Vulnerability indicators: the Case of South Africa's foreign exchange market[*]

Siobhan Redford and Logan Rangasamy[†],

31 August 2017

Abstract

This study uses the EMP index to identify periods during which the South African economy was subjected to exchange market pressure. Further, using the early warning signalling approach, a number of indicators which lead the crisis periods are also identified. The area of research undertaken in this study provides useful information about the channels of external vulnerability that affect the economy, something that is of particular interest to policy formulation in South Africa.

JEL Classification: E32, E44, E51, F47

Keywords: Vulnerability, Exchange Rate, Crisis, Leading indicator

PRELIMINARY DRAFT

PLEASE DO NOT QUOTE.

[*]The views expressed are those of the author(s) and do not necessarily represent those of the South African Reserve Bank or the policies of the SARB. The authors are grateful to colleagues at the SARB for comments on an earlier draft but remain responsible for any remaining errors/

[†] South African Reserve Bank

Contents

1. Introduction

The Global Financial Crisis has renewed interest in the identification of "early warning indicators" of a country's exposure to economic risks (Alessi and Detken, 2011; Rose and Spiegel 2011,). Röhn et al. (2015) provide an extensive review of the early warning indicators on currency, banking, and sovereign debt crises which Hermansen and Röhn (2015) show are very useful in signalling recessions and crises in OECD economies between 1970 and 2014. This paper follows a similar approach with the focus however, being on the identification of vulnerability indicators for South Africa's foreign exchange market.

This paper has two main objectives. Firstly, to determine the periods when South Africa's foreign exchange market has come under pressure. Secondly, to identify the indicators that could assist in signalling pressure in these exchange market.

This paper follows the convention in the empirical work on this subject matter by using an index of exchange market pressure to identify the crisis periods after which the "early warning signal approach" is employed to identify some leading indicators which help to identify the build-up of pressure in the foreign exchange market.

2. Literature Review

Transmission of shocks across borders has increased with the rise in globalisation. In general, the transmission of these shocks have been through the trade and financial channels (Eichengreen and Rose, 1999; Glick and Rose, 1999; Forbes, 2001; Kaminsky and Reinhart, 1999, 2003; van Rijckeghem and Weder, 2001; Fratzscher, 2000; Caramazza, Ricci, and Salgado,2000). Evidence suggests that financial shocks could be related to trade flows (Forbes and Chinn, 2004).

The rise in financial integration has led to the exchange rate becoming an important channel of transmission of spill-over effects (Takats and Vela, 2014; Mohanty, 2014). Currency depreciations are one of the defining characteristics for a financial crisis (Edwards, 1989; Edwards and Montiel, 1989; Edwards and Santaella, 1993; Frankel and Rose, 1996; Milesi-

Ferretti and Razin, 1998; Collins, 1995; Flood and Marion, 1995; Kaminsky, 1988; Klein and Marion, 1994).[1] A sudden stop in capital flows has been associated with a currency crisis (Hutchison and Noy, 2006; Arteta et al, 2003; Razin and Rubinstein, 2004). Sudden stops in capital inflows or a sudden rise in capital outflows exerts pressure on the exchange rate with adverse consequences for domestic demand and the real economy (Calvo, Izquierdo and Mejia, 2004; Calvo, Izquierdo and Talvi, 2003; Eichengreen and Choudhry, 2005).

Aizenman et al. (2010) analysed the extent to which crises are manifested in exchange market pressures (EMP) for emerging market economies (EMEs). The EMP index has also been used to examine the extent to which the global financial crisis was transmitted to EMEs (Aizenman and Hutchison, 2012). Feldkircher et al. (2014) have examined whether pre-crisis leading indicators highlighted exchange rate pressures that emerged during the global financial crisis.[2]

The EMP index has also been used to extract information about the potential impact on a currency from contagion effects (Tatomir, 2009). Eichengreen et al. (1994) use the EMP to determine a country's vulnerability to currency crises. The EMP has been also been used to analyse exchange rate regimes (Frankel and Wei, 2008; Van Poeck et al. (2007) and by Rose and Svensson (1994)) to analyse the credibility of the European exchange rate system before the European Monetary System crisis between 1992 and 1993.

