levels and in first differences. The exchange rate and the ratio of domestic to foreign prices have the same trend in the long term, suggesting that the PPP may hold for South Africa. The negative relationship between the exchange rate and the ratio of domestic to foreign output is only evident up to 2000. It is therefore not clear whether the PPP^A will be relevant for South Africa.

Figure 3: Exchange rate and ratio of domestic to foreign prices

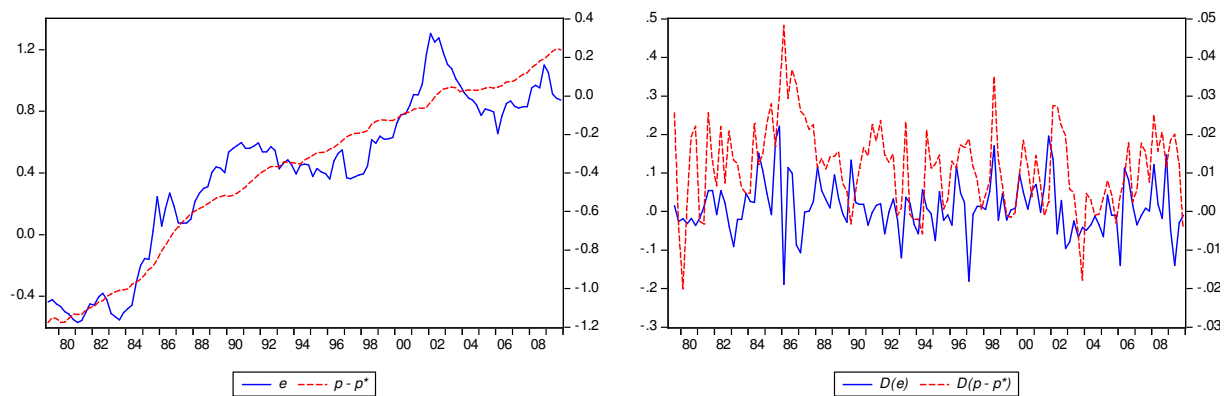
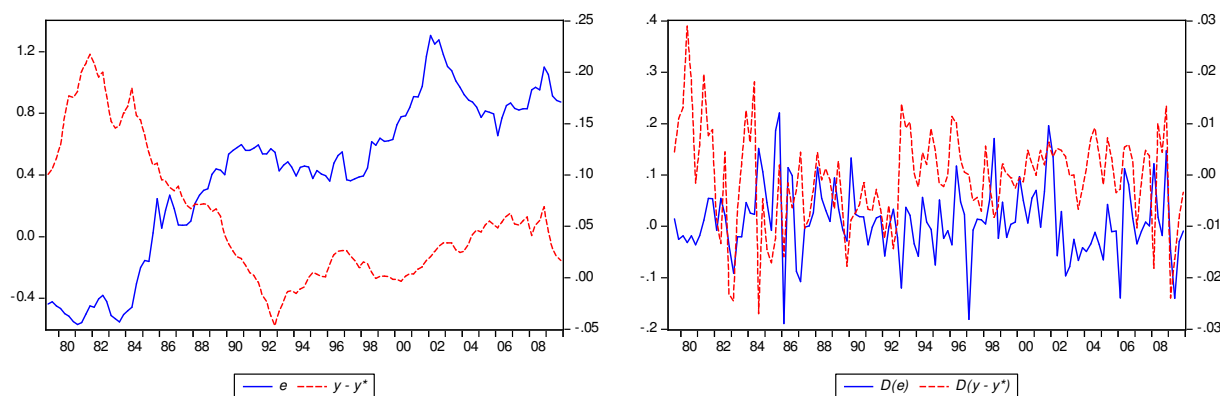
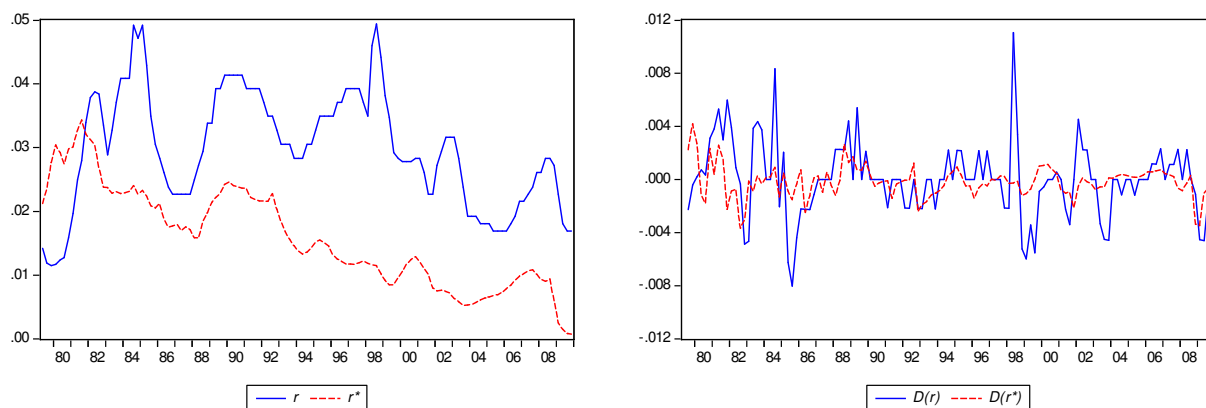


Figure 4: Exchange rate and ratio of domestic to foreign output



The UIP implies that the arbitrage process between domestic and foreign bonds will ensure that domestic and foreign interest rates will be in equilibrium in the long term. Figure 5 illustrates domestic and foreign short-term interest rates, first in levels and then in first differences.

Figure 5: Domestic and foreign short-term interest rates

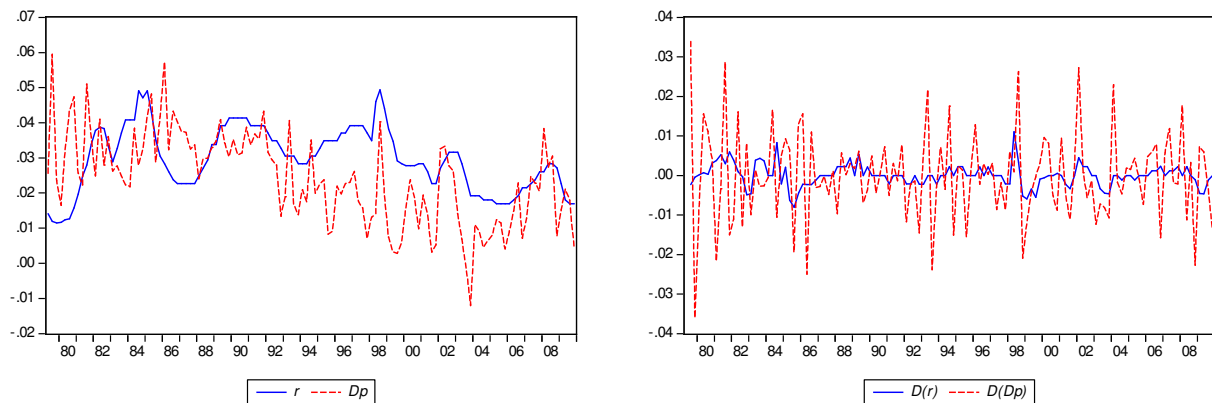


The short-term interest rates seem to have similar patterns over time, indicating that the UIP may hold for South Africa. The large gap between domestic and foreign rates is in line with

expectations, since South Africa is a developing country and the higher interest rate rewards investors for the risk faced.

For the connection between the domestic interest rate and domestic inflation (LIR), we consider the modified Fisher parity ($r - \beta_2 \pi$) in addition to the usual Fisher parity ($r - \pi$). Figure 6 shows this link, again in both levels and first differences. Interest rates and inflation seem to have the same long-term trends.

