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LINKING GLOBAL ECONOMIC DYNAMICS TO A SOUTH AFRICAN SPECIFIC CREDIT PORTFOLIO

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Abstract

Driven by intense competition for market share banks across the globe have increasingly allowed credit portfolios to become less diversified (across all dimensions - country, industry, sector and size) and were willing to accept lesser quality assets on their books. As a result, even well capitalised banks could come under severe solvency pressure when global economic conditions turn. The banking industry have realised the need for more sophisticated loan origination, credit and capital management practices. To this end, the reforms introduced by the Bank of International Settlement through the New Basel Accord (Basel II) aim to include exposure specific credit risk characteristics within the regulatory capital requirement framework. The new regulatory capital framework still does not allow diversification and concentration risk to be fully recognised within the credit portfolio because it does not account for systematic and idiosyncratic risk in a multifactor framework.

The core principle for addressing practical questions in credit portfolio management is enclosed in the ability to link the cyclical or systematic components of firm credit risk with the firm's own idiosyncratic credit risk as well as the systematic credit risk component of every other exposure in the portfolio. Simple structural credit portfolio management approaches have opted to represent the general economy or systematic risk by a single risk factor. The systematic component of all exposures, the process generating asset values and therefore the default thresholds are homogeneous across all firms. Indeed, this Asymptotic Single Risk Factor (ASRF) model has been the foundation for Basel II. While the ASRF framework is appealing due to its analytical closed-form properties for regulatory and generally universal application in large portfolios, the single risk factor characteristic is also its major drawback. Essentially it does not allow for enough flexibility in answering real life questions. Commercially available credit portfolio models make an effort to address this by introducing more systematic factors in the asset value generating process but from a practitioner's point of view, these models are often a "black-box" allowing little economic meaning or inference to be attributed to systematic factors.

The methodology proposed by Pesaran, Schuermann, and Weiner (2004) and supplemented by Pesaran, Schuermann, Treutler and Weiner (2006) has made a significant advance in credit risk modelling in that it avoids the use of proprietary balance sheet and distance to default data, focussing on credit ratings which are more freely available. Linking an adjusted structural default model to a structural global econometric model (GVAR) credit risk analysis and portfolio management can be done through the use of a conditional loss distribution estimation and simulation process. The GVAR model used in Pesaran *et al.* (2004) comprises a total of 25 countries which is grouped into 11 regions and accounts for 80 per cent of world production. In the case of South Africa the GVAR model lacks applicability since it does not include an African component.

♠ Any views expressed represent that of the authors only and not necessarily those of FirstRand Bank.

In this paper we construct a country specific macro-econometric risk driver engine which is compatible with and could feed into the GVAR model and framework of PSW (2004) using vector error correcting (VECM) techniques. This will allow conditional loss estimation of a South African specific credit portfolio but also opens the door for credit portfolio modelling on a global scale as such a model can easily be linked into the GVAR model. We extend the set of domestic factors beyond those used in PSW (2004) in such a way that the risk driver model is applicable for both retail and corporate credit risk. As such, the model can be applied to a total bank balance sheet, incorporating the correlation and diversification between both retail and corporate credit exposures.

Assuming statistical over-identification restrictions, our results indicate that it is possible to construct a South African component for the GVAR model and that such a component could easily be integrated into a global content. From a practical application perspective the framework and model is particularly appealing since it could be used as a theoretically consistent correlation model within a South African specific credit portfolio management tool.

Key words: Credit portfolio management, multifactor model, vector error correction model (VECM), credit correlations.

JEL classification: C32, C51, E44.

1. Introduction

Since the early 1990s intense competition for market share motivated banks across the globe to allow credit portfolios to become less diversified (across all dimensions - country, industry, sector and size) and accept lesser quality assets on their books without being adequately compensated for the higher risk. As a result, even well capitalised banks could come under severe solvency pressure when global economic conditions turn. The banking industry have realised the need for more sophisticated loan origination, credit and capital management practices.

From a credit portfolio perspective it is essential that portfolio managers understand the dynamics and interaction of two key elements of their exposures, namely. systematic and idiosyncratic risk. Systematic risk refers to the co-movement and risk associated with the relationship between exposures and the general economic environment while idiosyncratic risk refers to exposure specific risk factors such as leverage or cash flow ratios. The core principle for addressing practical questions in credit portfolio management is captured in the ability to link the cyclical or systematic components of firm credit risk with the firm's own idiosyncratic credit risk, as well as the systematic credit risk component of every other exposure in the portfolio. In general, this relationship is referred to as credit correlation. Conceptually one would expect that the correlation of individual exposures with the business cycle would imply that in an economic downturn portfolio credit risk is increased by the simultaneous increase in risk of exposures which is sensitive to the same macroeconomic variables. A better understanding of these correlations would not only allow better capital budgeting over the business cycle but would also allow portfolio managers to execute and more effectively exploit market opportunities.

The methodology proposed by Peasaran, Schuermann and Weiner (2004) (PSW) and Pesaran, Schuermann, Treutler and Weiner (2006) (PSTW) has made a significant advance in credit risk modelling by linking an adjusted structural default model to a structural global econometric model (their global vector autoregressive model (GVAR)) from which conditional credit risk analysis and portfolio management can be done. This paper therefore investigates the possibility to construct a country specific macro-econometric risk driver engine which is compatible with, and could feed into, the GVAR model and framework. This will allow conditional loss estimation of a South African specific credit portfolio but also opens the door for credit portfolio modelling on a global scale, as such a model can easily be linked to the GVAR model.

The paper is structured as follows. The first section discussess the basic problems faced by bank credit portfolio managers across the globe before highlighting the methodology and framework proposed by PSW (2004) and PSTW (2006) to develop a consistent econometric framework and model to estimate the dynamics of global credit markets in section 3. Section 4 gives an in-depth discussion on the data construction process, estimation results, dynamic properties and forecasting ability of the proposed South African specific vector error correction model (VECM). The paper concludes in section 5 by arguing that the proposed model could be used as a stand alone correlation model in a South African specific credit portfolio model or could be linked to the GVAR model as part of a global credit portfolio management tool.

2. Credit risk and the macro economy

Much of the discussion taking place since the introduction of the New Capital Accord under Basel II (BIS (2006)) has centred on the effects of business cycles on portfolio credit risk and economic capital (see for example Carpenter, Whitesell and Zakrajsek (2001), Carey (2002), Allen and Saunders (2004), Jarrow and van Deventer (2005) and Elizalde (2005)). However, most approaches have opted to represent the general economy or systematic risk by a single risk factor. The systematic component of all exposures, the process generating asset values, and therefore the default thresholds, are assumed to be homogeneous across all firms. Indeed this asymptotic single risk factor (ASRF) model (Gordy (2003)) has been the foundation for Basel II. While the ASRF framework is appealing due to its analytical closed-form properties for regulatory and generally universal application in large portfolios, the single risk factor characteristic is also its major drawback. Essentially it does not allow for enough flexibility in answering real life questions. Commercially available credit portfolio models made an effort to address this by introducing more systematic factors in the asset value generating process but have failed to provide any tractable economic meaning to their risk factors.

The methodology proposed by PSW (2004) and PSTW (2006) provides an applicable model for conditional credit loss modelling which combines the systematic risk with the idiosyncratic component of each exposure and also includes an explicit channel for default correlation. The methodology is particularly appealing in that it is not only flexible in answering practical portfolio questions (through scenario analysis) but also steers away from the data confidentiality problem that most practitioners face with commercially available credit portfolio models. In simple terms the methodology can be summarised as follows. The macro-econometric risk driver model will specify and represent the macroeconomic environment in which the credit portfolio operates. Using Monte Carlo simulations, various possible simulation paths of the economy are forecasted over a specific period. These macro factors feed into the firm specific return models in order to produce the value generating process of each firm. Using the return dynamics and the estimated equity default thresholds from PSTW (2004), the probability of default can be obtained through a structural-based credit default model. Finally, a conditional loss distribution for the credit portfolio is obtained and used to estimate various credit related parameters such as economic capital and allow for various scenario analyses to be performed.

Since the current PSW (2004) model do not include any African component, the aim in this paper is to construct a South African specific macro econometric risk driver engine which can feed into the Global Vector Autoregression (GVAR) model and framework proposed by PSW (2004). This will allow conditional loss estimation of a South African specific credit portfolio, but also opens the door for credit portfolio modelling on a global scale as such a model can easily be linked into the already established GVAR model. We make a significant enhancement to the set of domestic factors included in the VECM model to allow the incorporation of both corporate and retail credit risk elements to be modelled from the same system. This would allow simultaneous estimation of total bank portfolio credit risk which accounts for correlation and diversification between corporate and retail credit exposures. In order to estimate and provide such a South African specific model it is therefore necessary to analyse the construction of the GVAR model proposed by PSW (2004).