3. Overview of the Exchange Market Pressure Index

The concept of exchange market pressure (EMP) has its origins in a seminal paper by Girton and Roper (1977) which used a monetary model to identify pressure in the Canadian foreign exchange market. Weymark (1995) formalised the model by defining EMP as a weighted sum of exchange rate depreciation and international reserve losses, with other researchers also adding the interest rate to the model. The purpose of including international reserves

[1] See Kaminsky et al (1998) for a summary of 28 studies on currency crises for the pre-1990 period.
[2] Following the most recent global financial crisis, the identification of leading indicators as predicators of crises has come under the spotlight (Rose and Spiegel, 2009; Frankel and Saravelos, 2010).

and the interest rate is meant capture the policy effects on exchange rate movements. Exchange rate movements could be affected by changes in the policy rate (interest rate) and/or in international reserves. This has become popular in the empirical work on the identification of currency crises.

Changes in the EMP index indicate increasing or decreasing exchange market pressures. A rise in the value of the index depicts selling pressure on the domestic currency. A crisis period is characterised by a significant rise in the EMP index. Various methods have been used to determine the threshold for the identification of the crisis period and are detailed below.

There have been a number of approaches to calculating the EMP indices. These have included using the data in standardised form, but equally weighted, to weightings which are dependent on the standard deviation or by considering the relative standard deviation of the different variables used.

Herrera and Garcia (1999) define an index of Speculative Pressure (ISP_t):

$$ISP_t = standardise(\%\Delta e_t) + standardise(\%\Delta i_t) - standardise(\%\Delta r_t) \quad \text{.....(1)}$$

where (e_t) = the exchange rate; (i_t) = the interest rate; (r_t) = reserves; $(\%\Delta)$ = the percentage change. All the changes are standardised

Eichengreen, Rose and Wyplosz (1996) calculate the Exchange Market Pressure as follows:

$$EMP_t = \frac{\%\Delta e_t}{\sigma_e} - \frac{\%\Delta r_t}{\sigma_r} + \frac{\Delta i_t}{\sigma_i} \quad \text{.....(2)}$$

$$EMP_t = \frac{\%\Delta e_t}{\sigma_e^2} - \frac{\%\Delta r_t}{\sigma_r^2} + \frac{\Delta i_t}{\sigma_i^2} \quad \text{.....(3)}$$

Sachs, Tornell and Velasco (1996)

$$EMP_t = \frac{\sigma_c}{\sigma_e}\%\Delta e_t - \frac{\sigma_c}{\sigma_r}\%\Delta r_t + \frac{\sigma_c}{\sigma_i}\Delta i_t \quad \text{.....(4)}$$

where $\sigma_c^{-1} = \frac{1}{\sigma_e} + \frac{1}{\sigma_r} + \frac{1}{\sigma_i}$

Kaminsky, Lizondo and Reinhart (1998)

$$EMP_t = \%\Delta e_t - \frac{\sigma_e}{\sigma_r}\%\Delta r_t + \frac{\sigma_e}{\sigma_i}\Delta i_t \quad \text{.....(5)}$$

Klaasen and Jager (2011) have proposed an amendment to the standard calculations for EMP which they demonstrate is consistent with the definition of EMP. At the crux of this is that the interest rate should not be a spread with the rest of the world, or a time series change. Instead, the interest rate term should be the difference in the actual interest rate and what they term the counterfactual interest rate.[3]

4. Data and Methodology

The data pertaining to the nominal effective exchange rate (NEER), bank rate and international reserves used for the calculation of the EMP was sourced from the South African Reserve Bank (SARB). The NEER and international reserves enter all calculations as inverses. Additional data for the calculation of the Klaasen-Jager definition-consistent interest rate was sourced from Haver analytics.[4] The data is of monthly frequency and spans the period, January 1992 to May 2017. The analysis focuses on year-on-year percentage changes (percentage changes hereafter) which remove seasonality from the data and also results in less volatile variables.