Figure 6: Short-term interest rates and inflation



For the money demand (MD) connection defined in Table 1, $m - \beta_3 y - \beta_4 r$, β_3 (the income elasticity) is expected to be positive and β_4 (the interest rate elasticity) is expected to be negative. Figure 7 and Figure 8 confirm the anticipated relationships of money with output and interest rates respectively. The negative link between money and interest rates is only valid from late 1998 onwards.

Figure 7: Broad money (M3) and output

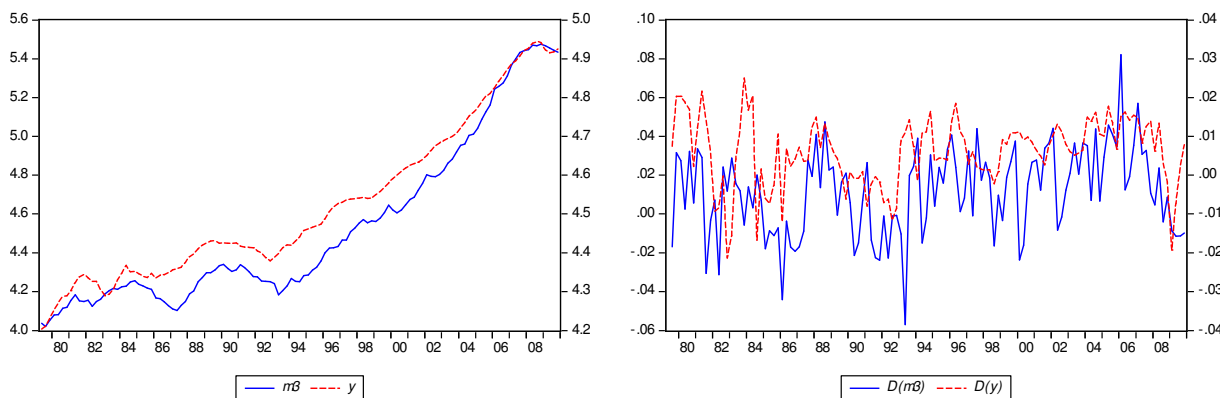
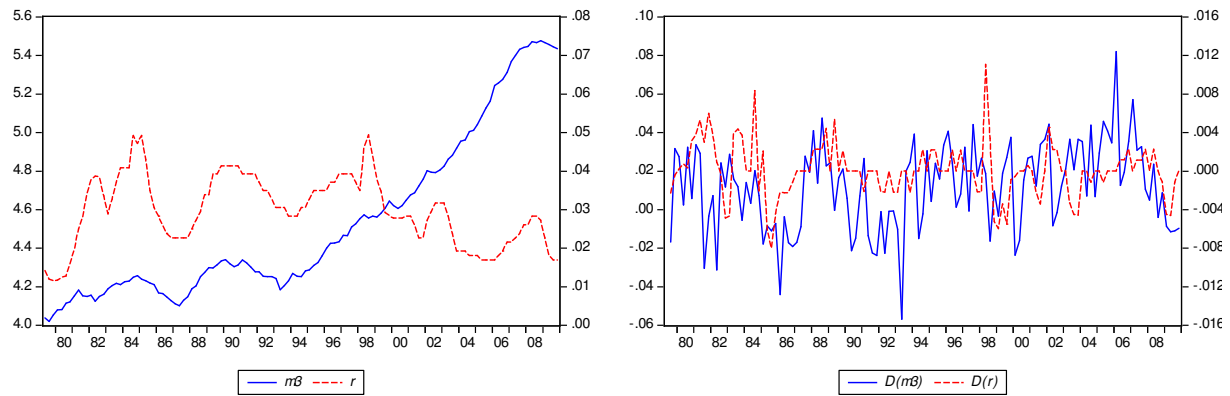
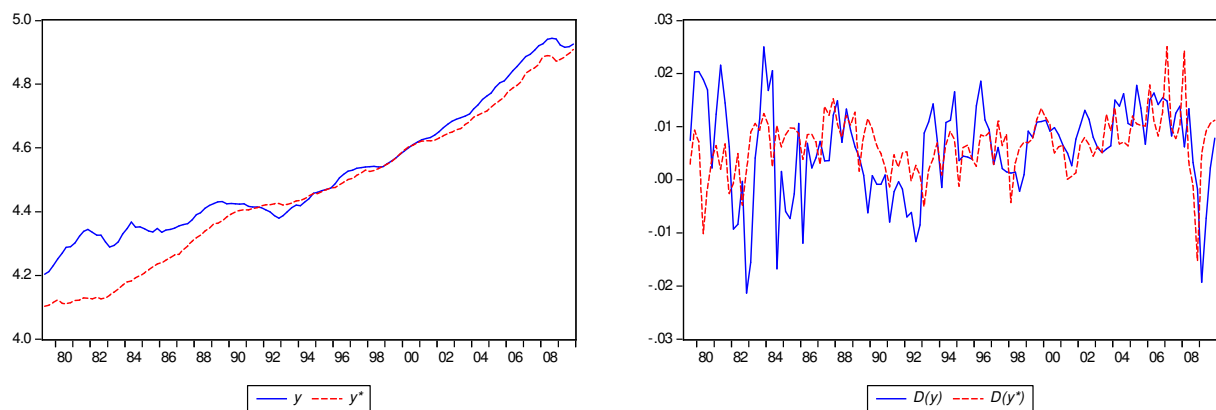


Figure 8: M3 and short-term interest rates



According to output convergence (GAP in Table 1), domestic and foreign output should converge in the long run. Figure 9, which includes the levels and first differences of domestic and foreign output, suggests that this relation may hold from 1994 onwards.

Figure 9: Domestic and foreign output



We use the ARDL cointegration approach (Pesaran & Shin, 1999; Pesaran *et al.*, 2001) to determine whether the above long-run relations are valid. Table 2 summarises the formal test results. The PPP^A, UIP and LIR long-run relations are valid for South Africa. The MD and GAP relations do not hold. Comparing South Africa's results to those from earlier VECX* studies (Table 1), the same long-run relations that hold for Indonesia are valid for South Africa.

To confirm the valid relations and to determine the causality of the relationships, we also use the cointegrated VAR approach. This confirms that the PPP^A, UIP and LIR long-run relationships are valid for South Africa. It further indicates that the direction of causality is in line with expectations, especially that domestic variables do not have an impact on foreign variables in the long term. It therefore verifies the assumption that the foreign variables are weakly exogenous.

Table 2: Long-term economic relationships: ARDL cointegration test results

	EC ^a	t-stat ^b	CV bounds ^c		F-stat ^b	CV bounds ^c		ARDL(p,q,s) ^d
PPP^A	-0.16	-3.39*	-2.57	-3.21	-3.91*	2.89 ^c	3.86 ^c	ARDL(4,0,1)
UIP	-0.12	-4.11*	-2.57	-2.91	8.01*	4.04	4.78	ARDL(2,0)
LIR	-0.10	-3.54*	-2.57	-2.91	5.42*	4.04	4.78	ARDL(2,0)
MD	-0.08	-2.94	-2.57	-3.21	3.81	3.17	4.14	ARDL(2,4,0)
GAP	-0.02	-1.19	-3.13	-3.40	2.24	5.59	6.26	ARDL(2,2)

^a Error correction term.

^b Significant t-stat or F-stat indicated by * (10% level of significance).

^c Lower and upper 90% critical value bounds (Pesaran, Shin & Smith, 2001).

^d Lag lengths selected by the Akaike information criterion (AIC), with maximum four lags. The models include an intercept, except for PPP^A that includes a dummy variable from 1992 onwards and GAP that includes an intercept and a trend.

^e Lower and upper 90% critical value bounds from Microfit 5.0 (Pesaran & Pesaran, 2009a). These critical values are simulated stochastically to be valid in the presence of the dummy variable in PPP^A.

