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Evidence from a Global VAR**

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The impact of economic shocks in the rest of the world on South Africa: Evidence from a global VAR

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Abstract

The significant change in South Africa's trade patterns over the past two decades should affect the impact of shocks in the rest of the world on the country, since South Africa is a small open economy. We investigate the effect with the use of a global vector autoregression (GVAR) model from 1979Q2 to 2009Q4. To account for changes in international trade linkages, we assemble the country-specific foreign variables with time-varying trade-weighted data. We show that the long-term impact of a shock to Chinese GDP on South African GDP is 330% stronger in 2009 than in 1995, due to the substantial increase in South Africa's trade with China since the mid-1990s. By 2005, a United States (US) GDP shock only has a quarter of the long-term impact on South African GDP compared to 1995, as trade with the US declined noticeably. By 2009, the impact of a US GDP shock on South African GDP is insignificant. The results indicate why the recent global crisis did not affect South Africa as much as it affected developed economies. It also stresses the increased risk, to the South African economy and economies in the rest of the world, should China experience slower GDP growth.

JEL Classification: C32, E32, F43, O55

Keywords: South Africa, developing economies, trade linkages, global macroeconomic modelling, global vector autoregression (GVAR)

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1. Introduction

South Africa is a small open economy. We therefore expect that the major movements observed in the trade shares of the country's trading partners, mainly since the mid-1990s, together with changes in global trade linkages, would affect the interactions of the South African economy with the economies of its trading partners. Our study confirms this expectation, since it shows that the impact of economic shocks in the rest of the world on South Africa has changed considerably with the change in trade patterns. The increased trade with China makes South Africa much more vulnerable to GDP shocks to the Chinese economy and less vulnerable to GDP shocks to the United States (US) economy. It is important for policy makers to consider this during scenario analysis and forecasting.

In this paper we use the global vector autoregression (GVAR) methodology as introduced, explained and expanded by Pesaran, Schuermann and Weiner (2004), Garratt, Lee, Pesaran and Shin (2006) and Déés, di Mauro, Pesaran and Smith (2007a). The GVAR approach incorporates global trade linkages, which enables analysis of the interactions between economies and the transmission of shocks to individual countries and/or specific regions (Di Mauro & Pesaran, 2013). This type of analysis is not possible using a factor-augmented vector autoregression (FAVAR) or a standalone dynamic stochastic general equilibrium (DSGE) model. We model a GVAR with data for 33 countries from 1979Q2 to 2009Q4. Due to the significant change in global trade linkages, we create the country-specific foreign variables in the GVAR with three-year moving average trade weights. We follow the model specification of Cesa-Bianchi, Pesaran, Rebucci and Xu (2012), who investigate the impact of China's growth on business cycles in Latin America.

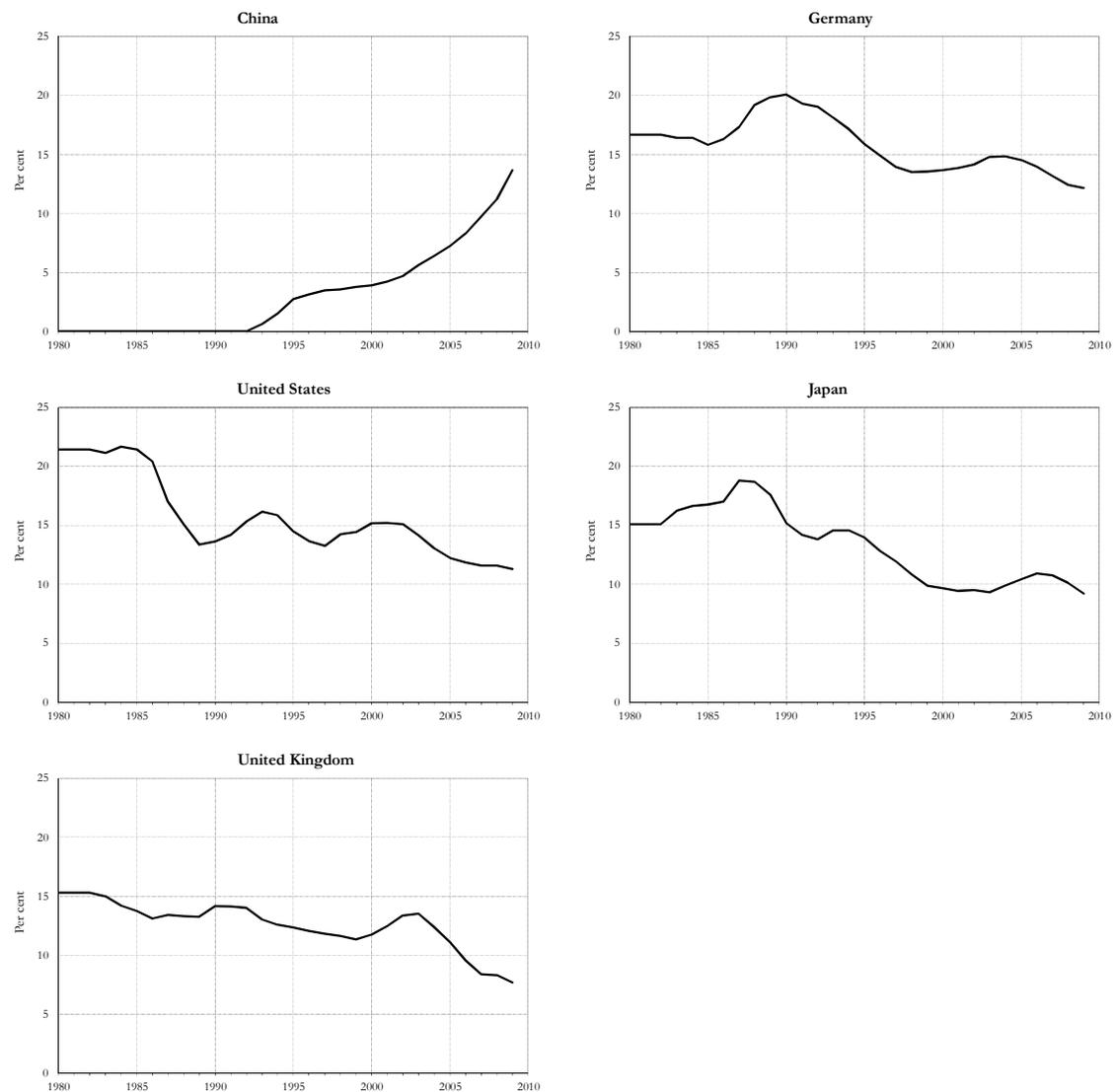
Along the lines of Cesa-Bianchi *et al.* (2012), we solve the GVAR a number of times – each time with a different configuration of cross-country interdependencies. This allows us to determine the change over time in the effect of GDP shocks in China and the US on South Africa. All the country-specific model estimations utilise time-varying foreign variables, but the solutions of the GVAR use fixed trade weights in four specific years (1995, 2000, 2005 and 2009).

To our knowledge, this is the first study for South Africa that investigates the impact of changes in international trade linkages on the transmission of international shocks to the South African economy, with the use of time-varying trade-weighted foreign data. The one South African application of the GVAR (Çakır & Kabundi, 2013) focuses on the transfer of trade shocks

between the BRIC (Brazil, Russia, India and China) countries and South Africa. The foreign variables for the individual country models are constructed with fixed trade weights, which do not take into account the substantial change in South Africa's trade linkages.