3. The PSW GVAR model

The macro-econometric risk driver model (GVAR) used in PSW (2004) comprises a total of 25 countries which are grouped into 11 regions and account for 80 per cent of world production. However, as stated by PSW (2004), a cointegration framework can become computationally very demanding and as such seven key economies are modelled alone i.e. U.S., U.K., Japan, China, Germany, France and Italy while all other countries are modelled as part of regional groups i.e. Western Europe, South East Asia, Latin America and the Middle East. In the case of South Africa the GVAR model lacks applicability since it does not include an African region. However, the approach is general enough so that country specific cointegration models can be linked into the global and already established GVAR model. Therefore, the use of cointegration is applied in such a fashion that heterogeneity that exists across regions and countries is acknowledged. This section draws on the core elements of the GVAR model as presented in PSW (2004) to illustrate the framework and put the methodology in context[1].

In general, the GVAR model proposed by PSW (2004) allows for interaction amongst countries and economies through three channels:

- Contemporaneous dependence between the endogenous variables (domestic ($\mathbf{x}_{it}$) and global ($\mathbf{x}^*_{it}$)) and on their own passed lagged variables;
- Dependence of country specific variables on common global effects such as oil prices; and
- Weak cross section dependence of the idiosyncratic shocks between countries.

This specification provided by PSW (2004) provides a complete system of *(N+1)* country specific variables which can be estimated simultaneously if data permits. Moreover, the dynamic, stability and forecast ability of the GVAR model is proven which makes it a suitable framework for credit portfolio model scenario and impulse response analysis (e.g. general impulse response analysis as argued in Koop, Peasaran, and Potter (1996), Peasaran and Shin (1998), and Peasaran and Smith (1998)). However the number of parameters that needs to be estimated in such a global model is often more than the number of data observations available.

3.1. Using individual country models to estimate the GVAR model

The GVAR model is theoretically very appealing but estimation of the model as a single system would not be feasible for any moderately high values of *N*. In fact, PSW (2004) argues that the number of parameters that need to be estimated is often more than the number of data observations available. As such it would seem as if the model is practically unusable.

[1] We refer the reader to PSTW (2004) for a full presentation of the methodology.

However, PSW (2004) makes a significant enhancement to the framework by proving that the model can indeed be estimated through individual country models on a name by name basis rather than simultaneously is feasible for large values of *N*. Essentially the conditions under which the individual country VECM models would lead to similar results as modelling the full model simultaneously provide a formal definition of a small open economy. In the context of this study this condition would be satisfied since South Africa can certainly be regarded as a small open economy in the global context.

Under the weak exogeneity conditions the parameters of the country specific models can be estimated using the reduced-rank approach pioneered and developed by Johansen (1989, 1992 and 1995). As such, one allows for the possibility that the levels of the macro economic variable might be long-run cointegrated. Although the methods developed by Johansen assumes that all variables are endogenously determined and of order I(1), Pesaran, Shin and Smith (2000) have modified the methodology to allow for weakly exogenous variables to be included in a reduced rank estimation procedure.

Therefore to estimate the country specific models subject to reduced rank restrictions and including a vector of common exogenous variables in the system (e.g. oil prices) $\mathbf{d}_t$ where $\mathbf{d}_t$ is a $(s \times 1)$ vector, the country specific model which governs the long-run relationships between the $k_i \times 1$ vector of domestic ($\mathbf{x}_{it}$) and $k_i^* \times 1$ vector of global ($\mathbf{x}_{it}^*$) variables are;

$$\mathbf{x}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \mathbf{\Phi}_i \mathbf{x}_{i,t-1} + \mathbf{\Lambda}_{i0}\mathbf{x}_{it}^* + \mathbf{\Lambda}_{i1}\mathbf{x}_{i,t-1}^* + \boldsymbol{\psi}_{i0}\mathbf{d}_t + \boldsymbol{\psi}_{i1}\mathbf{d}_{t-1} + \boldsymbol{\varepsilon}_{it}, \quad t = 1, 2, \ldots, T, \quad i = 1, 2, \ldots, N \tag{1}$$

While the error correction model are represented as

$$\Delta\mathbf{x}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \mathbf{\Pi}_i \mathbf{v}_{i,t-1} + \mathbf{\Lambda}_{i0}\Delta\mathbf{x}_{it}^* + \boldsymbol{\psi}_{i0}\Delta\mathbf{d}_t + \boldsymbol{\varepsilon}_{it}, \tag{2}$$

Where

$$\mathbf{\Pi}_i = \left(\mathbf{A}_i - \mathbf{B}_i, \boldsymbol{\psi}_{i0} - \boldsymbol{\psi}_{i1}\right) \tag{3}$$

And

$$\mathbf{v}_{i,t-1} = \begin{pmatrix} \mathbf{z}_{i,t-1} \\ \mathbf{d}_{t-1} \end{pmatrix}. \tag{4}$$

With

$$\mathbf{z}_{it} = (\mathbf{W}_i \mathbf{x}_t), \qquad i = 0,1,2,\ldots.N \tag{5}$$

Where $\mathbf{W}_i$ is a $(k_i + k_i^*) \times k$ matrix of fixed constants defined in terms of the country specific weights. PSW (2004) define $\mathbf{W}_i$ as the "link" matrix which allows the individual country models to be written in terms of the global variable vector $\mathbf{x}_{it}^*$.

Furthermore;

$\mathbf{A}_i = (\mathbf{I}_{ki}, -\mathbf{\Lambda}_{i0})$ and $\mathbf{B}_i = (\mathbf{\Phi}_i, \mathbf{\Lambda}_{i1})$ are $k_i \times (k_i + k_i^*)$ and $\mathbf{A}_i$ has full row rank, i.e. rank($\mathbf{A}_i$)= k_i .

Where

$\mathbf{\Phi}_i$ is a $k_i \times k_i$ matrix of lagged coefficients, $\mathbf{\Lambda}_{i0}$ and $\mathbf{\Lambda}_{i1}$ are $k_i \times k_i^*$ matrices of coefficients associated with the foreign specific variables, and $\boldsymbol{\varepsilon}_{it}$ is a $k_i \times 1$ vector of idiosyncratic country specific shocks which are serially uncorrelated with mean $\mathbf{0}$ and a non-singular covariance matrix, $\mathbf{\Sigma}_{ii} = (\sigma_{ii,ls})$.

The information regarding the long run cointegration relationships between the levels of the variables is contained in the $(k_i + k_i^* + s) \times 1$ matrix, $\mathbf{\Pi}_i$. If there is no cointegration amongst the variables $\mathbf{\Pi}_i = 0$ and equation 2 reduces to the normal first difference model

$$\Delta \mathbf{x}_{it} = \mathbf{a}_{i0} + \mathbf{\Lambda}_{i0} \Delta \mathbf{x}_{it}^* + \boldsymbol{\psi}_{i0} \Delta \mathbf{d}_t + \boldsymbol{\varepsilon}_{it}, \tag{6}$$

In general, one would expect $\mathbf{\Pi}_i \neq 0$, since there should be important interlinkages between the economic variables (both between domestic variables themselves and with foreign variables). However $\mathbf{\Pi}_i$ would probably be rank deficient so that $rank(\mathbf{\Pi}_i) = r_i < k_i$ and therefore the error correcting model in equation 2 needs to be estimated using reduced rank restrictions as proposed by Johansen (1989, 1992 and 1995).

4. Estimating a South African component for the GVAR model

Using the methodology outlined above, the construction of 7 country-specific and 4 regional specific models culminates into the GVAR model which captures the dynamics of 25 countries' macroeconomic developments. However, the GVAR model lacks an African element. In this section we apply the PSW (2004) methodology to South Africa and provide an individual country model which is believed to be compatible with the GVAR model. This would add an African component which is currently lacking from the GVAR model.

4.1. Foreign trade weights

The impact that the global economy has on domestic macroeconomic dynamics are captured by constructing country specific global time series of economic variables. These time series are constructed through weighting South Africa's major foreign role players' individual economic time series by utilizing foreign trade weightings.

With global integration and an ever increasing free trading environment, South Africa has seen an increase in the number of its major trading partners over the last decade. As such, the South African Reserve Bank has increased the number of trading partners considered in constructing the real effective exchange rate from four to fourteen to more accurately reflect the current foreign trade relations.

According to Walters and De Beer (1999) South Africa's major trading partners comprise of 14 countries which account for over 85 per cent of South Africa's trade in manufacturing goods. The 14 major trade partners include the Euro area, the United States of America, the United Kingdom, Japan, Switzerland, People's Republic of China: Mainland, People' Republic of China: Hong Kong, Korea, Zimbabwe, Canada, Australia, Sweden, Singapore and Israel. Walters and De Beer (1999) presents a full discussion on the Information Notice System (INS) of the International Monetary Fund's methodology used to calculate the new trade weights of South Africa and also applies the methodology retrospectively in order to provide information on the trade weights historically. The second column of table 1 shows the final weights used to construct the global (or "starred") macroeconomic variables.