The long-term equations from the ARDL method for the valid relations are included below, with the standard errors of the coefficients shown in brackets. The coefficients are all statistically significant. The real effective exchange rate is ep , calculated from the nominal effective exchange rate and domestic prices ($ep = e - p$). $d92$ is a dummy variable that is zero up to 1991 Q4 and one from 1992 Q1 onwards.

$$\text{PPP}^A: \quad ep_t = -0.754 p_t^* - 1.779(y_t - y_t^*) - 0.349(d92_t) + \varepsilon_t^1$$

$$(0.029) \quad (0.840) \quad (0.131)$$

$$\text{UIP:} \quad r_t = 0.018 + 0.649 r_t^* + \varepsilon_t^2$$

$$(0.004) \quad (0.219)$$

$$\text{LIR:} \quad r_t = 0.021 + 0.392 \pi_t + \varepsilon_t^3$$

$$(0.005) \quad (0.204)$$

In the UIP the coefficient of r^* is not significantly different from one, but in the LIR the coefficient of π is significantly different from one, suggesting that the modified Fisher parity may be more relevant. It should be taken into account that all the models tested are single-equation models. The VECX* will account for further interactions.

To summarise, the data results indicate three potential long-term economic relations for the country. The next section shows that the VECX* cointegration test results do suggest three cointegrating relations.

6. VECX* model results

We chose the variables to include in the VECX* model based on the results of the preliminary data analysis. The domestic endogenous variables included in the VECX* model are real output (y), the quarterly inflation rate (π), the repo rate (r), the long-term interest rate (lr) and the real effective exchange rate (calculated as $ep = e - p$, from the nominal effective exchange rate and prices). The weakly exogenous variables are foreign real output (y^*), foreign prices (p^*), the foreign short-term interest rate (r^*) and the oil price (p^{oil}). Interest rates are adjusted to be comparable with the quarterly inflation rate. All the variables are used in natural logarithmic form.

The VECX* model for South Africa was developed in Microfit 5.0 (Pesaran & Pesaran, 2009a; 2009b). The Akaike information criterion (AIC) indicates that the optimal model has two lags of the endogenous variables and one lag of the exogenous variables. Table 3 contains the cointegration test results for the model with an unrestricted intercept, a restricted trend, a restricted dummy variable ($d92$) and an unrestricted differenced dummy variable ($D(d92)$).

Table 3: Cointegration test results

Maximum Eigenvalue				
Null	Alternative	Statistic	95% critical value	90% critical value
$r = 0$	$r = 1$	65.76	52.34	49.18
$r \leq 1$	$r = 2$	58.49	45.42	41.89
$r \leq 2$	$r = 3$	36.83	37.79	34.81
$r \leq 3$	$r = 4$	19.45	30.05	27.44
$r \leq 4$	$r = 5$	17.39	21.78	19.06
Trace				
Null	Alternative	Statistic	95% critical value	90% critical value
$r = 0$	$r \geq 1$	197.92	135.94	130.02
$r \leq 1$	$r \geq 2$	132.16	100.48	95.03
$r \leq 2$	$r \geq 3$	73.67	68.97	64.71
$r \leq 3$	$r \geq 4$	36.84	43.34	40.08
$r \leq 4$	$r = 5$	17.39	21.78	19.06

The critical values (CVs) are simulated using 3000 replications. The CVs for two exogenous variables are considered, since there are two cointegrating relationships between the four exogenous variables.

The marginal models for the weakly exogenous foreign variables each include one lag for the differenced endogenous variables, one lag for the differenced exogenous variables and an intercept. In Table 3, the maximum eigenvalue statistic suggests a rank of three at a 10 per cent level of significance, while the trace statistic indicates a rank of three at a 5 per cent level of significance. Thus, there are three cointegrating relationships in the model, which is in line with the three significant long-run economic relations identified in Section 5.

These relations are the augmented purchasing power parity (PPP^A), the uncovered interest parity (UIP) and the modified Fisher parity (LIR). The restrictions of these relations are imposed on the VECX* to identify the model. The first cointegrating vector relates to PPP^A, which can be written as $ep + p^* - \beta_1(y - y^*)$. The restrictions are: $\pi = 0$, $r = 0$, $lr = 0$, $ep = 1$, $p^* = 1$, $r^* = 0$, $p^{oil} = 0$, $trend = 0$ and $d92 = 0$. In the second cointegrating vector, relating to UIP or $r - r^*$, the following variables are restricted: $y = 0$, $\pi = 0$, $r = 1$, $lr = 0$, $ep = 0$, $y^* = 0$, $p^* = 0$, $r^* = -1$, $p^{oil} = 0$, $trend = 0$ and $d92 = 0$. The third cointegrating vector, relating to LIR or $r - \beta_2\pi$, makes the following restrictions: $y = 0$, $r = -1$, $lr = 0$, $ep = 0$, $y^* = 0$, $p^* = 0$, $r^* = 0$, $p^{oil} = 0$, $trend = 0$ and $d92 = 0$.

The estimates³ of the overidentified cointegrating vectors are shown below, with the standard errors of the estimated coefficients shown in brackets. The intercepts of the three equations are b_{10} , b_{20} and b_{30} respectively, while the error correction terms are ξ_{1t} , ξ_{2t} and ξ_{3t} .

$$\text{PPP}^A: \quad ep_t = -p_t^* - 2.534(y_t - y_t^*) + b_{10} + \xi_{1t}$$

(0.827)

$$\text{UIP:} \quad r_t = r_t^* + b_{20} + \xi_{2t}$$

$$\text{LIR:} \quad r_t = 0.781\pi_t + b_{30} + \xi_{3t}$$

(0.204)

³ These estimates are in line with those of the Indonesian model (Affandi, 2007), where the same restrictions were imposed.

The log-likelihood ratio (LR) test, which has a $\chi^2(22)$ distribution, marginally rejects the 22 overidentifying restrictions. The LR test statistic of 85.53 is above the 99 per cent bootstrapped critical value of 80.83 (based on 3000 simulations). Since the LR test often over-rejects the null hypothesis that the restrictions are valid (Pesaran & Pesaran, 2009b), we decide to use the model with the overidentifying restrictions given the strong theoretical foundations of the three long-run relations. Overall the VECX* performs well according to the reduced-form error correction equations, the diagnostics statistics, the persistence profiles and the generalised impulse response functions. This would not have been the case if the long-run cointegrating restrictions were invalid.

Table 4 shows the reduced-form error correction equations and the diagnostics statistics of the VECX*. The lagged error corrections terms from the long-run relations, also known as deviations, are significant in several equations. Deviations from the PPP^A explain inflation and the real effective exchange rates. The deviation of the domestic repo rate from the foreign short-run interest rate is significant in the output, inflation, repo rate and long-run interest rate differential equations. A deviation from LIR explains changes in inflation.