The five largest trading partners of South Africa currently are (in order of importance) China, Germany, the US, Japan and the United Kingdom (UK). The movements in the trade shares of these countries from 1980 to 2009 are illustrated in Figure 1¹.

Figure 1: Three-year moving average trade weights of the five main trading partners (1980 - 2009)



¹ The trade weights are from the '2009 Vintage' GVAR dataset of the GVAR Toolbox 1.1 (Smith & Galesi, 2011).

South Africa did not trade with China before 1993, but due to significant growth in trade, China overtook Germany in 2009 as the main trading partner of South Africa. Trade with the other main trading partners declined noticeably over the same period.

Di Mauro and Pesaran (2013) highlight several additional advantages of the GVAR, which further motivates the use of the GVAR framework for this study. It is a compact model that provides a solution to the ‘curse of dimensionality’, which is typically associated with high-dimensional models, through the estimation of vector error-correction models (VECMs), conditional on weakly exogenous foreign variables, for each country in the model. The GVAR allows for both long-run and short-run economic relations. It further accounts for various international transmission channels: common observed global factors (e.g. an oil price shock), unobserved global factors (e.g. pervasive technological progress), specific national factors, and residual interdependencies resulting from policy or trade spillovers. The framework is very suitable for macroeconomic policy analysis as it accounts for global interdependencies.

In the next section, we review the relevant literature. Section 3 explains the GVAR methodology, while section 4 shows the specification and estimation of the GVAR. Section 5 contains the results of shocks to the GVAR, which illustrates the change in the effect of economic shocks on South Africa over time, and Section 6 concludes.

2. Literature review

Pesaran *et al.* (2004) introduced the GVAR framework to model regional interdependencies. Déés *et al.* (2007a) and Déés, Holly, Pesaran and Smith (2007b) respectively extended the GVAR framework to investigate global linkages of the Euro area and to test long-run macroeconomic relationships.

The GVAR literature has grown rapidly over the last few years. Early applications of the GVAR approach include modelling credit risk in a globalised economy (Pesaran, Schuermann & Treutler, 2007a), determining the impact if the UK and Sweden had entered the Euro in 1999 (Pesaran, Smith & Smith, 2007b) and forecasting with a GVAR (Pesaran, Schuermann & Smith, 2009a; 2009b).

Di Mauro and Pesaran (2013) divide recent applications of the GVAR into three categories. These categories are international transmission and forecasting (Eickmeier & Ng, 2013; Galesi &

Lombardi, 2013; Garratt, Lee & Shields, 2013; Greenwood-Nimmo, Nguyen & Shin, 2013; Lui & Mitchell, 2013; Smith, 2013a; Smith, 2013b), finance applications (Al-Haschimi & Déés, 2013; Favero, 2013; Nickel & Vansteenkiste, 2013) and regional applications (Assenmacher, 2013; Cesa-Bianchi, Pesaran, Rebucci & Xu, 2013; Déés, 2013; Fielding, Lee & Shields, 2013; Galesi & Sgherri, 2013).

Déés, Pesaran, Smith and Smith (2010) mention that “so far it has proved difficult to use ... reduced-form multi-country VARs to examine the effects of structural shocks with clear economic interpretation”. They extend the GVAR into a Multi-Country New Keynesian (MCNK) model, by basing it on a three-equation structural DSGE model. Smith (2013b) discusses the theoretical framework of the MCNK model. The individual country models determine inflation (with a Phillips curve), output (with an IS curve), interest rates (with a Taylor rule) and real exchange rates. The data are the deviations of variables from their steady state values. While shocks applied to the usual unrestricted GVAR are correlated within and across countries, shocks applied to the MCNK model are uncorrelated within countries due to the structural identification of the shocks. Due to the underlying structural theory, the nature and source of shocks can be determined. This enables Déés *et al.* (2010) to use the MCNK model to determine the clear effects of the following country-specific or global identified shocks: supply, demand and monetary policy shocks. The study highlights the importance of the incorporation of global interdependencies in economic modelling.

The paper by Cesa-Bianchi *et al.* (2012), with the condensed version in Cesa-Bianchi *et al.* (2013), has a similar purpose than our paper, but it focuses on Latin America. Their GVAR includes data from 1979Q2 to 2009Q4, with the foreign variables composed using time-varying trade weights. The GVAR is solved four times, each time with the fixed trade weights of a different year. The solution dates (1985, 1995, 2005 and 2009) differ from the solution dates of our study. We look at different years (1995, 2000, 2005 and 2009), since trade sanctions against South Africa limited trade in the 1980s and South Africa did not trade with China before 1993. The authors of the Latin America paper use their GVAR model to show how the impressive growth in China’s economy, especially in its exports, and the resulting increase in trade with Latin America have affected business cycles in five Latin American countries (Argentina, Brazil, Chile, Mexico and Peru). The long-run effect of a GDP shock to the US on the five Latin American countries has halved since 1995, while the long-run effect of a GDP shock to China on Latin America has tripled over this period. This illustrates why the impact of the recent global crisis on the Latin American region is smaller than the impact on other regions.

As mentioned in Section 1, Çakır and Kabundi (2013) use a GVAR model to analyse the trade linkages between South Africa and the BRIC countries between 1995Q1 and 2009Q4. Fixed trade weights are used to calculate the foreign variables of each of the countries in the GVAR. The domestic variables in the model include real GDP, inflation, exchange rates, real exports and real imports, while the foreign variables are real GDP and inflation. The oil price is a global variable that is included as domestic in the model of the dominant country (the US) and as foreign in the models of the other countries. Their main finding is that export shocks to each of the BRIC countries affect South African imports and GDP significantly.

Our paper is the first GVAR study that shows how the emergence of China in the global economy affects South Africa and its main trading partners in the context of using time-varying trade-weighted foreign data rather than fixed trade-weighted foreign data.

3. GVAR methodology

In this section we describe the theoretical GVAR model introduced, explained and expanded by Pesaran *et al.* (2004), Pesaran and Smith (2006), Garratt *et al.* (2006), Déés *et al.* (2007a), Déés *et al.* (2007b), Smith (2011), and Di Mauro and Pesaran (2013). The notation is from Di Mauro and Smith (2013), who replicate the paper of Déés *et al.* (2007a) using an updated data set.

The GVAR is a global model that combines many individual country models. It includes distinct VECMs with weakly exogenous foreign variables, denoted by VECX*, for every country in the GVAR. The VECX* models include domestic variables and weakly exogenous (X) country-specific foreign (*) variables. The GVAR uses a weight matrix, in this case a trade matrix, to link the countries through weighted country-specific foreign variables. The GVAR could also include global variables (e.g. the oil price), which enters the dominant country as endogenous and all the other countries as weakly exogenous.

3.1. Country-specific VECX* models

The assumption of weak exogeneity of the country-specific foreign variables, in the VECX* country models, implies that the foreign variables are long-run forcing for the domestic variables. Therefore, foreign variables affect domestic variables in the long term, but domestic variables do not affect foreign variables in the long term. Contemporaneous correlations between domestic

and foreign variables are allowed. Weak exogeneity tests (see Appendix B for more information) usually show that the assumption is correct, as expected, since most countries have small or relatively small open economies.

The US economy is the exception, being the dominant economy in the GVAR due to its dominance in global equity and bond markets. China's share in the global economy is increasing, but the US still has the largest share. Chudik and Smith (2013) motivate the use of the US as the dominant country by showing that it continues to be the major source of global economic interdependence.