Table 1 South African trade weights

Country	Weights before Jan 1999	Weights after Jan 1999
Euro Area:		
Germany	16.91%	
Italy	5.07%	
France	4.98%	
Netherlands	3.90%	
Belgium-Luxembourg	3.54%	
Spain	1.34%	
Ireland	0.86%	
Austria	0.83%	
Finland	0.81%	
Portugal	0.34%	
Euro Area	38.58%	35.70%
USA	14.44%	15.15%
UK	14.09%	14.91%
Japan	9.90%	10.26%
Switzerland	4.99%	5.28%
China: Mainland	2.91%	3.11%
China: Hong-Kong	2.59%	2.62%
Korea	2.50%	2.57%
Zimbabwe	2.27%	2.27%
Canada	1.87%	1.93%
Australia	1.59%	1.62%
Sweden	1.58%	1.79%
Singapore	1.55%	1.62%
Israel	1.14%	1.17%

Source: Walters and De Beer (1999)

Due to the implosion of their economy over the last couple of years the inclusion of Zimbabwe would skew the global variables over the near term. As such, Zimbabwe is excluded from the sample and its trade share apportioned pro-rata to the remaining foreign trading partners in the estimation process.

4.2. Global macroeconomic variables

Since this study is positioned to add an African component to the PSW (2004) GVAR model, it is necessary to use the same underlying data in construction so that it is possible to link this model to the outcomes generated by the PSW (2004) model in a dynamic global simulation and forecasting framework. Therefore, in order to construct the global macroeconomic data we referenced the same data sources as used in PSW (2004) to construct our global variables. The global variables used can be summarized as follows:

$$
\begin{aligned}
y_{it} &= \ln\left(\frac{GDP_{it}}{CPI_{it}}\right), & p_{it} &= \ln(CPI_{it}), \\
q_{it} &= \ln\left(\frac{EQ_{it}}{CPI_{it}}\right), & m_{it} &= \ln\left(\frac{M_{it}}{CPI_{it}}\right), \\
e_{it} &= \ln(E_{it}), & \rho_{it} &= 0.25\ln\left(1+\frac{R_{it}}{100}\right).
\end{aligned} \tag{7}
$$

Where i is an index representing the set of trading partners of South Africa as outlined above, GDP_{it} = nominal gross domestic product, CPI_{it} = consumer price index, M_{it} = nominal money supply in domestic currency, EQ_{it} = nominal equity price index, E_{it} = exchange rate of country i at time t with respect to the U.S. dollar, and R_{it} = nominal rate of interest per annum in percent.

The primary variables (in real terms) considered and data sources used in this study are therefore similar to those used and explained in PSW (2004) and are summarized in table 2.

Table 2 Global data series and data sources

Variables	Data source	Short name
Output (GDP)	IMF's International Financial Statistics (IFS) GDP (2000) series	*y**
General price indices	IMF's International Financial Statistics (IFS) Consumer Price Index (2000) series	*p **
Equity price indices	Bloomberg's	*q**
Interest rates	IMF's International Financial Statistics (IFS) series 60B the money rate	*rho**
Money supply	The sum of the IMF's International Financial Statistics (IFS) series 34 (money) and series 35 (quasi-money)	*m**

The construction of time series data for the Euro area for the time period before unification in 1998 was done based on the trade weights as provided by Walters and de Beer (1998). Clearly this would have led to some significant data gaps as well as unavailable time series for some countries particularly for the earlier time periods. Moreover, data series for the Euro area after 1998 may not always add up or link perfectly with the weighting system applied before 1998. As such, missing data was created by first interpolating the quarterly data from the annual data where available, if annual data was not available, the quarterly data was generated by backcasting using the average of the earliest available quarterly growth rates for that series. Thereafter, the time series for the Euro area before 1998 was adjusted by scaling the data to match the data obtained from the IFS data base for the time period after 1998. Similarly, in other data series such as for example China: Mainland and China: Hong Kong, missing data and time series was constructed first by interpolation of the annual time series or through approximation of the series by using growth rates[2].

In summary, the 10 country individual time series for the Euro zone before 1998 was combined into a single Euro area series for each variable by applying the country weights in table 1, these series were augmented by the Euro time series for the time period after 1998. In a similar fashion the foreign variables were constructed from the 14 individual economic time series by weighting them with their individual weights as obtained from table 1. As such, 5 time series from the 14 individual regional and country series will represent the dynamics of the global economic variables which are assumed to impact and shape the South African domestic economy's macroeconomic landscape. Formally the construction of the set of global variables $\mathbf{x}_{it}^*$ can be described by:

$$
\begin{aligned}
y_{it}^* &= \sum_{j=0}^{N} w_{ij}^y y_{it}, & p_{it}^* &= \sum_{j=0}^{N} w_{ij}^p p_{it}, \\
q_{it}^* &= \sum_{j=0}^{N} w_{ij}^q q_{it}, & e_{it}^* &= \sum_{j=0}^{N} w_{ij}^e e_{it}, \\
\rho_{it}^* &= \sum_{j=0}^{N} w_{ij}^\rho \rho_{it}, & m_{it}^* &= \sum_{j=0}^{N} w_{ij}^m m_{it}
\end{aligned}
\tag{8}
$$

With y_{it}, p_{it}, q_{it}, e_{it}, ρ_{it}, m_{it} , $w_{ij}^y, w_{ij}^p, w_{ij}^q, w_{ij}^e, w_{ij}^\rho$, and w_{ij}^m as defined above.

4.3. Domestic and exogenous macroeconomic variables

In the domestic economic specific variable selection we deviate slightly from the variable selection as applied in PSW (2004). Due to the fact that this study does not aim to provide region and country specific models for all trading partners but only to supply a South African specific element to the GVAR model, we investigate the possibility of

[2] Details on the construction and approximation of missing data series are available on request from the authors.

constructing a domestic VECM model which includes more credit market related variables. As such, we extend the number of data series beyond the series used to capture the global macro economic environment to include additional variables which is deemed to be important to credit markets in South Africa. Other than the output, general price levels, interest rates and money supply used for the global macro economic environment we consider possible inclusion of two additional variables for the South African domestic economy.

Household debt to income ratios have increased significantly over the last two years due to the structurally lower interest rate environment. Although debt repayments have been fairly stable, the absolute volume underlying credit extension can have a significant adverse effect on the economy if interest rates are to increase to historically observed levels. As such, the household debt to income ratio is included in the set of domestic variables as it will provide significant information with respect to the risk drivers of the domestic credit market.

A second significant development in the domestic market in recent times has been the increase experienced in property values. Similar to the global arena, property prices displayed phenomenal growth over the last three years which have led to significant wealth creation. Therefore, although the South African economy’s balance sheet has seen an increase in liabilities due to higher debt, on a net wealth basis the balance sheet quality has improved due to the increase in property values. We therefore include a house price index variable in the set of domestic variables in order to capture the impact and solvency risk posed to the macro economy by the developments of the property market.

The set of domestic and exogenous variables and their transformation in order to express them in real terms are:

$$y_t = \ln\left(\frac{GDP_t}{CPI_t}\right), \qquad p_t = \ln(CPI_t), \qquad d_t = \ln(Household\,debt\,to\,income)$$
$$q_t = \ln\left(\frac{EQ_t}{CPI_t}\right), \qquad m_t = \ln\left(\frac{M_t}{CPI_t}\right), \qquad h_t = \ln\left(\frac{HPI_t}{CPI_t}\right) \tag{9}$$
$$e_t = \ln(E_t), \qquad \rho_t = 0.25\ln\left(1+\frac{R_t}{100}\right) \qquad o_t = \ln(Oilp\$).$$

Where GDP_t = nominal gross domestic product, CPI_t = consumer price index, M_t = nominal money supply in domestic currency, EQ_t = nominal equity price index, E_t = real effective exchange rate, R_t = nominal rate of interest per annum in percent. *Household debt/Income*$_t$ = debt to income ratio of households, HPI_t = house price index depicting the general increase in property values, and *Oilp$* = Brent crude oil price in U.S. dollar terms.

The final set of domestic variables and the relevant data sources are summarized in table 3. Missing data was again approximated by interpolating the quarterly data from the annual data where available, if annual data was not available, the quarterly data was generated by backcasting using the average of the earliest available quarterly growth rates for that series.