Table 4: Reduced-form error correction equations

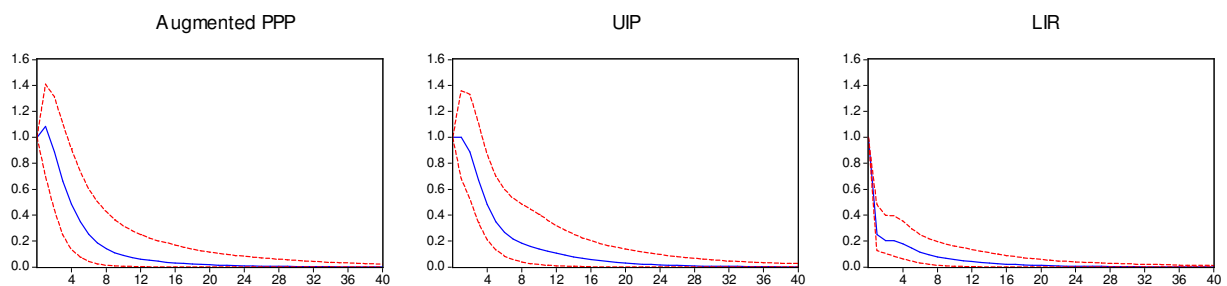
Equation	Δy_t	$\Delta \pi_t$	Δr_t	Δep_t	Δlr_t
$\xi_{1,t-1}$	-0.011	0.016*	-0.002	-0.077*	-0.001
$\xi_{2,t-1}$	-0.274*	-1.060*	-0.124*	0.360	-0.073*
$\xi_{3,t-1}$	0.002	0.959*	-0.035	-0.205	-0.028
Δy_{t-1}	0.468*	0.063	0.066*	0.141	-0.009
$\Delta \pi_{t-1}$	0.019	0.031	0.044*	0.128	0.037*
Δr_{t-1}	0.102	0.402	0.036*	2.217	0.092
Δep_{t-1}	-0.010	0.016	0.000	0.124	0.002
Δlr_{t-1}	0.441	0.645	0.001	-4.594	0.095
Δy_t^*	0.180	0.112	-0.013	1.445	0.034
Δp_t^*	-0.209	-0.575*	-0.031	0.559	-0.009
Δr_t^*	-0.004	0.624*	0.148	-0.825	-0.102
Δp_t^{oil}	0.010*	0.011*	0.001	-0.059	0.002*
<i>Intercept</i>	0.018*	-0.008	0.002	0.038	0.002
$\Delta d92$	-0.008	-0.004	-0.002	-0.077	-0.001
<i>Adjusted R²</i>	0.420	0.404	0.300	0.096	0.118
<i>Serial correlation:</i>	4.696	8.761*	1.361	8.523*	3.053
<i>Functional form:</i>	0.357	0.296	3.287*	0.220	0.959
<i>Normality: $\chi^2(2)$</i>	62.699*	1.137	237.57*	18.771*	35.252*
<i>Heteroscedasticity:</i>	0.006	0.010	0.006	0.300	0.034

An asterisk denotes significance at the 10% level.

At a 5 per cent level of significance, the diagnostic test results indicate that the residuals do not have normal distributions in most of the equations. At a 10 per cent level of significance, there is also some serial correlation in the equations for inflation and the real effective exchange rate, while there is misspecification in the interest rate equation.

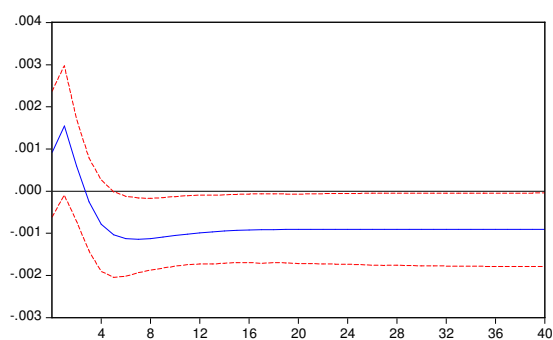
The persistence profiles (PPs) of the three cointegrating vectors (Figure 10) converge to zero, indicating that the model will return to its long-run equilibrium after shocks to the system⁴.

Figure 10: Persistence profiles of the effect of a system-wide shock to the cointegrating vectors with 95% bootstrapped confidence intervals



The generalised impulse response functions (GIRFs) are generally in line with expectations. Appendix B contains all the GIRFs for the VECX*.

Figure 11: Generalised impulse response for inflation to a one standard error shock to the repo rate with 95% bootstrapped confidence intervals



⁴ We compared the PPs of this model with those of the Indonesian model (Affandi, 2007). The PP of PPP^A for South Africa is more stable with smaller confidence intervals than the one for Indonesia. The PPs of UIP and LIR for Indonesia return to their long-run equilibrium at a faster pace than the PPs for South Africa, but the PP of UIP for Indonesia shows an impact on the cointegrating vector after a system-wide shock that is twice the size of that for the PP of UIP for South Africa.

The effect of a shock to the monetary policy interest rate (repo rate) on the inflation rate, as illustrated in Figure 11, suggests a monetary policy lag of around 24 months (8 quarters). A “prize puzzle” is only observed in the first quarter following the monetary policy shock. Thereafter, the inflation rate declines as expected in response to the interest rate increase. The same movements with monetary policy lags of about eight quarters are evident in the relevant impulse response functions of the models for Switzerland (Assenmacher-Wesche & Pesaran, 2009), Thailand (Akusuwan, 2005) and Indonesia (Affandi, 2007).

The VECX* model therefore shows the expected transmission of monetary policy in South Africa between 1979 and 2009, with results in line with those of VECX* models for other countries.

7. Conclusion and future research

We develop a new type of model for South Africa to investigate the “timing and effect” (Mishkin, 1995) of the monetary transmission mechanism. The model includes foreign variables calculated from time-varying trade-weighted data for 32 countries, due to substantial changes in South Africa’s main trading partners. This is also a first for South Africa, since previous models use the US as a proxy for the rest of the world or they use trade-weighted data for a fixed period to represent the rest of the world. Three statistically significant long-run economic relations identify the model. These are the purchasing power parity (PPP), the uncovered interest parity (UIP) and the Fisher parity (LIR). The lag between a change in the repo rate and the full impact on inflation is around 24 months. The VECX* model thus shows the effective transmission of monetary policy in South Africa between 1979 and 2009.

For future research, we want to determine whether and how global economic shocks affect the transmission of monetary policy in South Africa. Bain and Howells (2003) mention that many factors influence the time lags involved in the monetary transmission mechanism, including “the state of business and consumer confidence, how this confidence is influenced by monetary policy changes, events in the world economy and expectations about future inflation”. If global economic shocks do have an effect on the domestic monetary transmission mechanism, then policy makers would need to consider this in the aftermath of international crises.

To study this, we will incorporate the South African VECX* model in a customised GVAR model for South Africa, where all the foreign variables are endogenously determined from individual VECX* models for the main trading partners. We will utilise the theoretical framework introduced and expanded by Pesaran *et al.* (2004), Garratt *et al.* (2006), Dees, Di Mauro, Pesaran and Smith (2007), Pesaran, Schuermann and Smith (2009a) and Pesaran, Schuermann and Smith (2009b). The aim is to determine the impact of economic shocks in the rest of the world on the South African economy.

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Appendix A: Data

Except for broad money supply (M3) for South Africa, the data are from the GVAR Toolbox 1.1 dataset (Smith & Galesi, 2011), which includes data for 33 countries accounting for around 90 per cent of world output. Comprehensive information about the data sources and the methods of calculation for the GVAR Toolbox 1.1 database is included in Technical Appendix B of the User Guide compiled by Smith and Galesi (2011). M3 for South Africa is from the International Financial Statistics (IFS) of the International Monetary Fund (IMF).

For the creation of the foreign variables, the three-year moving average trade weights of South Africa with each of the other 32 countries in the GVAR dataset were calculated from the annual trade data (average of exports and imports, c.i.f.⁵) between 1980 and 2009. We used the time-varying trade shares to weigh each variable for all the countries. The summation of the weighted country data provided the specific foreign variable.

The 32 countries in the GVAR are responsible for 77 per cent of South Africa's average trade from 2006 to 2010 with the rest of the world, according to more recent data from the Direction of Trade Statistics (DOTS) of the IMF (2011). Table 5 shows the individual and total trade shares based on this data.

Table 5: Average trade shares of countries included in the model (2006 - 2010)

Country	Average trade share
China	10.58%
Germany	9.78%
USA	8.82%
Japan	7.45%
UK	5.52%
Saudi Arabia	3.20%
Netherlands	2.90%
India	2.74%
Spain	2.55%
Italy	2.50%
France	2.48%
Belgium	1.91%
Korea	1.89%
Australia	1.82%
Switzerland	1.64%
Brazil	1.43%
Thailand	1.39%

⁵ Cost, insurance and freight.

Country	Average trade share
Malaysia	1.09%
Sweden	1.08%
Singapore	0.97%
Argentina	0.91%
Canada	0.81%
Turkey	0.68%
Indonesia	0.67%
Austria	0.57%
Finland	0.50%
Mexico	0.36%
Norway	0.24%
New Zealand	0.17%
Philippines	0.13%
Chile	0.12%
Peru	0.05%
Total	76.95%
Euro countries	23.20%

Source: Calculated from DOTS of the IMF (Direction of Trade Statistics, 2011).