The weak exogeneity assumption is key to the GVAR framework, since it enables the individual estimation of country-specific VECX* models before solving these models simultaneously for the endogenous variables in the system, thereby avoiding the 'curse of dimensionality'. To satisfy the assumption of weak exogeneity, small countries (such as South Africa) generally require a large number of countries in the system, while large countries or regions (such as the US) require a small number of countries (Smith, 2011).

Before selecting the number of cointegrating relations for each country, individual VARX* models are estimated. VARX*(p, q) models are vector autoregressive (VAR) models with weakly exogenous (X) foreign (*) variables. The lag orders of the domestic and foreign variables, respectively p and q , are determined using the Akaike information criterion (AIC) or the Schwarz Bayesian criterion (SBC). Suppose a VARX*(2,2) structure for country i :

$$\mathbf{x}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \mathbf{\Phi}_{i1}\mathbf{x}_{i,t-1} + \mathbf{\Phi}_{i2}\mathbf{x}_{i,t-2} + \mathbf{\Lambda}_{i0}\mathbf{x}_{it}^* + \mathbf{\Lambda}_{i1}\mathbf{x}_{i,t-1}^* + \mathbf{\Lambda}_{i2}\mathbf{x}_{i,t-2}^* + \mathbf{u}_{it}, \quad (1)$$

where $i = 0, 1, 2, \dots, N$ and $t = 1, 2, \dots, T$. The global model contains data for $N + 1$ countries, with country 0 the reference country, over T time periods. \mathbf{x}_{it} is a $k_i \times 1$ vector of domestic $I(1)$ variables, \mathbf{x}_{it}^* is a $k_i^* \times 1$ vector of country-specific foreign $I(1)$ variables, and \mathbf{u}_{it} is a process with no serial correlation, but with weak dependency over cross sections.

The domestic variables are endogenous to the system, while the foreign variables are weakly exogenous. Any global variables are endogenous in the model of the dominant country, but weakly exogenous in all the other country models. k_i and k_i^* can differ for each country.

Either fixed trade weights or time-varying trade weights are used to construct the foreign variables for each country from the matching domestic variables of the other countries. Thus, $\mathbf{x}_{it}^* = \sum_{j=0}^N w_{ij} \mathbf{x}_{jt}$, where w_{ij} are trade weights that reflect the trade share of country j (with $j = 0, 1, 2, \dots, N$) in the trade (average of exports and imports) of country i . The weights are predetermined and satisfy the conditions $w_{ii} = 0$ and $\sum_{j=0}^N w_{ij} = 1$.

During the estimation process, the number of cointegrating relations (interpreted as the long-run relations) is determined. A possible VECX* representation, which includes the short-run and long-run relations, of equation (1) is

$$\Delta \mathbf{x}_{it} = \mathbf{c}_{i0} - \alpha_i \beta_i' [\mathbf{z}_{i,t-1} - \gamma_i(t-1)] + \Lambda_{i0} \Delta \mathbf{x}_{it}^* + \Gamma_i \Delta \mathbf{z}_{i,t-1} + \mathbf{u}_{it}, \quad (2)$$

where $\mathbf{z}_{it} = (\mathbf{x}'_{it}, \mathbf{x}'_{it}^*)'$. α_i is a $k_i \times r_i$ matrix with the speed of adjustment coefficients and β_i is a $(k_i + k_i^*) \times r_i$ matrix with the cointegrating vectors. The rank of both α_i and β_i is r_i . The r_i error-correction terms of equation (2) can be rewritten as

$$\beta_i' (\mathbf{z}_{it} - \gamma_i t) = \beta'_{ix} \mathbf{x}_{it} + \beta'_{ix^*} \mathbf{x}_{it}^* - (\beta'_i \gamma_i) t, \quad (3)$$

if β_i is partitioned as $\beta_i = (\beta'_{ix}, \beta'_{ix^*})'$. Thus, cointegration is possible in \mathbf{x}_{it} , between \mathbf{x}_{it} and \mathbf{x}_{it}^* , and between \mathbf{x}_{it} and \mathbf{x}_{jt} when $i \neq j$.

When estimating the VECX* models for each country, \mathbf{x}_{it}^* is seen as long-run forcing or weakly exogenous to the coefficients of equation (2). For the model of each country, r_i (the rank), α_i (the speed of adjustment coefficients) and β_i (the cointegrating vectors) are determined.

3.2. GVAR model solution

After the estimation of the VECX* models for each country, the GVAR model is solved simultaneously for all the countries for all the endogenous variables ($k = \sum_{i=0}^N k_i$) in the global system.

Use $\mathbf{z}_{it} = (\mathbf{x}'_{it}, \mathbf{x}^*_{it})'$ to rewrite the VARX*(2,2) models from equation (1) as

$$\mathbf{A}_{i0}\mathbf{z}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \mathbf{A}_{i1}\mathbf{z}_{i,t-1} + \mathbf{A}_{i2}\mathbf{z}_{i,t-2} + \mathbf{u}_{it}, \quad (4)$$

with $\mathbf{A}_{i0} = (\mathbf{I}_{k_i}, -\mathbf{A}_{i0})$, $\mathbf{A}_{i1} = (\mathbf{\Phi}_{i1}, \mathbf{\Lambda}_{i1})$ and $\mathbf{A}_{i2} = (\mathbf{\Phi}_{i2}, \mathbf{\Lambda}_{i2})$.

Then derive the identity $\mathbf{z}_{it} = \mathbf{W}_i\mathbf{x}_t$ where $\mathbf{x}_t = (\mathbf{x}'_{0t}, \mathbf{x}'_{1t}, \dots, \mathbf{x}'_{Nt})$ is a $k \times 1$ vector of endogenous variables and \mathbf{W}_i is a $(k_i + k_i^*) \times k$ link matrix. \mathbf{W}_i is constructed from the country-specific trade weights w_{ij} . Use the identity to write equation (4) as

$$\mathbf{A}_{i0}\mathbf{W}_i\mathbf{x}_t = \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \mathbf{A}_{i1}\mathbf{W}_i\mathbf{x}_{t-1} + \mathbf{A}_{i2}\mathbf{W}_i\mathbf{x}_{t-2} + \mathbf{u}_{it}. \quad (5)$$

For a model of the endogenous variables \mathbf{x}_t , the individual country models are stacked to obtain

$$\mathbf{G}_0\mathbf{x}_t = \mathbf{a}_0 + \mathbf{a}_1t + \mathbf{G}_1\mathbf{x}_{t-1} + \mathbf{G}_2\mathbf{x}_{t-2} + \mathbf{u}_t, \quad (6)$$

$$\text{where } \mathbf{G}_0 = \begin{pmatrix} \mathbf{A}_{00}\mathbf{W}_0 \\ \mathbf{A}_{10}\mathbf{W}_1 \\ \vdots \\ \mathbf{A}_{N0}\mathbf{W}_N \end{pmatrix}, \mathbf{a}_0 = \begin{pmatrix} \mathbf{a}_{00} \\ \mathbf{a}_{10} \\ \vdots \\ \mathbf{a}_{N0} \end{pmatrix}, \mathbf{a}_1 = \begin{pmatrix} \mathbf{a}_{01} \\ \mathbf{a}_{11} \\ \vdots \\ \mathbf{a}_{N1} \end{pmatrix}, \mathbf{G}_1 = \begin{pmatrix} \mathbf{A}_{01}\mathbf{W}_0 \\ \mathbf{A}_{11}\mathbf{W}_1 \\ \vdots \\ \mathbf{A}_{N1}\mathbf{W}_N \end{pmatrix}, \mathbf{G}_2 = \begin{pmatrix} \mathbf{A}_{02}\mathbf{W}_0 \\ \mathbf{A}_{12}\mathbf{W}_1 \\ \vdots \\ \mathbf{A}_{N2}\mathbf{W}_N \end{pmatrix} \text{ and}$$

$$\mathbf{u}_t = \begin{pmatrix} \mathbf{u}_{0t} \\ \mathbf{u}_{1t} \\ \vdots \\ \mathbf{u}_{Nt} \end{pmatrix}.$$