Table 3 Domestic and exogenous data series and data sources

Variables	Data source	Short name
Output (GDP)	South African Reserve Bank Quarterly Bulletin	*y*
General price indices	Statistics South Africa	*p*
Equity price indices	Johannesburg Stock Exchange	*q*
Exchange rates	IMF's International Financial Statistics (IFS) rf series	*e*
Interest rates	South African Reserve Bank Quarterly Bulletin	*ρ*
Money supply	South African Reserve Bank Quarterly Bulletin	*m*
Household debt to income ratio	South African Reserve Bank Quarterly Bulletin	*d*
House price index	ABSA bank	*h*
Oil prices	Inet bridge	*o*

The official policy rate in South Africa is the repurchase rate (Repo) of the South African Reserve Bank. However, this policy instrument was only introduced in 1998 rendering insufficient time series observations for inclusion in this study. We consider both the 3 month Banker's Acceptance (BA) and 91 day Treasury bill (T-bill) rate and propose to use the T-bill rate as a proxy for domestic short-term or policy rates.

4.4. Integration properties of the time series

The reduced form cointegration methodology proposed by Johansen (1988) assumes that the underlying data series within the system of equations are integrated of order one i.e. I(1). Although it is generally assumed that macroeconomic variables display I(1) behavior we nevertheless formally assess the integration properties of each series. Recognizing the fact that the Augmented Dickey-Fuller (ADF) test for unit roots may suffer power problems in small samples we also apply the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) unit root test. The KPSS test differs from other unit root tests in that the underlying data series are assumed to be (trend-) stationary under the null as apposed to non-stationary. By applying both the ADF and KPPS unit root test we reduce the risk of spurious inference due to low power properties displayed by the underlying unit root test.

The unit root tests are applied to the full sample of data available i.e. from 1980Q1 to 2006Q4 for all time series. Series were tested for unit roots based on the transformation as set out above. We start the maximum lag length of the underlying AR process assuming an AR process of order 5 and allow the final order of the ADF test statistic to be calculated based on the Akaike information criteria (AIC) in the case of the ADF test while the bandwidth of the KPPS test statistic is calculated based on the Newey-West criteria. We test for stationarity of variables in levels and first difference terms. For variables in level form, the ADF test statistic is evaluated assuming stationarity where there is no intercept (none), an intercept only and an intercept and trend in the underlying data generating process while the KPPS test is evaluated with an intercept and intercept plus trend in the underlying data series. For variables in first differences, no trend stationarity specification is included, i.e. ADF excluding and including an intercept and KPPS including an intercept are tested.

In general, the results from the unit root test for the domestic variables are in line with intuition and results found in the literature. Although the KPPS test suggests that some of the domestic variables might also be I(0) as apposed to I(1), the ADF test indicates unambiguously that all South African domestic variables are I(1). The results from the global variables are similar and suggest that real output (y^*), the price index (p^*), real money supply (m^*), real equity prices (q^*) and interest rates (ρ^*) are I(1) if evaluated by either the ADF or KPPS test statistic. While the ADF test suggests that all the variables are I(1) the KPPS test suggest that some of the series could be I(0). These conflicting results from the two unit root tests leads one to believe that the relative short time series of data as well as missing observations in the underlying data for countries such as China could skew results and lead to over fitting in the analysis from both the ADF and KPPS tests. As such, we will be guided by the literature and empirical results presented by for example PSW (2004) on their global variables integration tests and assume that those variables for which there is conflicting results are weakly I(1).

Table 4 Unit root test results: domestic and exogenous variables

Variables	Unit root test equation specification	ADF lag length	ADF test statistic H0: Non-stationary	KPPS band width	KPPS test statistic H0: Stationary
y	none	4	2.75		
	intercept	4	2.18	9	1.13*
	intercept and trend	4	-0.70	8	0.31*
Δy	none	3	-3.84*		
	intercept	3	-4.68*	10	0.5
p	none	0	1.06		
	intercept	0	-0.49	8	0.91*
	intercept and trend	0	-1.93	7	0.14
Δp	none	0	-10.68*		
	intercept	4	-6.59*	2	0.2
m	none	1	3.10		
	intercept	1	2.66	9	1.05*
	intercept and trend	1	0.61	8	0.30*
Δm	none	0	-5.86*		
	intercept	0	-6.60***	7	0.62
q	none	0	1.06		
	intercept	0	-0.49	8	0.91*
	intercept and trend	0	-1.93	7	0.15*
Δq	none	0	-10.61***		
	intercept	0	-10.68***	2	0.2
ρ	none	1	-0.40		
	intercept	4	-3.14	8	0.38
	intercept and trend	1	-3.70	8	0.17*
$\Delta \rho$	none	0	-5.87*		
	intercept	0	-5.84*	4	0.14
e	none	0	-3.87*		
	intercept	1	-1.73	9	1.09*
	intercept and trend	0	1.70	8	0.25*
Δe	none	0	-9.37*		
	intercept	0	-9.95*	2	0.21
h	none	1	0.43		
	intercept	1	-0.91	9	0.27
	intercept and trend	4	-0.21	9	0.26
Δh	none	0	-3.33*		
	intercept	0	-3.34*	8	0.44
d	none	1	1.97		
	intercept	1	-2.93	8	0.71
	intercept and trend	0	-3.32	8	0.07
Δd	none	0	-10.63*		
	intercept	0	-10.55*	6	0.15
o^*	none	0	0.25		
	intercept	0	-1.70	8	0.31
	intercept and trend	0	-1.87	8	0.27*
Δo^*	none	1	-9.41*		
	intercept	1	-9.39*	3	0.19

* indicates a rejection of the null hypothesis at a 5% level of significance.

Table 5 Unit root test results: global variables

Variables	Unit root test equation specification	ADF lag length	ADF test statistic H0: Non-stationary	KPPS band width	KPPS test statistic H0: Stationary
y*	none	4	0.75		
	intercept	4	-1.71	8	0.34***
	intercept and trend	4	-1.82	8	0.26***
Δy*	none	3	-3.91***		
	intercept	3	-3.68***	9	0.59
p*	none	5	2.00		
	intercept	5	-1.66	9	1.17*
	intercept and trend	5	-1.26	8	0.31*
Δp*	none	4	-2.49**		
	intercept	4	-3.06**	9	0.79
m*	none	5	4.04		
	intercept	5	-0.60	9	1.18*
	intercept and trend	4	-2.13	8	0.15*
Δm*	none	3	-2.23**		
	intercept	4	-4.70***	5	0.13
q*	none	0	2.15		
	intercept	0	-0.70	9	1.12*
	intercept and trend	0	-2.24	8	0.10
Δq*	none	0	-10.50***		
	intercept	0	-11.05***	2	0.06
ρ*	none	4	-1.48		
	intercept	4	-1.81	8	1.15*
	intercept and trend	3	-5.39***	7	0.06
Δρ*	none	5	-5.75***		
	intercept	5	-5.89***	4	0.04
e*	none	1	0.22		
	intercept	1	-1.53	8	0.83
	intercept and trend	3	-2.69	8	0.21
Δe*	none	0	-12.75***		
	intercept	0	-12.70***	6	0.09

* indicates a rejection of the null hypothesis at a 5% level of significance.

4.5. A South African specific VECM model

The unit root results above demonstrate that the VECM approach is appropriate within the South African context. After careful analysis of possible theoretical relationships and multicollinearity that may exist between the variables we select the set of domestic macroeconomic factors to be: real output (y), the price index (p), real equity prices (q), exchange rate (e), interest rates (ρ), real house price index (h) and the household debt ratio (*d*). Due to the fact that South Africa is a small global role player, it is reasonable to assume that the South African economy can be regarded as a small open economy. Theoretically, this implies that domestic economic variables should in the long run not have a significant impact on global macro economic events. As such we impose the theoretical assumption that the set of global variables is world output (y^*), real world equity prices (q^*) and world interest rates (ρ^*). Although these variables would be estimates within the GVAR model in order to provide estimates of the global factors for simulation purposes, these variables will be included within the VECM system and modeled accordingly. While it is not the aim of this paper to obtain structural estimates for the global economic factors the estimation results and forecasts from the VECM model will be evaluated for reasonability to ensure that these do not unduly bias the domestic variables' forecasts.

Cointegration and VECM techniques have become very popular and well known in the empirical econometric literature. Various asymptotic tests and procedures have been developed to test the cointegrating rank of a system as well as identify the system of equations in order to provide a unique solution. Asymptotically, these test are very appealing and most certainly correct, "…but for the sample sizes available in most practical situations we argue that the interaction of dynamic identification and long-run identification can have enormous effects on the size and power of the testing procedures conventionally used" and that "…the small sample properties of now familiar cointegration tests can be very poor in many practical situations". Moreover, "…in a common realistic modeling situation of a limited data set and the theory requirements of a fairly rich model, the techniques proposed in the existing literature are almost impossible to implement successfully." (Greenslade, Hall and Henry (2000)). Many researchers have thus been discouraged by the statistical result from their modeling efforts and abandoned it due to statistical properties that have not been satisfied completely or are not supported by economic theory. In our application the final VECM model and specification is arrived at and accepted based on economic theory, statistical correctness, in and out of sample estimation results, forecast simulation outcomes as well as keeping the specification as parsimonious as possible.