Table 6 lists the variables. Variables without an assigned type are not in the final VECX* model, but they are used for calculations and for analysis. Interest rates are adjusted to be comparable with the quarterly inflation rate. All the variables are used in natural logarithmic form. The foreign variables are calculated using the three-year moving average trade shares of the 32 trading partners to weigh the relevant foreign data. Unit root tests indicate that the variables in the model are $I(1)$.

Table 6: Variables

Variable	Name	Description	Type
y	Y	\ln real GDP	Endogenous $I(1)$
π	DP	Quarterly inflation rate: first difference of \ln CPI	Endogenous $I(1)$
r	R	$0.25 * \ln(1 + \text{repo rate}/100)$	Endogenous $I(1)$
e	E	\ln nominal effective exchange rate	
p	P	\ln CPI	
ep	EP	\ln real effective exchange rate = $e - p$	Endogenous $I(1)$
lr	LR	$0.25 * \ln(1 + \text{long-term interest rate}/100)$	Endogenous $I(1)$
$m3$	M3	\ln real M3	
y^*	YS	\ln foreign real GDP	Exogenous $I(1)$
p^*	PS	\ln foreign CPI	Exogenous $I(1)$
r^*	RS	$0.25 * \ln(1 + \text{foreign short-term interest rate}/100)$	Exogenous $I(1)$
p^{oil}	POIL	\ln oil price	Exogenous $I(1)$
$y - y^*$	Y_YS	Ratio of \ln real GDP to \ln foreign real GDP	
$p - p^*$	P_PS	Ratio of \ln CPI to \ln foreign CPI	
$d92$	D92	Dummy variable: 1 from 1992 Q1 onwards	Deterministic

Figure 12 presents graphs of all the variables, while Table 7 contains the simple correlation coefficients between the variables.

Figure 12: Graphs of variables

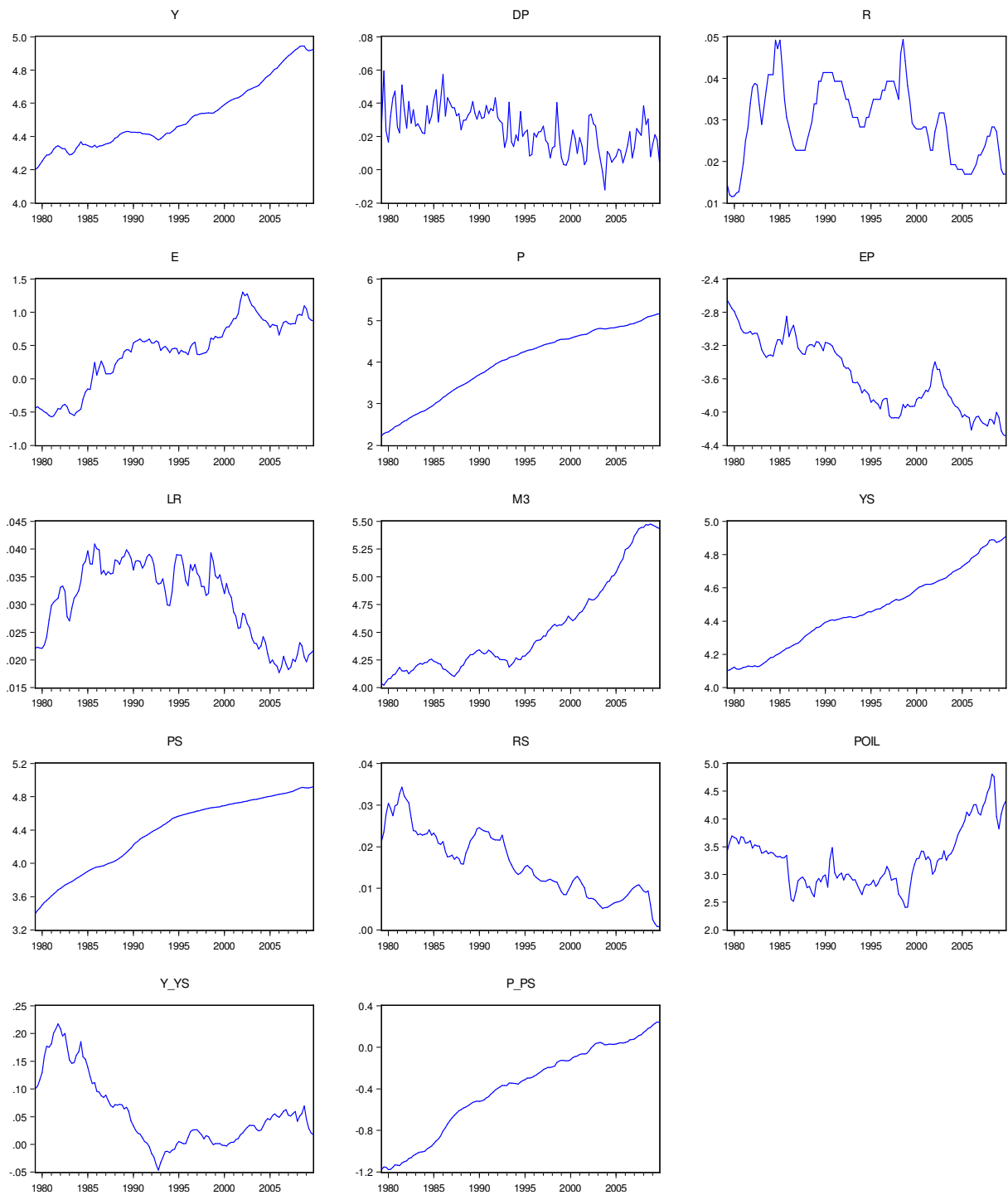


Table 7: Simple correlation coefficients

	y	π	r	e	p	ep	lr	$m3$	y^*	p^*	r^*	p^{oil}	$y-y^*$	$p-p^*$
y	1													
π	-0.54*	1												
r	-0.32*	0.24*	1											
e	0.80*	-0.48*	-0.12	1										
p	0.89*	-0.61*	-0.12	0.94*	1									
ep	-0.84*	0.66*	0.10	-0.70*	-0.91*	1								
lr	-0.65*	0.44*	0.72*	-0.29*	-0.37*	0.40*	1							
$m3$	0.99*	-0.51*	-0.35*	0.73*	0.82*	-0.79*	-0.72*	1						
y^*	0.97*	-0.58*	-0.26*	0.90*	0.97*	-0.88*	-0.54*	0.93*	1					
p^*	0.87*	-0.62*	-0.08	0.92*	0.99*	-0.92*	-0.34*	0.80*	0.95*	1				
r^*	-0.84*	0.64*	0.28*	-0.84*	-0.91*	0.84*	0.45*	-0.79*	-0.89*	-0.90*	1			
p^{oil}	0.61*	-0.15	-0.49*	0.14	0.23*	-0.29*	-0.79*	0.69*	0.44*	0.21*	-0.21*	1		
$y-y^*$	-0.40*	0.41*	-0.06	-0.77*	-0.75*	0.60*	-0.08	-0.31*	-0.62*	-0.76*	0.63*	0.28*	1	
$p-p^*$	0.90*	-0.60*	-0.16*	0.95*	0.99*	-0.89*	-0.40*	0.83*	0.97*	0.99*	-0.92*	0.25*	-0.75*	1

An asterisk denotes significance at the 10% level.

