

# Institut für *Halle Institute for Economic Research* Wirtschaftsforschung Halle



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October 2006

Nr. 19

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## Signaling currency crises in South Africa

### Abstract

Currency crises episodes of 1996, 1998, and 2001 are used to identify common country specific causes of currency crises in South Africa. The paper identifies crises by the use of an Exchange Market Pressure (EMP) index as introduced by Eichengreen, Rose and Wyplosz (1996). It extends the Signals Approach introduced by Kaminsky and Reinhart (1996, 1998) by developing a composite indicator in order to measure the evolution of currency crisis risk in South Africa. The analysis considers the standard suspects from international currency crises and country specifics as identified by the Myburgh Commission (2002) and current literature as potentially relevant indicators.

**Keywords:** signals approach, currency crises, South Africa

**JEL classification:** E5, F3, G1

### Zusammenfassung

Diese Arbeit betrachtet die südafrikanischen Währungskrisenepisoden von 1996, 1998 und 2001, um gemeinsame länderspezifische Ursachen für Währungskrisen in Südafrika zu ermitteln. Die Identifikation der Währungskrisen erfolgt mittels des Exchange Market Pressure Indexes, welcher von Eichengreen, Rose und Wyplosz (1996) entwickelt wurde. Dann wird ein Signalansatz, basierend auf Kaminsky und Reinhart (1996, 1998) verwendet, um mit dessen Hilfe das Risiko für Währungskrisen in Südafrika zu evaluieren. Die Arbeit berücksichtigt als potentielle Einflussgrößen die üblichen Variablen aus der Währungskrisentheorie sowie länderspezifische Faktoren, welche sich aus dem Bericht der Myburgh Commission (2002) und aktueller Literatur ergeben.

**Schlagworte:** Signalansatz, Währungskrisen, Südafrika



## 1 Introduction

As most of the emerging market economies, South Africa is facing turbulences on foreign exchange markets, which appear in form of high volatility in prices of its domestic currency, the South African rand. The increased volatility of exchange rates in emerging markets is usually attributed to the smaller size of their economies and consequently the smaller size of the market for their currency. Under these conditions transactions have a greater impact on exchange rates than in larger and more mature economies. Additionally, a generally higher risk of investment projects and the macroeconomic, as well as political, stability are recognized as reasons for a higher variance in currency markets. Higher exchange rate volatility in emerging market countries is therefore a comprehensible expectation and reflects fundamental differences in the structure of economies.

However, if exchange rate volatility increases drastically it can evolve into a currency crisis, which results in significant depreciation of the domestic currency. These depreciation episodes are often accompanied by interventions of central banks by raising interest rates and buying domestic currency with their foreign exchange reserves. If interventions are not successful, currency crises may cause microeconomic distortions mainly in the financial sector but also in the import and foreign finance dependent sectors of the economy. On a macroeconomic level currency crises may result in instability of further aggregates such as the domestic price level and also lower economic growth. Furthermore, the costliness of exchange rate interventions is one of the reasons why a number of central banks, including the South African Reserve Bank since 2000, opt against regular intervention on foreign exchange markets and rather take the crises as given evil.

In any case, central banks and the private sector are dependent on evaluating the future risk of currency crises in order to prepare policy measures or to either hedge or stay away from certain types of transactions. The literature describes different concepts of how to signal or forecast currency crises. One line of concepts are signals approaches (Kaminsky and Reinhart, 1996, 1998). This paper employs such a signals approach for the case of South Africa in order to inquire into country specific determinants of currency crises.

The remainder of the paper is structured as follows. In the following section the definition of currency crises is discussed resulting in the identification of an appropriate measure of currency crises. The third section aims at identifying currency crises in South Africa. The fourth section introduces the concept of the signals approach. The fifth section employs the signals approach to the South African case. The sixth section concludes.

## 2 Identifying currency crises – A literature review

Broad definitions of currency crises include one common element: the significant loss of value of the domestic currency.<sup>1</sup> The event of significant depreciation or devaluation of a currency is called a crisis since it has been shown that such an event may trigger microeconomic distortions resulting in financial or banking crises. This could cause macroeconomic aggregates to be negatively affected, e.g. by higher inflation rates or lower economic growth. Consequently some authors use a certain percentage fluctuation in the value of a currency within a certain time period as the indicator of a currency crisis. For instance Brüggemann and Linne (2002) define a 20 percent depreciation within ten trading days as a currency crisis.