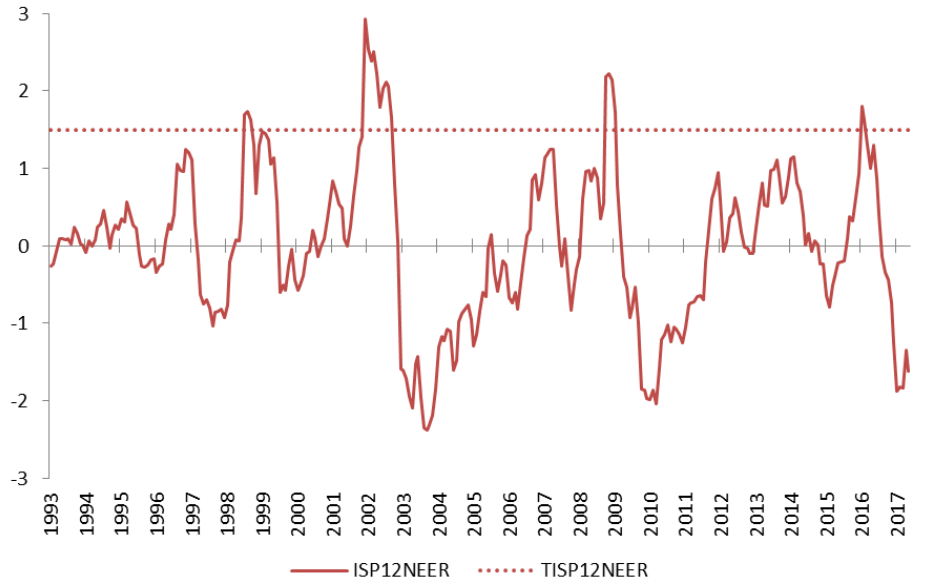
We start off by calculating a basic crisis benchmark indicator using only the normalised percentage change in the NEER, and identify crises as the periods in which the NEER

[3] The form offered for the counterfactual interest rate is:
$i_t^d = i_t^* + (\pi_t^e - \pi_t^{*e}) + \gamma^*(g_t - g_t^*) + (\gamma - \gamma^*)g_t + \left(r_t^{eq} - r_t^{*eq}\right)$
Where i_t^d is the counterfactual interest rate, i_t^* the foreign short term interest rate (in fact, all variables with star superscripts indicate that the variables are for foreign counterparts), π_t^e is inflation expectations, g_t indicates the inflation rate gap and the output gap, r_t^{eq} is the real equilibrium interest rate.

[4] The foreign short term interest rate is the effective federal funds rate. In addition, inflation expectations have been proxied by producer price inflation for South Africa and the US. The reason for this is that inflation expectations for South Africa were not collected in the form of surveys or breakeven rates until the late nineties. In addition, the inflation and growth gap contributed very little to the measure and thus have been excluded for the purposes of analysis.

breached 1.5 times the standard deviation (see figure 1). The crisis periods using this benchmark are reflected in table 1.

Figure 1: Normalised Nominal Effective Exchange Rate and 1.5 SD threshold



Thereafter, the EMP indices as depicted by equations 1 to 5 are calculated using both rand and dollar denominated foreign reserves. To identify crises for each EMP we have set the threshold at the mean+1.5*(standard deviation) over the full period for each index. EMP indices given by equations 2, 4 and 5, are strongly correlated and hence the rest of our analysis only considers equations 1, 2 and 3.

The crisis periods identified on the basis of equations 1,2 and 3 are are reflected in Table 1.