Appendix B: GIRFs

Figure 13: Generalised impulse responses for output with 95% bootstrapped confidence intervals

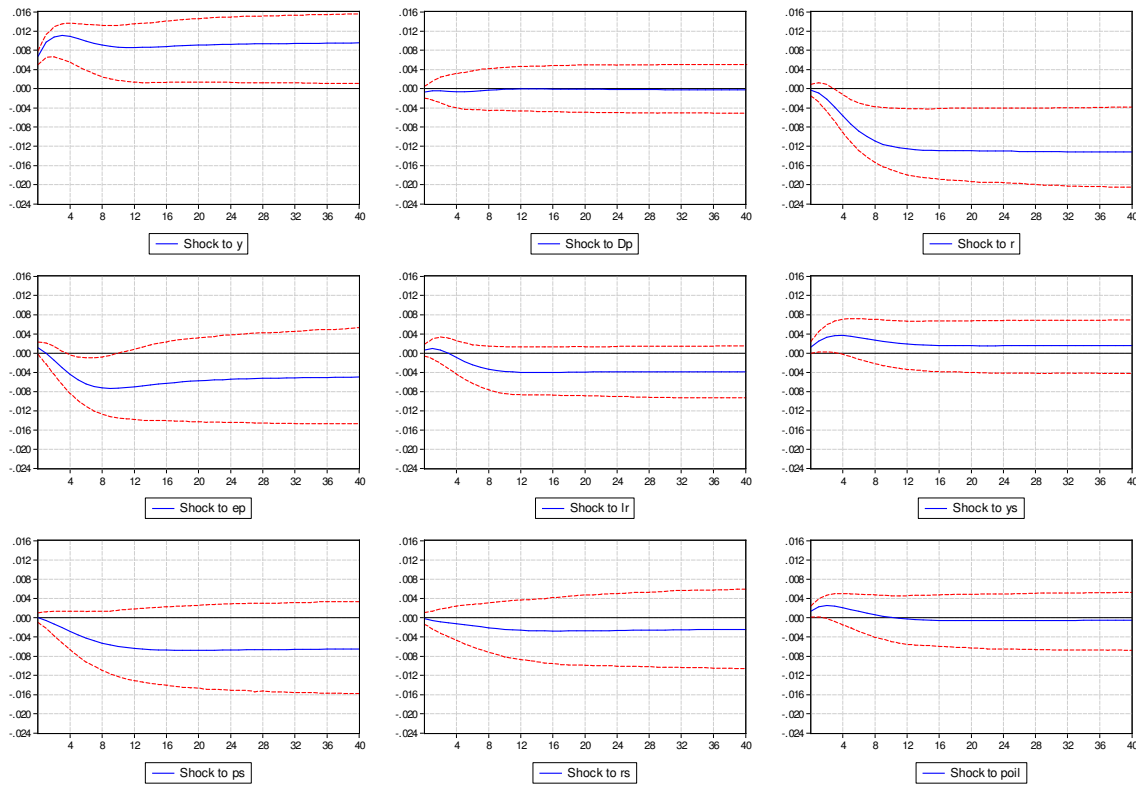


Figure 14: Generalised impulse responses for inflation with 95% bootstrapped confidence intervals

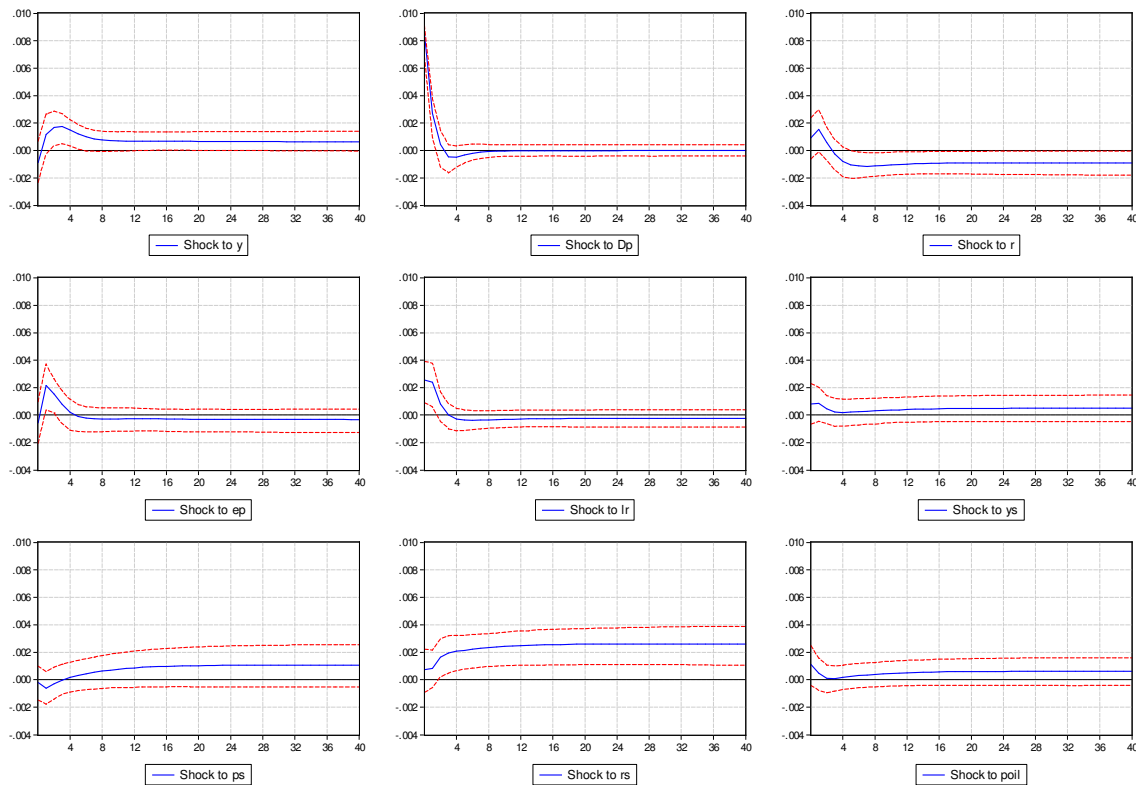


Figure 15: Generalised impulse responses for repo rate with 95% bootstrapped confidence intervals

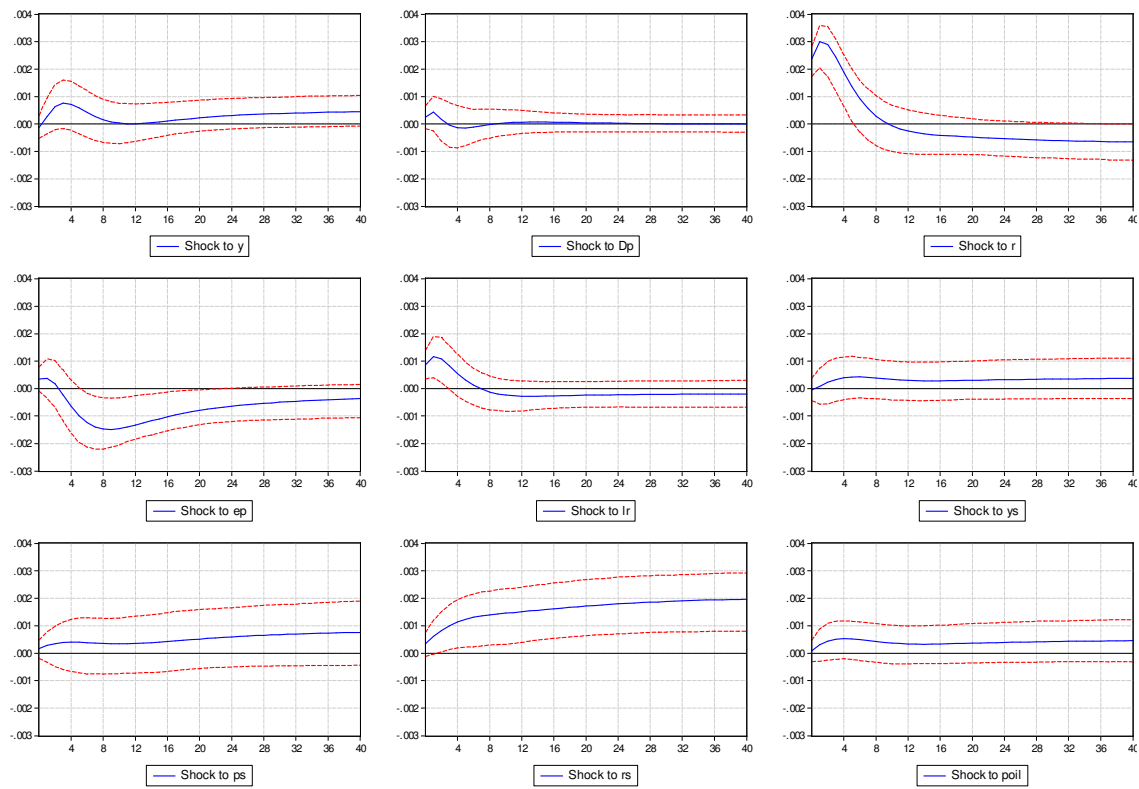


Figure 16: Generalised impulse responses for real effective exchange rate with 95% bootstrapped confidence intervals