Equation (6) is then premultiplied by \mathbf{G}_0^{-1} , since \mathbf{G}_0 is a known non-singular matrix. The GVAR(2) model is

$$\mathbf{x}_t = \mathbf{b}_0 + \mathbf{b}_1t + \mathbf{F}_1\mathbf{x}_{t-1} + \mathbf{F}_2\mathbf{x}_{t-2} + \boldsymbol{\varepsilon}_t, \quad (7)$$

where $\mathbf{b}_0 = \mathbf{G}_0^{-1}\mathbf{a}_0$, $\mathbf{b}_1 = \mathbf{G}_0^{-1}\mathbf{a}_1$, $\mathbf{F}_1 = \mathbf{G}_0^{-1}\mathbf{G}_1$, $\mathbf{F}_2 = \mathbf{G}_0^{-1}\mathbf{G}_2$ and $\boldsymbol{\varepsilon}_t = \mathbf{G}_0^{-1}\mathbf{u}_t$.

This model is solved recursively, usually with no restrictions on the covariance matrix

$\Sigma_{\varepsilon} = \mathbf{E}(\varepsilon_t \varepsilon_t')$. Due to the multivariate dynamics in the GVAR system, a small number of lags suffice. For quarterly data, two lags are the maximum number of lags necessary.

The linkages of the countries in the GVAR are through three channels: contemporaneous dependence of domestic variables (\mathbf{x}_{it}) on country-specific foreign variables (\mathbf{x}_{it}^*) and on lagged variables; dependence of domestic variables (\mathbf{x}_{it}) on common global variables (\mathbf{d}_t); and contemporaneous dependence of shocks (\mathbf{u}_{it}) across countries.

4. GVAR specification and empirical estimation

The model includes quarterly data for 33 countries (which include South Africa) from 1979Q2 to 2009Q4. We use the data from the ‘2009 Vintage’ GVAR database (Smith & Galesi, 2011).

Appendix A contains more information about the data source, the countries in the model and the methods of calculation of the variables. The 33 countries collectively account for around 90 per cent of world output. Trade between South Africa and the 32 countries that represent its trading partners makes up about 77 per cent of South Africa’s average trade between 2005 and 2009².

We use the GVAR Toolbox 1.1 (Smith & Galesi, 2011) to specify and estimate the models. The eight countries in the GVAR dataset that are part of the Euro area (Austria, Belgium, Finland, France, Germany, Italy, the Netherlands and Spain) are combined into a single economy before estimation. The GVAR therefore includes 26 countries, with the Euro area being one of the economies.

To incorporate the major shift in international trade linkages, we construct the foreign-specific variables for each country using time-varying trade weighted foreign variables. More specifically, three-year moving average trade weights are used to create the country-specific foreign variables. The final model specification is in line with that of Cesa-Bianchi *et al.* (2012). We solve the GVAR four times. Each of the solutions uses fixed trade shares in a different year to solve the model. The solution years are 1995, 2000, 2005 and 2009. This allows us to investigate whether the impact of economic shocks in the rest of the world on South Africa changed over time due to

² The data for this calculation are from the Direction of Trade Statistics (DOTS) of the IMF (2011).

the change in the key trading partners of South Africa and the change in international trade linkages.

For each country, depending on data availability, the domestic variables included are real GDP (y_{it}), inflation (π_{it}), real equity prices (q_{it}), real exchange rates ($ep_{it} = e_{it} - p_{it}$, i.e. nominal exchange rates minus domestic prices), short-term interest rates (ρ_{it}^S) and long-term interest rates (ρ_{it}^L). Country-specific foreign variables included for each country are foreign real GDP (y_{it}^*), foreign inflation (π_{it}^*), foreign real equity prices (q_{it}^*), foreign short-term interest rates (ρ_{it}^{S*}) and foreign long-term interest rates (ρ_{it}^{L*}). These foreign variables and the global variable, the oil price (p_t^{oil}), are weakly exogenous, as defined in Section 3.1, in the country models. The US is the dominant country in the model; therefore, it has a different specification. Domestic GDP, inflation, real equity prices, short-term interest rates, long-term interest rates and the global oil price are endogenous in the US model. The weakly exogenous variables for the US are foreign GDP ($y_{US,t}^*$), foreign inflation ($\pi_{US,t}^*$), foreign exchange rates ($ep_{US,t}^* = e_{US,t}^* - p_{US,t}^*$) and foreign short-term interest rates ($\rho_{US,t}^{S*}$). Due to the importance of real equity prices and long-term interest rates of the US in foreign markets, these variables are not included as weakly exogenous in the US model. A compact representation of the variables in the GVAR is provided in Table 1.

Table 1: Variables included in the individual VARX* models

Variable	All countries excluding US		US	
	Domestic	Foreign	Domestic	Foreign
Real GDP	y_{it}	y_{it}^*	$y_{US,t}$	$y_{US,t}^*$
Inflation	π_{it}	π_{it}^*	$\pi_{US,t}$	$\pi_{US,t}^*$
Real equity prices	q_{it}	q_{it}^*	$q_{US,t}$	-
Real exchange rates	$ep_{it} = e_{it} - p_{it}$	-	-	$ep_{US,t}^* = e_{US,t}^* - p_{US,t}^*$
Short-term interest rates	ρ_{it}^S	ρ_{it}^{S*}	$\rho_{US,t}^S$	$\rho_{US,t}^{S*}$
Long-term interest rates	ρ_{it}^L	ρ_{it}^{L*}	$\rho_{US,t}^L$	-
Oil price	-	p_t^{oil}	p_t^{oil}	-

We perform the Weighted-Symmetric augmented Dickey Fuller (WS-ADF) unit root test on all the variables³. The WS-ADF results indicate that the variables in the model are mostly $I(1)$, since in most cases the null hypothesis of a unit root (non-stationarity) cannot be rejected when the

³ The results of the WS-ADF test are available from the authors on request.

variables are tested in level form, while it is rejected when the variables are tested in first-differenced form. We therefore assume that all variables are $I(1)$ for the specification and estimation of the GVAR.

The AIC is used to select the lag order of the domestic variables (p_i) and the lag order of the foreign variables (q_i) for each of the country-specific VARX* models. Maximum lag orders of two are allowed for both p_i and q_i . We prefer the AIC to the SBC for the selection of the lag orders, since the AIC tends to suggest more lags, thereby reducing serial correlation in the models. For most of the countries, a VARX*(2,1) specification is chosen, while a VARX*(1,1) specification is sufficient for Australia, China, Malaysia, Mexico and Singapore.

Two tests are available to determine the number of cointegrating vectors (i.e. the rank of the cointegrating space) of each country model: the trace statistic and the maximum eigenvalue statistic for models with weakly exogenous $I(1)$ regressors proposed by Pesaran, Shin and Smith (2000). The rank chosen by the trace statistic is used, since the trace test has higher power in smaller samples. Section B.1 in Appendix B includes the trace statistics (Table 5) and a brief discussion of the results.