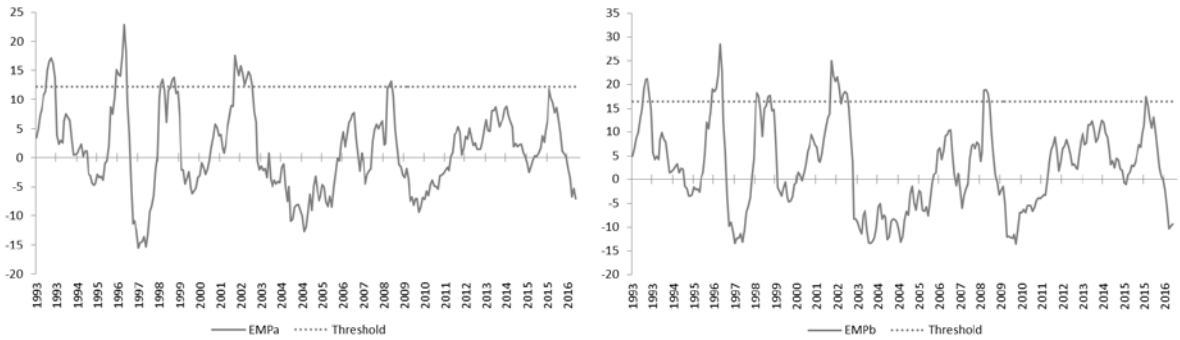
Table 1: Identified crises from EMP indices

NEER crises			Variance weighted EMPa			Variance weighted EMPb			ISPa			ISPb			SD weighted EMPa			SD weighted EMPb		
Begin	*End*	*Duration*	*Begin*	*End*	*Duration*	*Begin*	*End*	*Duration*	*Begin*	*End*	*Duration*	*Begin*	*End*	*Duration*	*Begin*	*End*	*Duration*	*Begin*	*End*	*Duration*
			Jul-93	Nov-93	5 months	Jul-93	Oct-93	4 months	Apr-93	Nov-93	8 months	May-93	Nov-93	7 months	Apr-93	Nov-93	8 months	May-93	Nov-93	7 months
			Aug-96	Jan-97	6 months	Aug-96	Jan-97	6 months	May-96	Feb-97	10 months	May-96	Feb-97	10 months	May-96	Feb-97	10 months	May-96	Feb-97	10 months
Jul-98	Sep-98	3 months	Aug-98	Mar-99	8 months	Aug-98	Mar-99	8 months	Jul-98	May-99	11 months	Jul-98	May-99	11 months	Jul-98	May-99	11 months	Jul-98	May-99	11 months
Dec-01	Sep-02	10 months	Dec-01	Sep-02	10 months	Dec-01	Aug-02	9 months	Jun-03	Nov-03	6 months	Dec-01		1 month	Jun-03	Nov-03	6 months	Dec-01	1 month	
Oct-08	Jan-09	4 months	Nov-08	Dec-08	2 months	Oct-08	Dec-08	3 months												
Jan-16	Feb-16	2 months				Jan-16		1 month												

Note: The Variance weighted EMP indices referred to in the above table have been calculated using equation 3. ISPa and ISPb have been calculated using equation1, and SD weighted EMPa and EMPb are standard deviation weighted EMP's. The 'a' suffix indicates that the index has been calculated using rand-denominated foreign reserves while the 'b' suffix indicates the use of dollar-denominated foreign reserves.

The identified crisis periods are very similar, however the periods identified by equations 1 and 2 do not capture developments during the great financial crisis. Additionally identification of the 2001 exchange rate crisis is very lagged by these indices. It is for this reason that we will proceed with analysis based on the crises identified by equation 3 (EMPb) which is intuitively more accurate and in line with the crisis periods highlighted by the benchmark indicator in Figure 1.

Figure 2: Index of Exchange Market Pressure



Note: These EMP indices have been calculated from equation 2 in the text, EMPa (left-hand graph), consistent with the description in table 1, includes the percentage change in the NEER, the difference between the bank rate and definition-consistent exchange rate and the percentage change in rand-denominated foreign reserves. EMPb (right-hand graph) is the similar to EMPa, but includes the percentage change dollar-denominated foreign reserves rather than rand-denominated.