4.6. Cointegrating rank properties of the system

The first step in estimating the South African specific VECM component to the GVAR model is to test the cointegrating rank of the system. As a result of the relative short time span of available data, the order of the lag structure is assumed to be 1 and the cointegration rank tests is performed accordingly. The data is assumed to have a linear deterministic trend while including an intercept in the cointegration equation as well as the test VAR. The trace and maximum eigenvalue test statistics and critical values are provided in table 6.

The trace test indicates that there are 3 cointegrating relationships between the variables included in the VAR model while the maximum eigenvalue test indicates that there are only 2 cointegrating relationships present. However, it is generally accepted in the literature that the eigenvalue test is very sensitive to small samples and non-normality of the underlying data included in the test VAR. As such we base our inference in the trace statistic which indicates 3 cointegrating equation in the system.

Table 6 Cointegration rank test statistics

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.535730	318.2110	239.2354	0.0000
At most 1 *	0.436495	236.8783	197.3709	0.0001
At most 2 *	0.382633	176.0789	159.5297	0.0045
At most 3	0.264284	124.9560	125.6154	0.0548
Trace test indicates 3 cointegrating eqn(s) at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level **MacKinnon-Haug-Michelis (1999) p-values				
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.535730	81.33274	64.50472	0.0006
At most 1 *	0.436495	60.79936	58.43354	0.0287
At most 2	0.382633	51.12296	52.36261	0.0666
Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level **MacKinnon-Haug-Michelis (1999) p-values				

4.7. Imposing restrictions on the VECM system

Due to the theoretical exogeneity assumptions placed on the global variables we are left with identifying three long-run cointegrating equations from a set of seven endogenous domestic variables by imposing just identifying or over identifying restrictions on the system. Due to the complexity of multivariate cointegration techniques and the 13 different VECM models comprising the GVAR model, it is practical for PSW (2004) to derive their country specific VECM models based on exact identification restriction. Although all exact identified systems produce a just identified system and subsequent coefficient estimates, these results may not always conform to economic theory. While this study do not aim to provide unchallengeable structural relationship to the South African VECM model but rather a theoretical consistent simulation model to be used in a South African credit portfolio model, we need to ensure that the restrictions placed on the system are in line with economic rationale. We will therefore aim to identify the system as well as ensure that the coefficient estimates are consistent with expectations. The set of possible normalization restriction can be based on the following set of domestic variables: real output (y), the price index (p), real equity prices (q), exchange rate (e), interest rates (ρ), real house price index (h) and the household debt ratio (d). We propose the identification of equations for the exchange rate (e), the real house price index (h) and real equity prices (q).

For the real equity price (q) equation we use the principles behind the dividend discount model used in equity stock analysis to derive the main components of the specification. The dividend discount model estimates the present value of a share as the value of future cash flows discounted by an appropriate interest rate. As such, we include real output (y) as a cash flow variable with interest rates as the representative discount rate. Equity prices should increase with increased future cash flows and decrease if discount rates increase. Due to the massive increase in house price asset values in recent times many investors have substituted equities for property in order to diversify portfolios and also tap into the massive property price boom experienced in global markets. Especially in

South Africa, property is the primary substitution asset for equities and therefore should be included in the specification. Increases in property values should therefore result in a substitution away from equities and into property, resulting in equity price deflation. As argued above, South Africa is definitely not immune to global financial market developments. In fact, global equity and financial market developments have a significant impact on our equity market's performance. Historically, Asian and emerging market developments (contagion effects from 1998 and 2001) have had a significant impact on the outcome of equity market returns. One would therefore expect a positive relationship between domestic and global equity market prices while the discount rate used in international markets could be seen as a global discount rate which is also applicable for South African equities. Finally, deterioration in the currency would not only lower relative return from a global investor's perspective but could also point to other fundamental problems such as current account deficit concerns. As such, one can expect that deterioration in the exchange rate would be harmful to equity prices in the long run. The domestic equity price specification can therefore be presented as follows:

$$q = f\left(\rho^{*}, q^{*}, e, \rho, h\right) \tag{10}$$

As stated above, global property markets have performed significantly well over the last couple of years. South African house prices have not been excluded from this property boom. Strong economic growth and structurally lower inflation and interest rates have significantly lowered the repayment to income ratios of households which have enabled them to access the equity locked-up in properties. If the domestic growth performance continues, one can expect property prices to remain robust while higher leverage and interest rates would have a dampening effect on property price growth. Once again, we acknowledge the fact that investors are able to substitute between domestic property and equity investments while also being able to tap into international markets. As such, one would expect that higher equity prices, strong global growth and subsequent international asset prices and a depreciating domestic currency would lead to a substitution away from domestic property markets. The final specification for property prices is illustrated below:

$$h = f\left(\rho^*, y^*, e, q, y, d\right) \tag{11}$$

The final relationship that we aim to identify within our VECM specification is the exchange rate. Following the theoretical discussions from Abel and Bernanke (2001) we impose the theoretical constraints as applicable to a small open economy. According to Abel and Bernanke (2001) one can expect that the exchange rate of a small open economy (real or nominal) could be influenced by domestic and global currency demand and supply factors. An increase in foreign income or liquidity would increase demand for domestic goods and currency resulting in a strengthening in the value of the domestic currency. Higher real rate of return on domestic assets e.g. interest rates and property values would also increase the demand for domestic currency as more investors would be looking to invest in the domestic market. On the other hand, increases in domestic income and inflation rates would result in an increase in the demand for foreign goods and a loss in purchasing power respectively, both of which would led to a deterioration in the domestic currency value. We use global equity prices as a proxy for global liquidity, with domestic GDP and property prices a proxy for domestic income and asset returns. We thus propose to estimate the following exchange rate equation:

$$e = f\left(\rho^*, q^*, y, h,\right) \tag{12}$$

The final theoretical specification provides a total of 15 over-identification restrictions on the system of 3 long-run cointegrating vectors i.e. 3 normalization and 12 theoretical exclusion restrictions.

4.8. Estimation results

The VECM results for the theoretical specification outlined above are presented in table 7. The estimation results of the cointegration equations are of particular interest as it would govern the long-run relationship of the model simulations in the portfolio model and should therefore provide theoretically consistent estimates of the interaction between the variables. According to the Likelihood-ratio test, the Chi-square statistic of 6.57

(probability equal to 0.36) indicates that the theoretical constraints placed on the system are valid and binding and identify all cointegrating vectors. While the R-squared values from the dynamic estimation output indicate that a significant portion of the variation in the dynamics of the variables is explained by the system, the discussion would focus on the long-run estimation results.

The first cointegrating equation displays the theoretical specification for the exchange rate. The estimation results conform to economic theory and individual t-statistic results indicate statistical significance of the independent variables in the specification. Higher global interest rates would lead to a substitution away from Rand denominated assets while increased liquidity (as proxied by global equity prices) would lead to more funds flowing into the country and a subsequent strengthening of the Rand. The coefficients for domestic income growth and inflation show the expected depreciation in the currency due to higher import volumes and a loss in purchasing power. Finally, increases in asset values would lead to increased demand for Rand denominated assets and a strengthening of the currency.

The cointegrating equation for property values is also in line with *a priory* expectation and shows a strong positive correlation between the growth in domestic income and property values. Higher indebtedness would place downward pressure on property prices while substitution away from fixed assets into more liquid equity assets would take place if relative returns are more attractive. Global asset growth rates (proxied by higher global economic growth rates) would lead to a substitution of domestic assets while increased global interest rates should also lead to a substitution away from domestic properties. Since the exchange rate relates domestic prices to international prices it is reasonable to expect that a weakening of the domestic currency (i.e. a strengthening in the foreign currency) would deplete property returns on a relative basis and as such have a the negative signed coefficient.