Persistence profiles illustrate the movements in the cointegrating vectors after a shock to the system. To show that the system will return to its long-run equilibrium following a system-wide shock, persistence profiles should converge to zero in the long term. Generally, GVAR studies use a ten-year or 40-quarter period within which the persistence profiles should converge to zero. Non-converging persistence profiles are thought to be caused by some misspecification in the model (Smith, 2011). Reduced ranks are used for the countries that exhibit non-convergent persistence profiles when using the original number of cointegrating relations chosen by the trace statistic for the country-specific VARX* models. In our model specification, rank reductions are as follows: from two to one (China, Euro area, India, Indonesia, Philippines, Saudi Arabia, South Africa and Thailand); from three to two (Mexico, New Zealand and the US); from three to one (Argentina, Canada, Japan, Peru, Singapore and the UK); from four to two (Australia and Chile); and from four to one (Korea).

A generalised impulse response function (GIRF) traces the effect over time of a one standard error or a one per cent shock to a specific variable in a specific country/region, on that variable and other variables of all the countries in the system. GIRFs should stabilise over time, since unstable GIRFs could point to instability due to misspecification in the GVAR (Smith, 2011). To

achieve stable GIRFs in this GVAR, the domestic lags for Argentina, Brazil, Chile, India, Indonesia, New Zealand, Norway, Peru and Sweden are lowered from two to one, thus we use VARX*(1,1) specifications for these countries instead of the VARX*(2,1) specifications initially selected by the AIC.

Table 2 contains a summary of the final model specification, with the number of domestic lags (p_i), the number of foreign lags (q_i) and the number of cointegrating vectors (i.e. the rank) for each of the countries in the model. The specification is consistent with that of Cesa-Bianchi *et al.* (2012). Section B.2 in Appendix B shows and interprets the persistence profiles of South Africa and its main trading partners (Figure 4), based on the final model specification.

Table 2: Individual VARX* specifications

Country	p_i	q_i	Rank	Country	p_i	q_i	Rank
Argentina	1	1	1	New Zealand	1	1	2
Australia	1	1	2	Norway	1	1	2
Brazil	1	1	1	Peru	1	1	1
Canada	2	1	1	Philippines	2	1	1
Chile	1	1	2	Saudi Arabia	2	1	1
China	1	1	1	Singapore	1	1	1
Euro area	2	1	1	South Africa	2	1	1
India	1	1	1	Sweden	1	1	1
Indonesia	1	1	1	Switzerland	2	1	2
Japan	2	1	1	Thailand	2	1	1
Korea	2	1	1	Turkey	2	1	2
Malaysia	1	1	1	United Kingdom	2	1	1
Mexico	1	1	2	United States	2	1	2

In section 3.1, the assumption of weak exogeneity of the foreign variables in the country specific VARX* models is explained. We perform the weak exogeneity test on all the foreign and global variables that are assumed to be weakly exogenous in our model specification. Section B.3 in Appendix B provides details of the weak exogeneity test and the test results (Table 6). At a five per cent significance level, we reject the null hypothesis of weak exogeneity for nine (i.e. six per cent) of the 154 variables. One expects to reject the null hypothesis incorrectly in around five per cent of cases, given the critical values at a five per cent level of significance. Thus, the weak exogeneity test results are satisfactory. Despite the large increase in the Chinese economy, the foreign variables in the VARX* model for China are all confirmed to be weakly exogenous.

All the country-specific VECX* models are then estimated including an unrestricted trend and a trend restricted to lie in the cointegrating space. Thereafter, the GVAR is solved for 1995, 2000, 2005 and 2009.

In the next section, we look at the effect of shocks to GDP in China and the US on the GDP of South Africa and its main trading partners. These shocks cannot be interpreted as pure demand/supply or monetary policy shocks, since the GIRFs allow for correlation between the error terms (\mathbf{u}) in Equation 6 in Section 3.2. To be able to investigate a pure monetary policy, demand or supply shock, the variance-covariance matrix of \mathbf{u} , i.e. $\Sigma_{\mathbf{u}}$, must include structural restrictions. As mentioned by Cesa-Bianchi *et al.* (2012) it is not necessary to impose structural restrictions to the shocks for our type of analysis, since we are comparing the effect of GDP shocks to specific economies on other economies at different points in time. The identification of the sources of the shocks, which would be possible by imposing structural restrictions, is not our focus.

5. Results of shocks to the GVAR

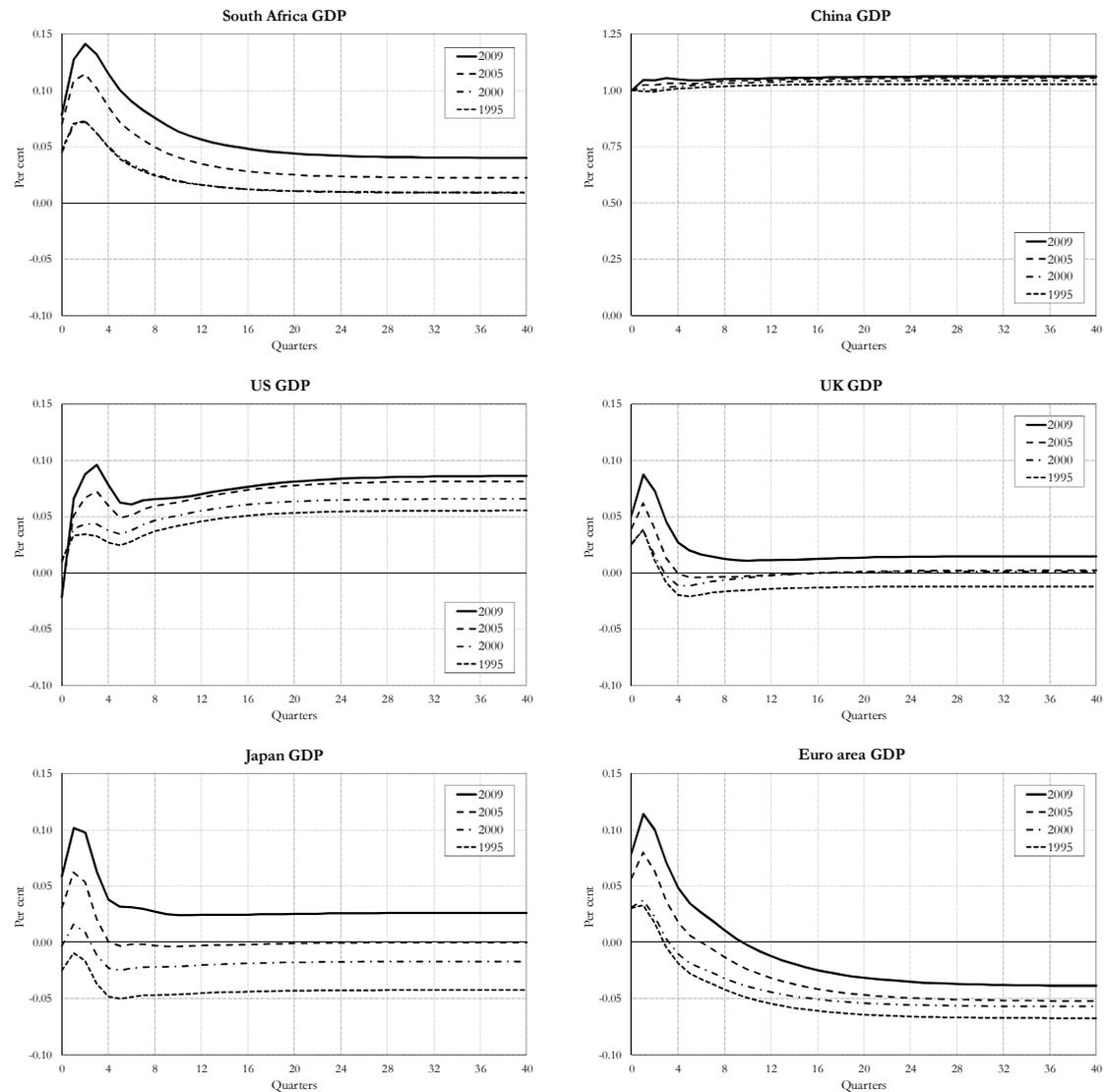
To investigate whether the impact of GDP shocks in the rest of the world on GDP in South Africa has changed over time, we solve the GVAR in four different years: 1995, 2000, 2005 and 2009. The effects of a one per cent GDP shock to China and a one per cent GDP shock to the US are then compared for the different years to quantify any differences (see Figure 2 and Figure 3). We apply a shock to China's GDP, since we want to determine whether the substantial growth in trade between China and South Africa affects the transfer of shocks. We use the US as the reference country, since the US is often used in South African studies as a proxy for the rest of the world. We also know that trade between the US and South Africa declined noticeably since 1995 (refer to Figure 1).