Figure 2 depicts the EMP index is calculated on the basis of equation 2 and is used in the analysis in this paper. EMPa (left-hand graph), consistent with the description in table 1, includes the percentage change in the NEER, the difference between the bank rate and

definition-consistent interest rate and the percentage change in rand-denominated foreign reserves. EMPb (right-hand graph) includes the percentage change dollar-denominated foreign reserves.

The next section will attempt to identify some indicators that could serve as early warning signals to the buildup of pressure in the foreign exchange market.

5. Early Warning Signals

A number of series were used to test for their viability as leading indicators of a foreign exchange crisis (see appendix for full list). The series were transformed into month-on-month (m-o-m) and year-on-year percentage changes.

As in Kaminsky et al (1998), the identification of a signal for these series was chosen according to a threshold that minimised the noise-to-signal ratio.[5] A dummy was created whenever the indicator series rose above (fell below) the different thresholds for each variable at each point in time.[6] A signal was then extracted when the variables rose above (below) the thresholds within 24 months of an identified crisis. Noise was identified when the variable breached the threshold when there was no crisis within 24 months. We then calculated the noise-to-signal ratio for each variable with each threshold. The threshold chosen for each indicator was then chosen according to which threshold resulted in the lowest noise-to-signal ratio. These variables are monthly and span the period January 1990 to December 2015.

Table 2 reflects the variables that were most successful (lowest noise to signal ratio) at identifying the crisis in the foreign exchange market. These all have noise-to-signal ratios below 1 – such that the percentage of good signals as a percentage of possible good signals exceeded the percentage of bad signals as a percentage of possible bad signals. We further

[5] In this case the 80 per cent to 90 per cent (and 20 per cent to 10 per cent) thresholds were identified for each variable using 1 percentage point steps – thus defining 11 thresholds per variable.
[6] The choice of the right or left tail thresholds was according to whether the variable indicated pressure by increasing or falling, for example a significant fall in manufacturing would signal pressures in the economy, thus manufacturing was evaluated against the 10 per cent to 20 per cent thresholds.

calculated the difference between the conditional probability of a crisis and the unconditional probability of a crisis for each of the possible leading indicators. Those reported all enhanced the probability of identifying a crisis taking into account a signal against the unconditional probability by over 6 percentage points.

The identified indicators include, domestic credit extension, non-resident bond flows, the All Share index, domestic private loans and advances, M2, mom inflation, loans extended to banks by the SARB, the difference between South African m-o-m inflation and the United States' m-o-m inflation, manufacturing production, and the real effective exchange rate (see table 2).

Table 2: Early warning indicators

	Good signals as a percentage of possible good signals	Bad signals as a percentage of possible bad signals	Noise to signal	P(crisis|signal)	P(crisis)	Pr(crisis|signal) P(crisis)
	A	*B*	*(B/A)*	*C*	*D*	*(C-D)*
Domestic credit	17.5	4.6	0.26	75.0	43.9	31.1
Non-resident bond flows	21.7	10.2	0.47	61.0	42.3	18.7
All-share index	16.8	8.6	0.51	60.5	43.9	16.6
Domestic private loans and advances	15.3	8.0	0.52	60.0	43.9	16.1
M2	21.9	11.4	0.52	60.0	43.9	16.1
Consumer price index (CPI)	18.2	10.9	0.59	56.8	43.9	12.9
Domestic private credit extension	13.1	8.0	0.61	56.3	43.9	12.3
Bank liabilities to SARB	12.8	8.3	0.65	55.2	44.3	10.8
CPI gap	21.9	14.9	0.68	53.6	43.9	9.7
Manufacturing production	13.1	9.7	0.74	51.4	43.9	7.5
Real effective exchange rate	13.9	10.9	0.8	50.0	43.9	6.1

Note: Column A represents the number of times a signal was issued within 24 months before a crisis was dated as a percentage of all possible periods in which a good signal could be issued, similarly, column B represents the number of times a signal was issued as a percentage of those periods that were not within 24 months of a dated crisis. The noise-to-signal ratio is then a ratio of these two figures. P(crisis|signal) is calculated as the number of times a good signal was issued as a percentage of all signals issued. P(crisis) is the number of good signals over the full period of observations available for each indicator.