Not only the actual depreciation or devaluation of a currency can be associated with economic losses, but also efforts to avoid or stop the fall of the currency can be costly. Therefore, most definitions of currency crises also include interventions by the respective central banks. These interventions can take the form of increases in interest rates – in order to make the domestic currency more attractive to investors – and interventions in foreign exchange markets – in order to stabilize the demand for the domestic currency to avoid price reactions.<sup>2</sup> All three measures are combined in the Exchange Market Pressure (EMP) index. A general expression of the EMP index is:<sup>3</sup>

$$EMP_{i,t} = \alpha \cdot \Delta e_{i,t} + \beta \cdot \Delta i_{i,t} + \gamma \cdot \Delta r_{i,t} \quad (1)$$

The EMP is the weighted sum of the percentage change in the exchange rate of country  $i$  at time  $t$  ( $\Delta e_{i,t}$ ), changes in interest rates ( $\Delta i_{i,t}$ ) and the percentage change in foreign exchange reserves ( $\Delta r_{i,t}$ ).  $\alpha, \beta, \gamma$  are the weights of the respective measures. The signs of the measures are adjusted so that an increase of the measure indicates increasing pressure. A crisis is indicated if the following condition holds:

$$CRISIS = \begin{cases} 1, & \text{if } EMP_{i,t} > \mu_{EMP} + \delta \cdot \sigma_{EMP} \\ 0, & \text{otherwise} \end{cases} \quad (2)$$

A crisis is indicated if the current value of the EMP index exceeds the mean of the EMP time series ( $\mu_{EMP}$ ) plus the standard deviation of the EMP time series ( $\sigma_{EMP}$ ) multiplied by a weight ( $\delta$ ).

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1 Compare Angkinand, Li, Willett (2006), Calvo, Reinhart (1999: 26), Gerber (2002, p. 264).

2 Kaminsky, Reinhart (1996, p. 4), Eichengreen, Rose, Wyplosz (1996, pp. 474-475).

3 Compare Bhundia, Ricci (2005, p. 157)

While the empirical literature on currency crises widely uses this general framework, it differs notably on the details of EMP definition and the crisis threshold. With respect to equation (1), there are versions of the equation that use changes in the interest rate differential to a reference country instead of changes in domestic interest rates alone. There are also variations in which changes of currency reserves relative to monetary aggregates are used instead of foreign currency reserves of the country of interest itself.<sup>4</sup> Most importantly, differences lie in the calculation of the weights  $\alpha, \beta, \gamma$ . Some studies set one or two of the weights equal to zero. It is sometimes argued that adequate interest rate data is not available for emerging market economies and  $\beta$  is therefore set at zero.<sup>5</sup> In other studies it has been argued that interventions in foreign exchange markets play a minor role, e.g. because a central bank opts not to intervene in currency markets or because reserves fluctuate too much in non-crisis times due to other reasons which overlay the currency crisis effect, therefore  $\gamma$  is set at zero.<sup>6</sup> One rather common way of tackling the weighting problem is to weight the (remaining) measures according to their inverse standard deviations. The so-calculated weights can be normalized to sum up to unity if each weight is divided by the sum of the inverse standard deviations of all measures, e.g.  $\alpha$  would be:<sup>7</sup>

$$\alpha = \frac{1/\sigma_e}{1/\sigma_e + 1/\sigma_r + 1/\sigma_i} \quad (3).$$

This means that a large variance of one measure would result in a lower weight of this measure compared to the other measures entering the EMP equation. The calculation of this so-called precision weights is disputed in the literature, especially because of the understatement of unsuccessful speculation against fixed exchange rates and an overstatement of successful speculation (high weights on the fixed exchange rate, low weights on the volatile reserves).<sup>8</sup> If the fluctuation of exchange rates would be close to zero, the relative weight of reserves would also be closed to zero.