First, we investigate how the increase in China's importance in the world economy changes the transmission of GDP shocks from China to South Africa and its main trading partners. Figure 2 shows the GIRFs for a one per cent increase in Chinese GDP on GDP in South Africa, China, the US, the UK, Japan and the Euro area.

The effects of a shock to Chinese GDP on the GDP of South Africa and its main trading partners have increased systematically and substantially since 1995. A numerical comparison of

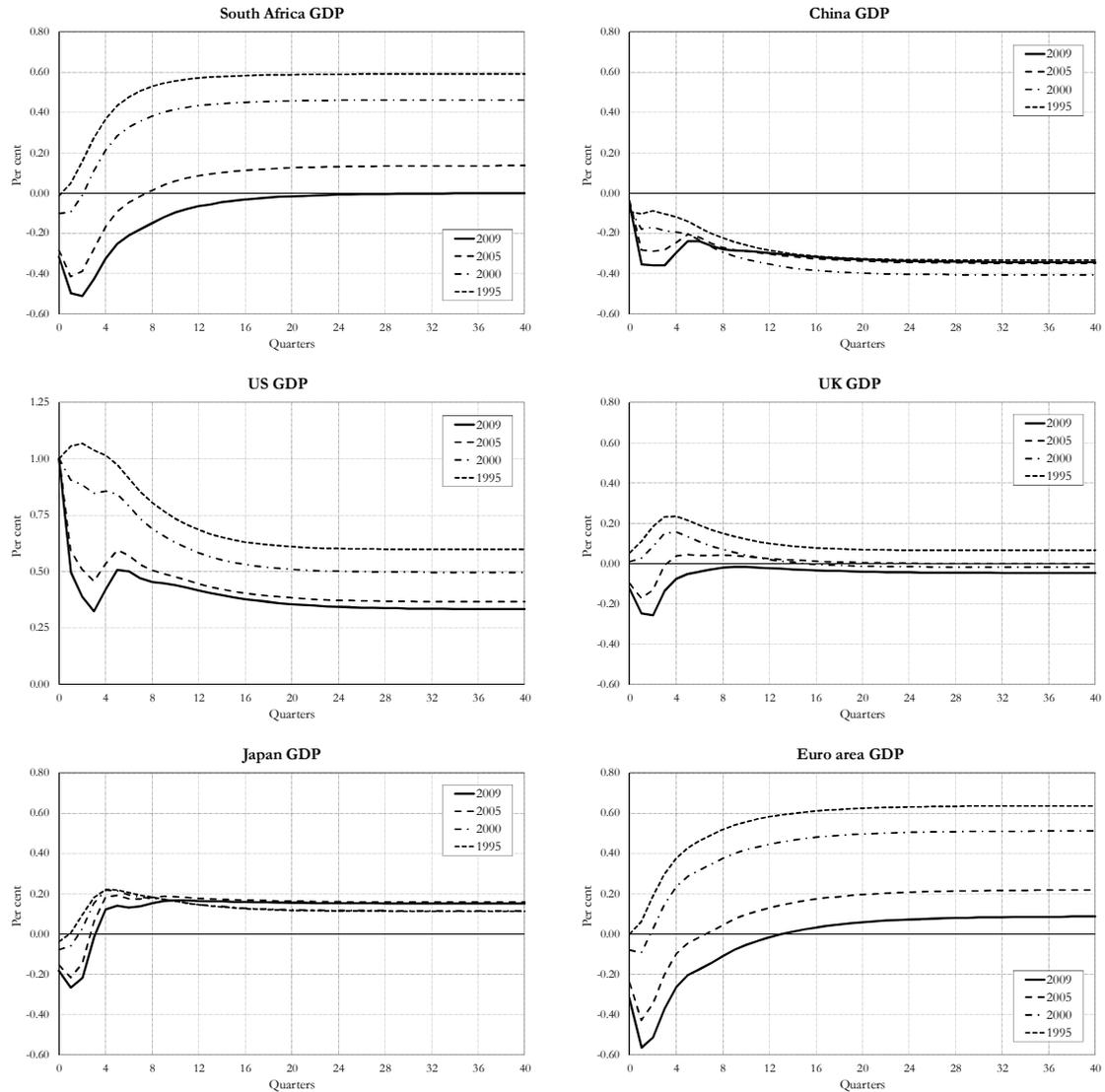
the long-term effects of a shock to Chinese GDP in 2009 to a shock in 1995, 2000 or 2005 confirms this. The long-term impact of a one per cent increase in Chinese GDP on South African GDP is 330% stronger in 2009 than in 1995 and 2000, albeit off a low base, while the impact on US GDP is 55% stronger compared to 1995 and 30% stronger compared to 2000. The long-term effects of a Chinese GDP shock in 2009 on GDP in South Africa and the US respectively are 80% and 6% more than in 2005. A shock to GDP in China in 2009 also has higher impacts on GDP in the UK, Japan and the Euro area, in comparison to shocks in 1995, 2000 and 2005.

Figure 2: GIRFs for a one per cent increase in China GDP



Second, we determine the long-term effects of lower trade between South Africa and the US on the transfer of GDP shocks from the US to South Africa and its key trading partners. The results of a one per cent shock in US GDP are evident in Figure 3.

Figure 3: GIRFs for a one per cent increase in US GDP



Due to the increase in China's importance in the world economy, a shock in US GDP in 2009 mostly has a lower impact on GDP in the other economies than a shock in 1995. For South Africa, the long-term impact of a one per cent shock in US GDP in 2005 was only a quarter of that of a similar shock in 1995. By 2009, the impact of a US GDP shock on South Africa is 100% less than in 1995 and it is insignificant. Due to changes in trade interdependencies, the effect of a shock to US GDP on US GDP itself has decreased since 1995, with the effect in 2009

only 56% of that in 1995. In comparison with the transmission of a US GDP shock to the Euro area in 1995, the transmission is 20% less in 2000, 66% less in 2005 and 86% less in 2009. The effect of a US GDP shock on Chinese GDP has not changed markedly over the long run. The changing impact on UK GDP and Japan GDP following a shock to US GDP is much larger in the short term than in the long term.