Table 7 VECM estimation output (cointegrating relationships)

Vector Error Correction Estimates			
Convergence achieved after 46 iterations			
Standard errors in ( ) & t-statistics in [ ]			
LR test for binding restrictions (rank = 3):			
Chi-square(6) 6.569966 Probability 0.362451			
Cointegrating Eq:	**CointEq1**	**CointEq2**	**CointEq3**
ρ^* (-1)	4.354969 (0.63723) [6.83424]	-1.143138 (0.27953) [-4.08950]	-6.853144 (1.12493) [-6.09204]
q^* (-1)	-1.158226 (0.15594) [-7.42727]	0.000000	0.944547 (0.14881) [6.34733]
y^* (-1)	0.000000	-0.785906 (0.41977) [-1.87223]	0.000000
e(-1)	-1.000000	-0.678427 (0.11127) [-6.09707]	-0.892159 (0.32293) [-2.76269]
ρ(-1)	0.000000	0.000000	-1.131678 (0.28902) [-3.91551]
q(-1)	0.000000	-0.117511 (0.05789) [-2.02985]	-1.000000
y (-1)	7.259275 (0.66937) [10.8449]	2.517437 (0.21393) [11.7677]	0.000000
d (-1)	0.000000	-1.059918 (0.15578) [-6.80377]	0.000000
h(-1)	-1.941245 (0.34212) [-5.67417]	-1.000000	-1.166295 (0.34930) [-3.33899]
p(-1)	0.000000	0.000000	0.000000
c	-84.37718	-16.83612	21.89473

VECM estimation output (dynamic relationships)

Error Correction:	D(ρ^*)	D(q^*)	D(y^*)	D(e)	D(ρ)	D(q)	D(y)	D(d)	D(h)	D(p)
CointEq1	-0.001227	0.576336	-0.008710	0.101736	0.007617	0.181914	-0.041745	-0.031800	-0.014536	-0.003814
	(0.02778)	(0.11722)	(0.01056)	(0.08889)	(0.03240)	(0.12456)	(0.02499)	(0.03094)	(0.01481)	(0.00881)
	[-0.04416]	[4.91670]	[-0.82516]	[1.14455]	[0.23505]	[1.46049]	[-1.67023]	[-1.02768]	[-0.98182]	[-0.43282]
CointEq2	-0.128798	-1.164789	0.009110	-0.399000	-0.049034	-0.595047	-0.038536	0.126981	0.085943	-0.011492
	(0.06487)	(0.27369)	(0.02465)	(0.20754)	(0.07566)	(0.29082)	(0.05836)	(0.07225)	(0.03457)	(0.02057)
	[-1.98537]	[-4.25581]	[0.36965]	[-1.92252]	[-0.64808]	[-2.04607]	[-0.66035]	[1.75755]	[2.48618]	[-0.55859]
CointEq3	0.032475	0.538559	-0.002351	0.123962	0.011513	0.210269	-0.004895	-0.050492	-0.013952	-0.005802
	(0.02649)	(0.11176)	(0.01006)	(0.08474)	(0.03089)	(0.11875)	(0.02383)	(0.02950)	(0.01412)	(0.00840)
	[1.22595]	[4.81900]	[-0.23360]	[1.46277]	[0.37266]	[1.77066]	[-0.20541]	[-1.71152]	[-0.98845]	[-0.69062]
D(ρ^* (-1))	0.041540	-0.331655	0.057744	0.307237	0.114120	-0.212165	0.148357	0.129215	0.168297	-0.074538
	(0.10531)	(0.44428)	(0.04001)	(0.33689)	(0.12282)	(0.47209)	(0.09473)	(0.11728)	(0.05611)	(0.03340)
	[0.39447]	[-0.74650]	[1.44336]	[0.91197]	[0.92918]	[-0.44942]	[1.56612]	[1.10177]	[2.99922]	[-2.23194]
D(q^* (-1))	-0.014527	-0.146435	0.002649	-0.211170	-0.012579	-0.024123	-0.009020	0.041843	0.020115	-0.010760
	(0.03110)	(0.13122)	(0.01182)	(0.09950)	(0.03628)	(0.13943)	(0.02798)	(0.03464)	(0.01657)	(0.00986)
	[-0.46704]	[-1.11594]	[0.22416]	[-2.12222]	[-0.34677]	[-0.17301]	[-0.32239]	[1.20796]	[1.21365]	[-1.09082]
D(y^* (-1))	-0.110487	-0.716089	-0.479173	-1.644138	-0.185945	-0.058397	-1.838074	-0.372860	-0.077459	0.136572
	(0.32067)	(1.35288)	(0.12182)	(1.02588)	(0.37399)	(1.43756)	(0.28846)	(0.35713)	(0.17087)	(0.10170)
	[-0.34455]	[-0.52931]	[-3.93329]	[-1.60266]	[-0.49719]	[-0.04062]	[-6.37201]	[-1.04405]	[-0.45331]	[1.34295]
D(e(-1))	-0.126569	-0.029775	0.020252	-0.111954	0.003674	-0.232182	-0.049879	0.002147	-0.016820	0.013548
	(0.04235)	(0.17866)	(0.01609)	(0.13547)	(0.04939)	(0.18984)	(0.03809)	(0.04716)	(0.02256)	(0.01343)
	[-2.98888]	[-0.16666]	[1.25885]	[-0.82639]	[0.07440]	[-1.22306]	[-1.30940]	[0.04553]	[-0.74540]	[1.00881]
D(ρ(-1))	0.344405	-0.101865	-0.042684	0.163716	0.473866	0.066836	-0.007473	0.164473	-0.164599	0.035700
	(0.10682)	(0.45064)	(0.04058)	(0.34172)	(0.12458)	(0.47885)	(0.09609)	(0.11896)	(0.05692)	(0.03387)
	[3.22430]	[-0.22604]	[-1.05187]	[0.47910]	[3.80383]	[0.13958]	[-0.07777]	[1.38261]	[-2.89190]	[1.05389]
D(q(-1))	0.083301	0.159932	-0.017325	0.112480	0.014306	-0.032428	0.004952	-0.009118	0.010975	0.009286
	(0.03824)	(0.16133)	(0.01453)	(0.12233)	(0.04460)	(0.17142)	(0.03440)	(0.04259)	(0.02038)	(0.01213)
	[2.17843]	[0.99136]	[-1.19259]	[0.91946]	[0.32079]	[-0.18917]	[0.14396]	[-0.21411]	[0.53863]	[0.76574]
D(y (-1))	0.348473	-0.326117	0.138143	0.382529	0.091481	0.083573	0.242029	0.042314	0.005844	-0.014149
	(0.12251)	(0.51685)	(0.04654)	(0.39192)	(0.14288)	(0.54920)	(0.11020)	(0.13644)	(0.06528)	(0.03885)
	[2.84447]	[-0.63097]	[2.96816]	[0.97603]	[0.64027]	[0.15217]	[2.19622]	[0.31014]	[0.08951]	[-0.36417]
D(d (-1))	-0.110194	-0.656812	0.016388	-0.165913	-0.133943	-0.182133	0.058105	-0.052178	0.176295	-0.047449
	(0.11093)	(0.46800)	(0.04214)	(0.35488)	(0.12937)	(0.49729)	(0.09979)	(0.12354)	(0.05911)	(0.03518)
	[-0.99337]	[-1.40346]	[0.38886]	[-0.46752]	[-1.03532]	[-0.36625]	[0.58229]	[-0.42236]	[2.98252]	[-1.34878]

D(h(-1))	0.283041	0.701182	-0.100254	-0.837546	0.301516	-0.227473	-0.194628	0.188766	0.466278	0.100735
	(0.17909)	(0.75554)	(0.06804)	(0.57292)	(0.20886)	(0.80283)	(0.16110)	(0.19944)	(0.09543)	(0.05679)
	[1.58048]	[0.92805]	[-1.47356]	[-1.46189]	[1.44360]	[-0.28334]	[-1.20815]	[0.94646]	[4.88623]	[1.77370]
D(p(-1))	0.610144	1.843755	0.070143	-2.577975	0.130681	-2.869612	-0.305533	-0.619391	0.552412	0.325331
	(0.46432)	(1.95890)	(0.17640)	(1.48542)	(0.54152)	(2.08150)	(0.41768)	(0.51710)	(0.24741)	(0.14725)
	[1.31407]	[0.94122]	[0.39764]	[-1.73552]	[0.24132]	[-1.37862]	[-0.73151]	[-1.19781]	[2.23273]	[2.20938]
C	-0.021231	-0.014296	-0.001659	0.087816	-0.005905	0.081244	0.016990	0.017153	-0.010048	0.014604
	(0.01188)	(0.05012)	(0.00451)	(0.03800)	(0.01385)	(0.05326)	(0.01069)	(0.01323)	(0.00633)	(0.00377)
	[-1.78722]	[-0.28525]	[-0.36766]	[2.31068]	[-0.42620]	[1.52555]	[1.58987]	[1.29654]	[-1.58738]	[3.87631]
R-squared	0.429976	0.324599	0.322863	0.187056	0.306124	0.159793	0.551635	0.231204	0.830101	0.691881
Adj. R-squared	0.327055	0.202651	0.200602	0.040274	0.180841	0.008089	0.470680	0.092394	0.799425	0.636248
Sum sq. resids	0.046403	0.825928	0.006697	0.474915	0.063118	0.932554	0.037549	0.057554	0.013176	0.004667
S.E. equation	0.025387	0.107104	0.009645	0.081216	0.029608	0.113807	0.022837	0.028273	0.013528	0.008051
F-statistic	4.177727	2.661790	2.640766	1.274384	2.443458	1.053324	6.814100	1.665613	27.06013	12.43658
Log likelihood	201.5347	77.73185	284.7687	101.5269	188.3064	72.51083	210.6390	192.2748	255.6718	300.3005
Akaike AIC	-4.361272	-1.482136	-6.296947	-2.035508	-4.053638	-1.360717	-4.572999	-4.145925	-5.620275	-6.658151
Schwarz SC	-3.961727	-1.082591	-5.897403	-1.635963	-3.654093	-0.961172	-4.173455	-3.746380	-5.220731	-6.258606
Meandependent	-0.007582	0.026130	0.000453	0.017265	-0.004864	0.010833	0.008089	0.002915	0.004736	0.022741
S.D. dependent	0.030947	0.119945	0.010787	0.082903	0.032713	0.114271	0.031389	0.029677	0.030205	0.013349

The final cointegrating relationship capturing domestic equity price movements illustrates the high dependence of the South African financial market on global economic conditions. While the substitution between equity and fixed assets are still significant, global and domestic interest rates are clearly very significant discounting factors. As might be expected, the positive correlation between global and domestic equity movements illustrates the relationship between domestic and global financial development while the negative sign of the exchange rate also conforms to our theoretical expectations.