6. Areas for further Research

The robustness of the results in this paper could be enhanced by considering other real economy and financial variables that have been used in the studies. The effectiveness of the best indicators can also be enhanced by combining them into an index as was undertaken in the study by Kaminsky (1999).

This analysis has employed a simple approach to looking at the tail events that indicate crisis periods. A more formal approach using extreme value theory could be used to test the robustness of the results in this paper. In addition, there are also a number of parametric approaches to assessing vulnerabilities which could also be considered.

7. Conclusion

This study has used the EMP index to identify periods during which the South African economy was subjected to exchange market pressure. Using the early warning signalling approach, a number of indicators which lead the crisis periods were also identified. The results in this paper could be useful in developing a composite leading indicator for identifying pressure in South Africa's foreign exchange market. The area of research undertaken in this study provides useful information about the channels of external vulnerability that affect the economy, something that is of particular interest to policy formulation in South Africa

8. References

Arteta, C.O., Eichengreen, B., Wyplosz, C. 2003. On the growth effects of capital account liberalization. Economic Policy in the International Economy: Essays in Honor of Assaf Razin. Helpman E.,Sadka, E. Eds. Cambridge University Press.

Calvo, Guillermo A., Alejandro Izquierdo and Luis-Fernando Mejia (2004) On the Empirics of Sudden Stops: the Relevance of Balance-Sheet Effects. NBER Working Paper 10520

Calvo, Guillermo A., Alejandro Izquierdo and Ernesto Talvi (2003) Sudden Stops, the Real Exchange Rate, and Fiscal Sustainability: Argentina's Lessons. NBER Working Paper 9828

Caramazza, Francesco, Luca Antonio Ricci, and Ranil Salgado, 2000, "Trade and Financial Contagion in Currency Crises," IMF Working Paper 00/55 (Washington: International Monetary Fund).

Eichengreen, B. and Choudhry, O. (2005) "Managing Capital Inflows: Eastern Europe in an Asian Mirror", Paper presented at the Turkish Central Bank and Center for European Integration Studies Conference on Macroeconomic Policies for EU Accession, Ankara, 6-7 May.

Eichengreen, B., Rose, A. K. and Wyplosz, C., 1994. "Speculative attacks on pegged exchange rates: an empirical exploration with special reference to the European Monetary System", NBER working Paper no 4898, NBER.

Eichengreen, B., and Rose, A. 1999, "Contagious Currency Crises: Channels of Conveyance," in Changes in Exchange Rates in Rapidly Developing Economies, ed. by Takatoshi Ito and Anne Krueger (Chicago: University of Chicago Press).

Forbes, K. 2001, "Are Trade Linkages Important Determinants of Country Vulnerability to Crises?" NBER Working Paper No. 8194 (Cambridge, Massachusetts: National Bureau of Economic Research).

Forbes, Kristin, and Menzie D. Chinn, 2004, "A Decomposition of Global Linkages in Financial Markets Over Time," *The Review of Economics and Statistics*, Vol. 86, No. 3, pp. 705–22.

Frankel, J. A. and Wei, S.-J., 2008. "Estimation of de facto exchange rate regimes: synthesis of the techniques for inferring flexibility and basket weights". IMF Staff Papers, 55 (3), 384-416.

Fratzscher, Marcel, 2000, "On Currency Crises and Contagion," Peterson Institute for International Economics Working Paper No. 00–9 (Washington: Peterson Institute for International Economics).

Forbes, Kristin, 2001, "Are Trade Linkages Important Determinants of Country Vulnerability to Crises?" NBER Working Paper No. 8194 (Cambridge, Massachusetts: National Bureau of Economic Research).