The graphs indicate that changes in the trade linkages of South Africa with China and the US have an influential impact on the transfer of GDP shocks between these countries and South Africa. This trend is not confined to South Africa. Due to China's emergence in the world economy, Chinese GDP shocks have a much larger impact than before, while the effect of US GDP shocks have declined.

6. Conclusion

The GVAR results confirm our expectations that the large changes in the trade shares of South Africa's trading patterns have a marked impact on the transmission of GDP shocks in China and the US on GDP in South Africa. South Africa did not trade with China before 1993, but due to the substantial growth in trade between the two countries, China has taken the position of its main trading partner on a country level. Trade with the US is much lower than in the 1990s. The long-term impact on South African GDP of a GDP shock in China in 2009 is more than 300% higher in 2009 than in 1995, while the long-term impact of a US GDP shock on South African GDP in 2009 is a quarter of the impact in 2005. By 2009, the long-term impact of a US GDP shock on South African GDP compared to 1995 is insignificant. This explains why the recent global crisis did not affect South Africa as much as it affected developed economies.

The results indicate that a slowdown in economic growth in China could result in a marked slowdown in economic growth in South Africa and the rest of the world. Thus, policy makers in South Africa and the rest of the world should monitor the changing international trade linkages, especially since trade with China has increased further in the past few years. It is important for policy makers to consider the changes in global trade linkages and the resulting changes in the transmission of shocks during model building, forecasting and simulations of different scenarios; else, the results may be misleading.

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Appendix A: Data

The data for the GVAR model are from the ‘2009 Vintage’ GVAR database (Smith & Galesi, 2011). The database contains data for 33 countries (including South Africa) between 1979Q2 and 2009Q4. The average trade shares with South Africa between 2007 and 2009, of the 32 countries in the GVAR that represents South Africa’s trading partners, are shown in Table 3.

Table 3: Average trade shares of countries in the GVAR with South Africa (2007 - 2009)

Country	Average trade share
China	13.69%
Germany	12.17%
United States	11.31%
Japan	9.23%
United Kingdom	7.67%
Saudi Arabia	3.99%
Spain	3.98%
Netherlands	3.68%
Italy	3.38%
India	3.15%
France	3.05%
Belgium	2.71%
Korea	2.46%
Australia	2.30%
Switzerland	2.19%
Brazil	1.93%
Thailand	1.82%
Argentina	1.54%
Sweden	1.44%
Malaysia	1.35%
Turkey	1.23%
Canada	1.16%
Singapore	0.98%
Indonesia	0.85%
Austria	0.75%
Finland	0.62%
Mexico	0.41%
Norway	0.32%
New Zealand	0.22%
Philippines	0.16%
Chile	0.15%
Peru	0.10%
Total	100.00%
Euro area	30.35%

Source: ‘2009 Vintage’ GVAR database (Smith & Galesi, 2011)

The Euro area in the GVAR includes Austria, Belgium, Finland, France, Germany, Italy, the Netherlands and Spain.

Technical Appendix B of the GVAR Toolbox 1.1 User Guide by Smith and Galesi (2011) provides detailed information about the data sources of the ‘2009 Vintage’ GVAR database and the methods of calculation of the data. Table 4 lists the GVAR variables, variable descriptions and calculation methods. Interest rates are adjusted from annual rates to quarterly rates, for comparison with the quarterly inflation rates. All the variables are used in natural logarithmic form. The country-specific foreign variables are calculated using three-year moving average trade shares to weigh the relevant foreign data.

Table 4: GVAR variables

Variable	Description	Calculation
y_{it}	Domestic real GDP	\ln real GDP for country i during period t
π_{it}	Domestic inflation	Quarterly inflation rate: first difference of \ln CPI for country i at time t
q_{it}	Domestic real equity prices	\ln real equity prices for country i at time t
ϕ_{it}	Domestic real exchange rates	\ln nominal exchange rate in terms of US dollars – \ln CPI for country i at time t
ρ_{it}^S	Domestic short-term interest rates	$0.25 * \ln(1 + \text{short-term interest rate}/100)$ for country i at time t
ρ_{it}^L	Domestic long-term interest rates	$0.25 * \ln(1 + \text{long-term interest rate}/100)$ for country i at time t
y_{it}^*	Foreign real GDP	\ln foreign real GDP for country i during period t
π_{it}^*	Foreign inflation	Quarterly foreign inflation rate: first difference of \ln foreign CPI for country i at time t
q_{it}^*	Foreign real equity prices	\ln foreign real equity prices for country i at time t
ϕ_{it}^*	Foreign real exchange rates	\ln foreign nominal exchange rate in terms of US dollar – \ln foreign CPI for country i at time t
ρ_{it}^{S*}	Foreign short-term interest rates	$0.25 * \ln(1 + \text{foreign short-term interest rate}/100)$ for country i at time t
ρ_{it}^{L*}	Foreign long-term interest rates	$0.25 * \ln(1 + \text{foreign long-term interest rate}/100)$ for country i at time t
p_t^{oil}	Oil price	\ln oil price at time t

Appendix B: Model specification results

B.1 Ranks of the country-specific VARX* models

Table 5: Trace statistics at different rank orders for cointegration testing

<i>Statistic</i>	<i>Argentina</i>	<i>Australia</i>	<i>Brazil</i>	<i>Canada</i>	<i>Chile</i>	<i>China</i>	<i>Euro area</i>
# Domestic	5	6	4	6	5	4	6
# Foreign	6	6	6	6	6	6	6
$r = 0$	463.92†	346.99†	323.50†	267.86†	309.50†	164.88†	260.99†
$r = 1$	177.79†	238.33†	79.77	185.18†	195.00†	93.17†	184.31†
$r = 2$	85.46†	160.67†	27.76	121.47†	113.19†	42.53	117.86
$r = 3$	27.10	92.40†	9.60	79.31	58.36†	19.46	76.11
$r = 4$	12.17	48.73		47.45	18.79		42.97
$r = 5$		17.66		18.49			14.93
<i>Statistic</i>	<i>India</i>	<i>Indonesia</i>	<i>Japan</i>	<i>Korea</i>	<i>Malaysia</i>	<i>Mexico</i>	<i>New Zealand</i>
# Domestic	5	4	6	6	5	4	6
# Foreign	6	6	6	6	6	6	6
$r = 0$	198.45†	184.13†	281.53†	331.90†	184.51†	220.10†	372.98†
$r = 1$	128.08†	108.25†	179.38†	251.37†	117.86	112.25†	258.27†
$r = 2$	78.35	55.14	122.16†	172.91†	65.44	58.50†	162.13†
$r = 3$	43.58	21.09	72.12	98.15†	29.89	22.82	80.70
$r = 4$	14.06		46.16	49.84	11.65		44.49
$r = 5$			21.45	21.30			21.82
<i>Statistic</i>	<i>Norway</i>	<i>Peru</i>	<i>Philippines</i>	<i>Saudi Arabia</i>	<i>Singapore</i>	<i>South Africa</i>	<i>Sweden</i>
# Domestic	6	4	5	3	5	6	6
# Foreign	6	6	6	6	6	6	6
$r = 0$	324.61†	324.37†	235.27†	132.99†	221.21†	256.73†	242.69†
$r = 1$	193.59†	136.16†	144.09†	70.50†	137.33†	172.69†	153.24
$r = 2$	116.41	66.59†	68.04	23.82	89.46†	114.65	99.14
$r = 3$	72.90	16.03	30.48		52.21	62.03	60.61
$r = 4$	30.75		7.42		17.91	35.16	33.79
$r = 5$	9.58					15.23	12.74
<i>Statistic</i>	<i>Switzerland</i>	<i>Thailand</i>	<i>Turkey</i>	<i>United Kingdom</i>	<i>United States</i>		
# Domestic	6	5	4	6	6		
# Foreign	6	6	6	6	4		
$r = 0$	263.17†	201.07†	148.50†	299.36†	273.46†		
$r = 1$	178.68†	129.14†	92.88†	175.62†	185.14†		
$r = 2$	115.50	73.32	46.23	120.40†	105.22†		
$r = 3$	70.20	43.06	15.67	77.74	66.76		
$r = 4$	37.04	18.39		37.70	29.77		
$r = 5$	13.01			15.61	11.81		

† Null hypothesis rejected at the 5 per cent level of statistical significance.