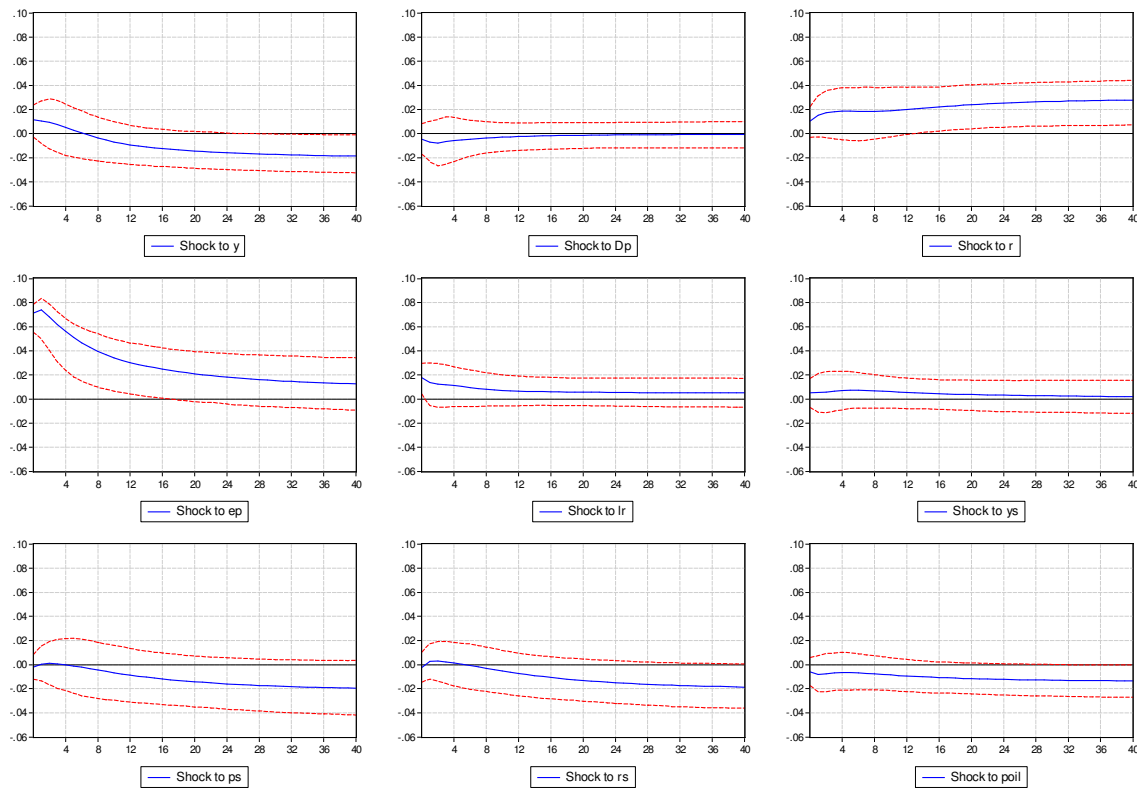


Figure 17: Generalised impulse responses for long-run interest rate with 95% bootstrapped confidence intervals

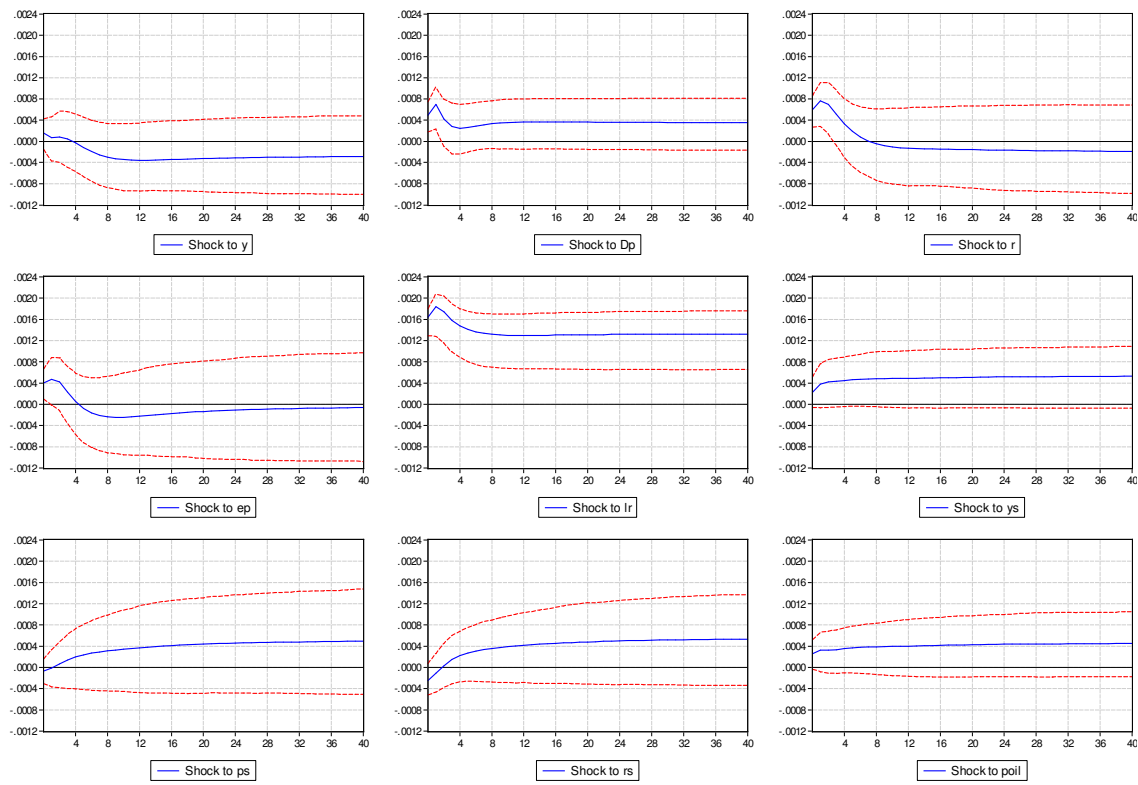


Figure 18: Generalised impulse responses for foreign output with 95% bootstrapped confidence intervals