Girton, L., Roper, D., 1977. A monetary model of exchange market pressure applied to the postwar canadian experience. Am. Econ. Rev. 67, 537–548.
Glick, Reuven, and Andrew K. Rose, 1999, "Contagion and Trade: Why Are Currency Crises Regional?" *Journal of International Money and Finance*, Vol. 18 (August), pp. 603–17.

Kaminsky, Graciela L., and Carmen M. Reinhart, 1999, "The Twin Crises: The Causes of Banking and Balance-of-Payments Problems," *American Economic Review,* Vol. 89 (June) pp. 473–500.

Kaminsky, Graciela L., and Carmen M. Reinhart, 2003, "The Center and the Periphery: The Globalization of Financial Turmoil," NBER Working Paper No. 9479 (Cambridge, Massachusetts: National Bureau of Economic Research).

Mohanty, M. S., 2014, "The transmission of unconventional monetary policy to the emerging markets-An overview," BIS Papers, no: 78.

Kaminsky, G. (1999). "Currency and Banking Crises: The Early Warnings of Distress". IMF Working Paper, WP/99/178.

Kaminsky, Graciela, Saul Lizondo, Carmen M. Reinhart (1998). "Leading Indicators of Currency Crises". IMF Staff Papers, Vol. 45, No. 1 (March 1998).

Razin, A. and Y. Rubinstein. 2004. "Exchange Rate Regimes, Capital Account Liberalization and Growth and Crises: A Nuanced View", mimeograph. Israel: Tel Aviv University.

Rose, A. K. and Svensson, L. E. O., 1994. "European exchange rate credibility before the fall". European Economic Review, 38, 1185-1216.
Supriyadi, A. 2014. External Vulnerability Indicators: The Case of Indonesia, Bank of Indonesia, Paper delivered at the Seventh IFC Biennial Conference on 4 – 5 September 2014

Tatomir, S. (2009). Exchange Market Pressure on the Croatian Kuna Financial Theory and Practice 33 (2) 187-199.

Takats, Elod and Vela, Abraham, 2014, "International Monetary Policy Transmission," BIS Paper No. 78b, Bank for International Settlements, Basel.

Van Poeck, A., Vanneste J. and Veiner, M., 2007. "Exchange rate regimes and exchange market pressure in the new EU member states". Journal of Common Market Studies, 45, 459-485.

van Rijckeghem, Caroline, and Beatrice Weder, 2001, "Sources of Contagion: Is It Finance or Trade?" *Journal of International Economics*, Vol. 54, No. 2, pp. 293–308.

Appendix

Tested leading indicators of EMP crises	Sources
All monetary institutions: Total domestic credit extension	KBP1368M
All monetary institutions : Credit extended to the domestic private sector: Total loans and advances	KBP1369M
All monetary institutions: Total credit extended to the private sector	KBP1347M
Monetary sector assets: Claims on the government sector - Total credit	KBP1353M
Manufacturing: Total volume of production (Manufacturing)	KBP7085N
Real effective exchange rate of the rand: Average for the period - 20 trading partners - Trade in manufactured good	KBP5392M
Monetary aggregates / Money supply: M2	KBP1373M
Total gold and other foreign reserves of the Reserve Bank : Amount as at end of period	KBP5273M
Ratio of M2 to Foreign Reserves	own calculations
Liabilities of banking institutions: Total deposits	KBP1077M
Net purchases of shares by non-residents on the Johannesburg Stock Exchange (JSE)	KBP2050M
Share prices: All shares	KBP2077A
Net purchases of bonds by non-residents on the Bond Exchange of South Africa (BESA)	KBP2051M
Bankrate (lowest rediscount rate at SARB)	KBP1401M
Liabilities of banking institutions	KBP1500M+KBP1501M+KBP1514M
US month-on-month consumer price inflation	OECD statistics
US year-on-year consumer price inflation	OECD statistics
SA month-on-month consumer price inflation	Statistics South Africa
SA year-on-year consumer price inflation	Statistics South Africa
SA m-o-m inflation - US m-o-m inflation	own calculations
SA y-oy inflation - US y-o-y inflation	own calculations

Source: SARB and Statistics South Africa