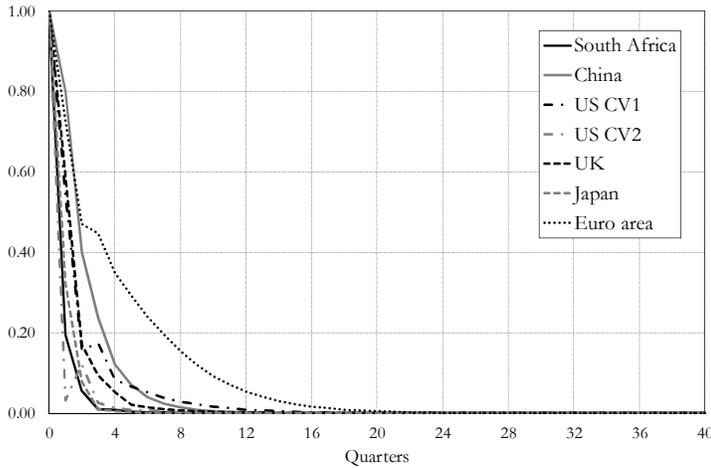
Table 5 contains the trace statistics of Pesaran *et al.* (2000) for cointegration testing. The trace statistics in bold font indicate the first statistic for each country where the null hypothesis, that

the rank is equal to r , cannot be rejected at a five per cent significance level, thereby showing the rank chosen by the trace statistic for each country.

B.2 Persistence profiles

Figure 4 plots the persistence profiles of the cointegrating vectors (CVs) of South Africa and its key trading partners, based on the GVAR solution in 2009. As with the persistence profiles of the selected countries in Figure 4, the persistence profiles of all the cointegrating vectors of all the countries in the GVAR converge to zero, thus the system will return to its long-run equilibrium after a system-wide shock to the cointegrating vectors.

Figure 4: Persistence profiles of key trading partners for selected cointegrating vectors



B.3 Testing for weak exogeneity

Di Mauro and Smith (2013) describe the formal test of the assumption of weak exogeneity for the country-specific foreign variables (\mathbf{x}_{it}^*) and the global variable. We provide a short summary of the test.

It is an F -test of the joint significance of the error-correction terms in auxiliary regressions for \mathbf{x}_{it}^* . Thus, the F -statistic for weak exogeneity tests the joint hypothesis that $\delta_{ij,\ell} = 0$ in the estimated auxiliary regression, for the ℓ th element of \mathbf{x}_{it}^* ,

$$\Delta \mathbf{x}_{it}^* = a_{it} + \sum_{j=1}^{r_i} \delta_{ij,\ell} ECM_{ij,t-1} + \sum_{k=1}^{s_i} \phi'_{ik,\ell} \Delta \mathbf{x}_{i,t-k} + \sum_{m=1}^{n_i} \psi'_{im,\ell} \Delta \tilde{\mathbf{x}}_{i,t-m}^* + \eta_{it,\ell}, \quad (8)$$

where $\Delta \tilde{\mathbf{x}}_{it}^* = (\Delta \mathbf{x}'_{it}, \Delta ep_{it}^*, \Delta p_t^{oil})'$ for $i = 1, 2, \dots, N$. In the case of the US, $ep_{US,t}^*$ is included in $\Delta \tilde{\mathbf{x}}_{it}^*$. $ECM_{ij,t-1}$ ($j = 1, 2, \dots, r_i$) are the estimated error-correction terms that matches the r_i long-run relations (rank) of the i th country. We set the lag orders for the lagged differenced domestic variables (s_i) and the lagged differenced foreign variables (n_i) respectively to p_i lags (see Table 2 in Section 4) and to two lags, in keeping with Cesa-Bianchi *et al.* (2013).

Table 6 displays the F -statistics of the weak exogeneity test. As stated in Section 4, the null hypothesis of weak exogeneity is only rejected for nine of the 154 variables.

Table 6: Weak exogeneity test statistics

Country	F -test	y^*	π^*	q^*	ep^*	ρ^{S^*}	ρ^{L^*}	p^{oil}
Argentina	F(1,99)	3.79	0.00	2.25		0.35	0.36	0.07
Australia	F(2,97)	0.27	0.13	0.67		0.41	0.56	0.36
Brazil	F(1,100)	0.07	0.78	0.04		0.11	0.11	4.74†
Canada	F(1,92)	0.12	0.50	0.26		2.08	0.18	0.03
Chile	F(1,100)	0.06	0.02	0.03		0.90	3.81	1.65
China	F(2,98)	0.79	1.07	0.17		1.34	0.80	0.41
Euro area	F(1,92)	0.48	1.26	0.24		0.02	2.72	2.31
India	F(1,99)	0.09	0.06	0.51		0.32	0.03	2.85
Indonesia	F(1,100)	0.16	0.20	1.87		0.07	0.80	0.11
Japan	F(1,92)	0.04	1.24	0.25		4.44†	5.67†	3.18
Korea	F(1,92)	0.02	1.07	2.38		0.03	0.13	1.19
Malaysia	F(1,99)	2.94	3.66	5.28†		1.74	0.02	3.41
Mexico	F(2,99)	3.44†	0.31	1.03		1.27	1.59	0.05
New Zealand	F(2,97)	0.83	3.73†	0.16		1.83	0.76	3.81†
Norway	F(2,97)	2.29	1.54	0.16		0.09	0.15	1.08
Peru	F(1,100)	1.40	2.15	0.49		1.14	0.09	1.63
Philippines	F(1,94)	4.16†	1.80	1.43		0.00	0.25	4.01†
Saudi Arabia	F(1,92)	1.15	0.60	0.65		0.42	2.66	0.14
Singapore	F(1,98)	0.09	0.66	0.84		0.20	0.04	0.03
South Africa	F(1,99)	0.53	0.09	0.72		0.05	2.53	0.00
Sweden	F(1,98)	0.24	0.36	0.58		0.99	0.04	0.06
Switzerland	F(2,91)	2.08	0.58	2.03		0.12	0.51	0.07
Thailand	F(1,94)	0.01	0.72	0.01		0.01	0.04	0.45
Turkey	F(2,95)	0.68	1.70	0.02		2.92	0.15	0.45
United Kingdom	F(1,92)	0.10	0.89	1.00		0.76	0.00	2.04
United States	F(2,93)	0.65	0.06		0.45	2.12		

† Null hypothesis of weak exogeneity rejected at the 5 per cent level of statistical significance.