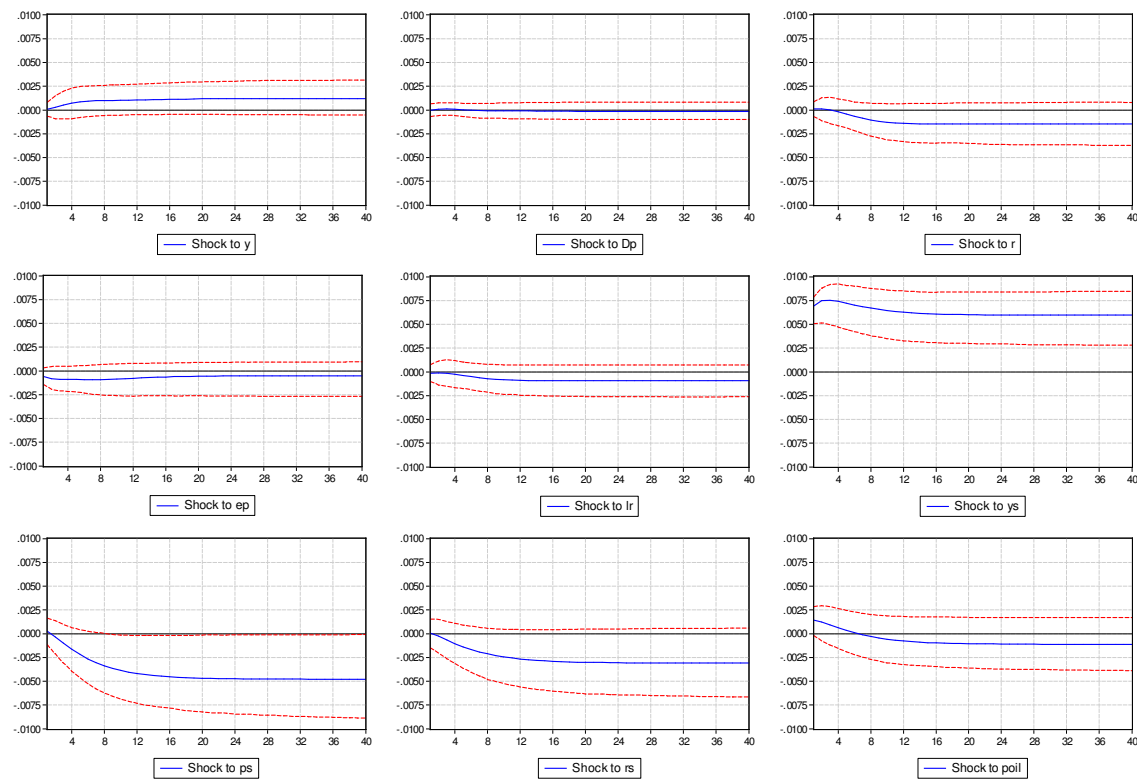


Figure 19: Generalised impulse responses for foreign prices with 95% bootstrapped confidence intervals

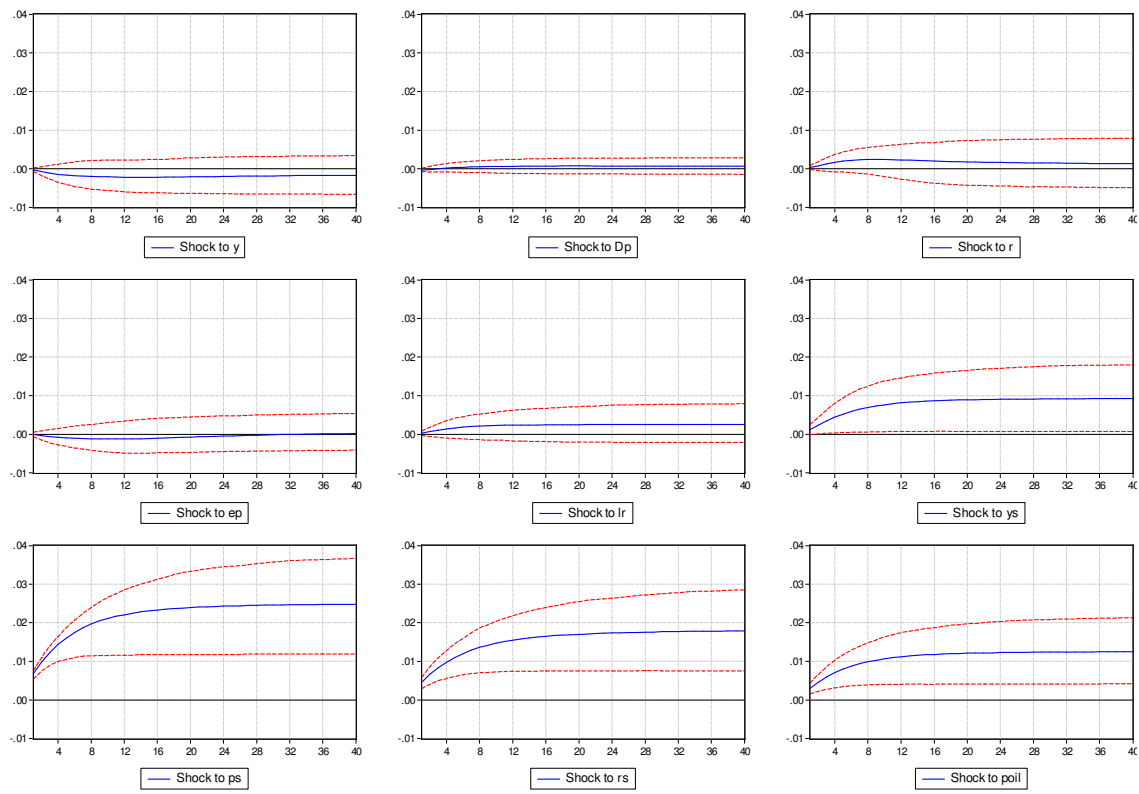


Figure 20: Generalised impulse responses for foreign short-term interest rates with 95% bootstrapped confidence intervals

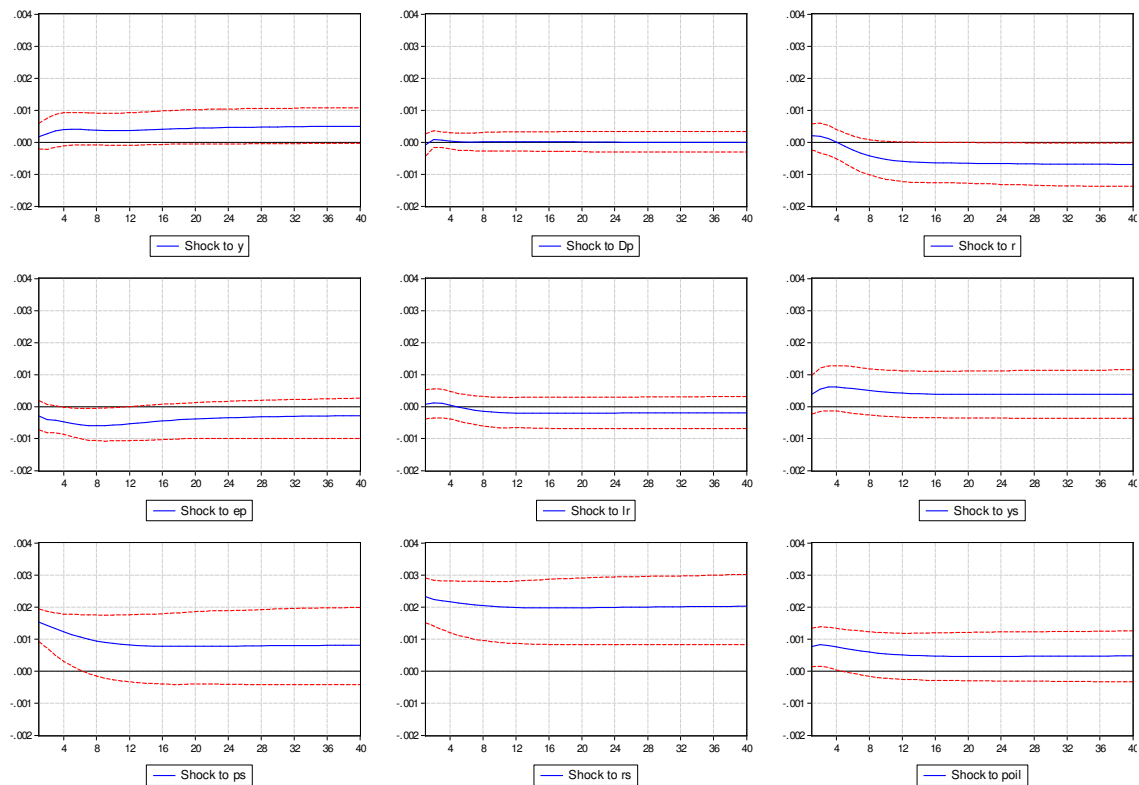


Figure 21: Generalised impulse responses for oil price with 95% bootstrapped confidence intervals