4.9. Residual diagnostics and VECM stability test

Due to the fact that the VECM model will be used to simulate “economic states” in the credit portfolio model it is important that the model exhibits stability in order to avoid generating unrealistic economic realizations. As such, various diagnostic tests have been performed and are presented below to assess the appropriateness of the VECM specification and also to give comfort to the identification restrictions imposed in the system.

As presented in table 8 overall residual unit root tests assuming a common unit root process as well as individual unit root processes indicate that the null hypothesis of a unit root is rejected, while only the residual for the world output equation indicates that there is still significant information which is not captured by the model specification.

Table 8 Residual unit root and heteroskedasticity tests

Group unit root test: Summary				
Method	**Statistic**	**Prob.****	**sections**	**Obs**
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-27.9038	0.0000	10	846
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-26.6337	0.0000	10	846
ADF - Fisher Chi-square	276.153	0.0000	10	846
PP - Fisher Chi-square	288.745	0.0000	10	850
** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.				
VEC Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares) Chi-sq 1482.464, df=1430 , prob.= 0.1631				

VEC Residual Portmanteau Tests for Autocorrelations

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	31.56020	NA*	31.93150	NA*	NA*
2	104.0871	0.3699	106.1852	0.3172	100
3	216.8384	0.1970	223.0119	0.1267	200
4	350.6682	0.0233	363.3699	0.0071	300

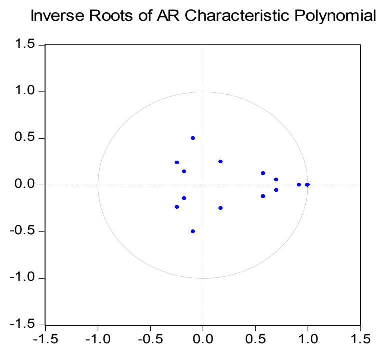
*The test is valid only for lags larger than the VAR lag order.

Residual heteroskedasticity tests also indicate that the null hypothesis of no joint residual heteroskedasticity cannot be rejected. Finally, autocorrelation tests also indicate that there are no systematic patterns in the errors up to lag 4. As such, the results indicate that the model does not suffer significant miss-specification and as result provide serial correlated or heteroskedastic error terms.

The next test for appropriateness is to assess the number of roots created in the AR characteristic polynomial. As outlined by PSW (2004) this is a significant condition which should be met for the GVAR model to be estimated as individual country specific models. In the VECM context, for a VECM with r cointegrating relations, k-r roots should be equal to unity. In current system this implies that we should have 7 (10-3) unit roots. The results of the stability conditions check is summarized in table 9 and shows that the VEC specification imposes the expected 7 unit roots and should be significantly stable when used in simulations and forecasts within the portfolio model. These results give further support to the theoretical specification and identification restrictions imposed on the model.

Table 9 Stability conditions: AR characteristic polynomial roots

Roots of Characteristic Polynomial:
VEC specification imposes 7 unit root(s)

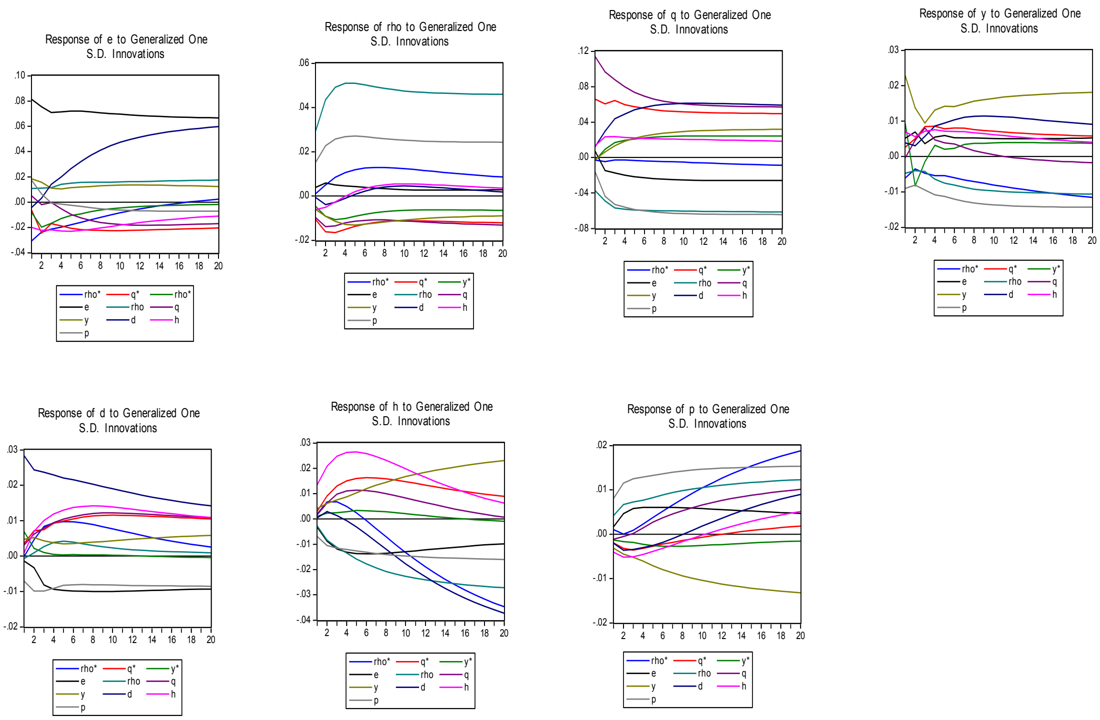


4.10. Dynamic properties of the VECM

Although the estimation output gives the elasticity of the model dependent variables to changes in the independent variables, a more satisfactory method of analysing the full dynamics and interdependencies of the model variables is to use general impulse response analysis (GIRF). Due to the unit root properties of the VECM model it is expected that shocks or changes in variables as imposed by general impulse response analysis should have transitory as well as permanent effects on other model variables. Although it is true that it is not "…possible to provide 'structural' or economic interpretation of these shocks... GIRF provide a theoretical consistent account of the interdependencies of idiosyncratic shocks" (PSW (2004)).

Due to its small open economy status, South Africa has been prone to be influenced significantly by international market developments. As such we consider the impact of a generalised one standard deviation positive shock to all the variables in the VECM and focus on the time it takes for these impacts to manifest in new equilibrium levels but more importantly focus on whether the adjustment process is smooth.

Figure 1 GIRF analyses of global macroeconomic shocks



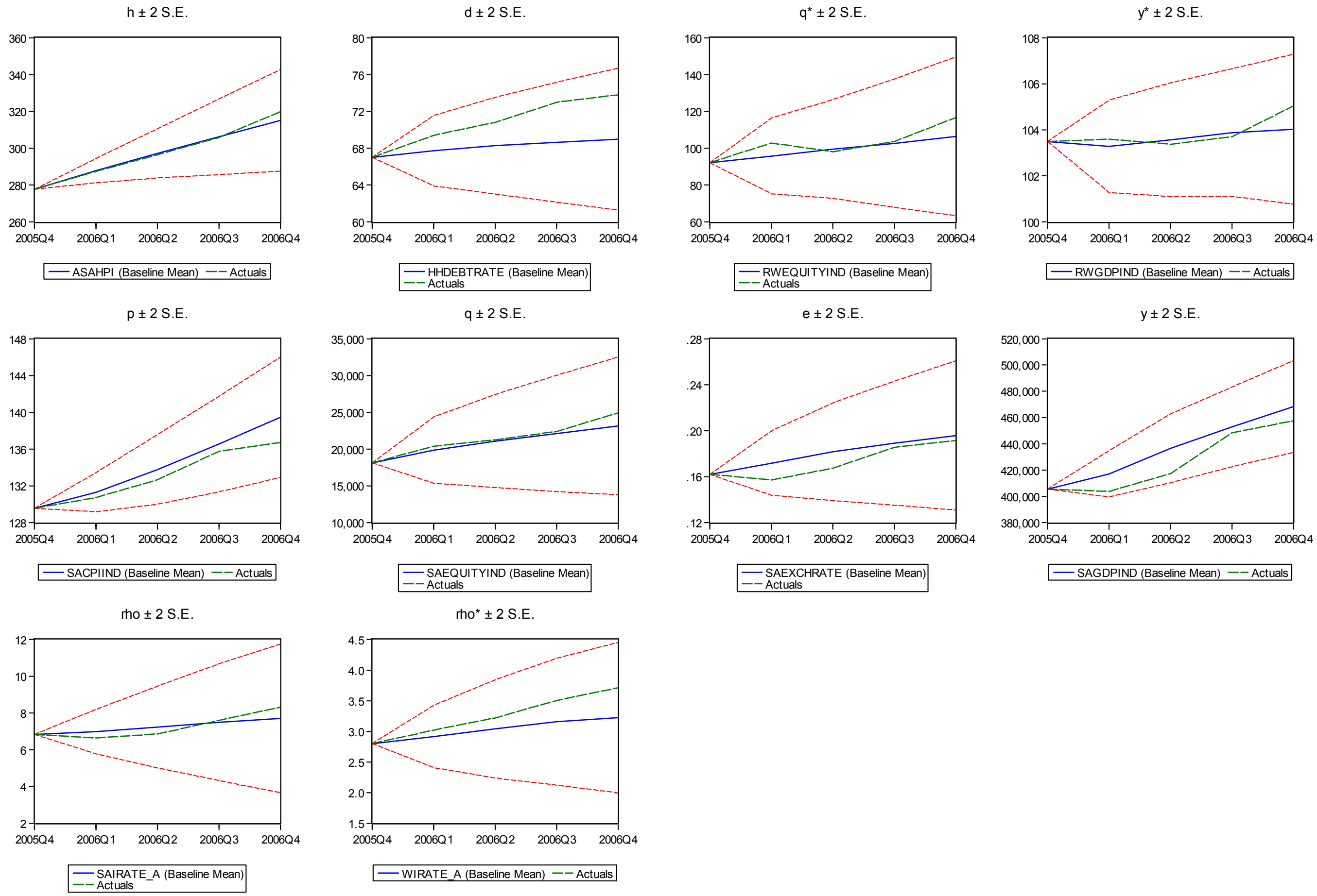
The results of the GIRF analysis are summarised in figure 1. In general, it takes shocks 20 quarters (i.e. 5 years) to result in new equilibrium levels to be achieved in the domestic market. This is consistent with the small open economy status of the South African economy and highlights the sensitivity of the domestic market to global market developments. The GIRF analysis will be employed in portfolio simulation analysis and form an integral part of the credit portfolio simulation process. The results presented here indicate that the VECM model and specification provided reasonable impact dynamics and that the model is appropriate for use in forecast and scenario generation within a credit portfolio model framework.

4.11. Stochastic forecast properties of the VECM model

The final test which is performed on the VECM model in order to assess its appropriateness within the proposed credit portfolio model context is to test the model's ability to provide reasonable stochastic forecasts. Since a typical bank assesses its conditional loss distribution over a one year period in order to allocate capital, it is essential that the VECM model provide consistent forecasts over a one year period. The estimated VECM model is therefore simulated over a one year period, in- and out-of-sample, i.e. from 2006Q1 to 2006Q4 and from 2007Q1 to 2007Q4 to assess forecast robustness.

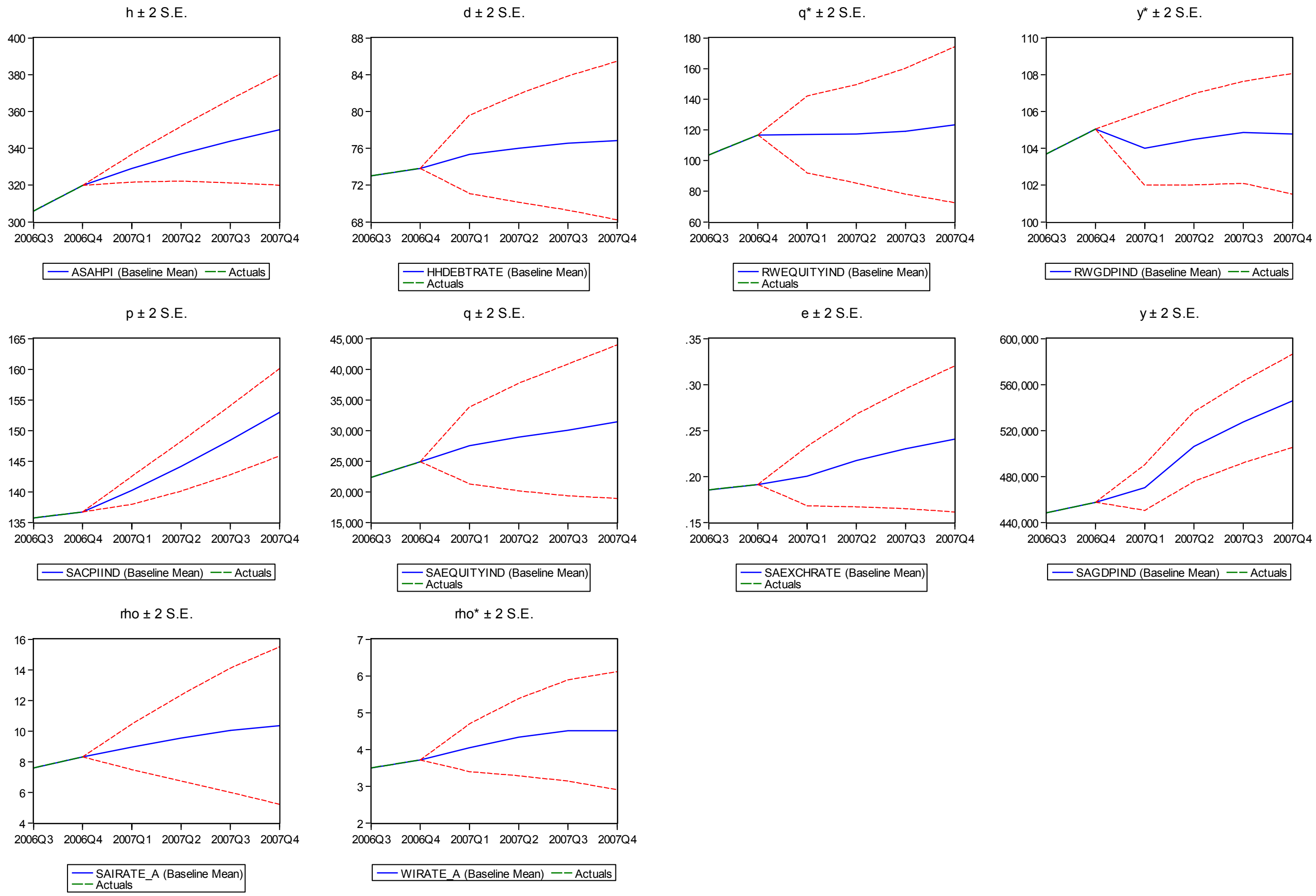
The results of the in- and out-of-sample stochastic simulations are presented in figures 2 and 3. Analysing the in-sample simulations, the VECM model predicts the actual realisation of the model variables with a high degree of accuracy and does not display any significant degree of bias in variable predictions. Moreover, although the actual variable realisation may have deviated from the model predicted or expected outcomes no such deviations fell outside the model 2-standard-error confidence intervals. As such, we conclude that the stochastic model simulation results include appropriate simulation variance to capture and include model forecast error and also provide additional variance to allow for unexpected economic events.

Figure 2 In-sample stochastic simulation results[3]



[3] Domestic variables have been converted to nominal terms for illustration and benchmarking purposes. Global variables are presented in real terms.

Figure 3 Out-of-sample stochastic simulation results[4]



[4] Domestic variables have been converted to nominal terms for illustration and benchmarking purposes. Global variables are presented in real terms.

5. Conclusion

Based on the methodology proposed by PSW (2004) and PSTW (2006) this paper proposes a South African specific credit market correlation model which could be linked to the current GVAR model proposed by PSW (2004). The model is based on a VECM system which includes credit market related domestic and global economic variables. Although PSW (2004) only places statistical exact identifying restrictions on their individual country VECM model we proposed a set of theoretical consistent over-identifying restrictions on our VECM system in order to identify coefficient estimates that conform to theoretical expectations.

Although it is not the aim of the model to provide forecast results for the global factors, but rather to provide South African specific elements to the GVAR model, in- and out-of-sample forecasts have shown that stochastic simulations are in line with actual variable realisation and expectations. As such, we argue that the correlation model could be employed as a stand-alone model within a South African specific credit portfolio management tool.

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