With regard to the crisis threshold, equation (2), there are also wide differences in its use in literature. While the general framework is used in most studies, the differences lie in the weight ( $\delta$ ) of the standard deviation of the EMP index that spans a value range of

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4 See *Eichengreen, Rose, Wyplosz* (1996, p. 457), *Girton, Roper* (1997).

5 E.g. *Aziz, Caramazza, Salgado* (2000), *Kaminsky, Reinhart* (1999), *Glick, Hutchison* (2001). Most of the citations in this section are adopted from *Angkinand, Li, Willett* (2006), who provide an excellent overview over different EMP variations.

6 E.g. *Bubula, Otker-Robe* (2003).

7 See *Angkinand, Li, Willett* (2006).

8 See *Angkinand, Li, Willett* (2006), *Eichengreen, Rose, Wyplosz* (1995).



1.5 in some studies to 3.0 in others.<sup>9</sup> Obviously this may have an effect on calling an event a crisis. Besides the above mentioned use of changes in exchange rates as crises indicator there are also authors which use a combination of the EMP based crises indication and an exchange rate measure. Thus a crisis is called a crisis if equation (2) is fulfilled and if the exchange rate depreciated by a certain percentage change over some time.<sup>10</sup>

Acknowledging the various types of crises identification frameworks, the following section employs different versions in order to confirm the existence of South African currency crises seen in the literature and to evaluate their robustness to changes in the type of the framework.

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<sup>9</sup> “1.5” is used in *Eichengreen, Rose, Wyplosz* (1996, p. 475); *IMF* (1998), *Aziz, Caramazza, Salgado* (2000); *Ahluwalia* (2000); *Bordo et al.* (2001). “1.645” is used in *Caramazza, Ricci, Salgado* (2000); *Bhunia, Ricci* (2005). “1.7” is used by *Kamin, Schindler, Samuel* (2001). “2.0” is used in *Eichengreen, Rose, Wyplosz* (1994); *Glick, Hutchinson* (2001). “2.5” is used *Edison* (2000). “3.0” is used by *Kaminsky, Reinhart* (1999); *Berg, Patillo* (1999a); *Bubula, Otker-Robe* (2003). More detailed surveys can be found in *Angkinand, Li, Willett* (2006) and *Abiad* (2003).

<sup>10</sup> E.g. *Moreno* (2000, p. 12) uses the additional criterion of 25 percent annual depreciation.

### 3 Identifying currency crises in South Africa

The literature identifies various currency crises in the recent past of South Africa. Bhundia and Ricci (2005: 156) identify currency crises between the end of April and the end of August 1998 and also between the end of September and the end of December 2001. Aron and Muellbauer (2000: 19-20) identify currency crises in February 1996 (the first South African currency crisis), in October 1996, November 1997 and April 1998. Interestingly enough, Aron and Muellbauer (2005) do *not* call the 2001 “event” a currency crisis (see Box 1).

Box 1:

Events commonly referred to as currency crises in South Africa

**February-April 1996:** South Africa was confronted with large capital inflows after the successful elections in 1994. The Reserve Bank was following a dual strategy: an interest rate policy based on monetary targets and a nominal exchange rate stabilization policy. The unsterilized interventions to avoid appreciation in 1994 resulted in monetary expansion. This led to inflationary pressure in 1995. Additionally, the liberalization policy (also with regard to exchange controls) along with the end of international sanctions resulted in concerns about the increase of the current account deficit, rising inflation and increasing public debt at the end of 1995. The depreciation episode started in mid-February 1996, accumulating to 20 percent by April 1996. The Reserve Bank intervened heavily in the spot and forward markets to counteract the depreciation.<sup>11</sup>

**April-August 1998:** During 1997 South Africa saw capital inflows due to a large interest rate differential to the US and a slow appreciation process. The crisis started in the second quarter 1998 when funds were moving out of emerging markets in reaction to currency crises in Russia and Asia. The interventions of the Reserve Bank in the forward markets led to arbitrary profits by borrowing Rand, turn them into US\$, buying US assets and hedge the transaction on forward markets. This increased the depreciative pressure on the spot rate. Heavy interventions and interest rate increases could not prevent a depreciation of 34 percent by July 1998. The Reserve Bank stopped interventions, which resulted in further depreciation.<sup>12</sup>

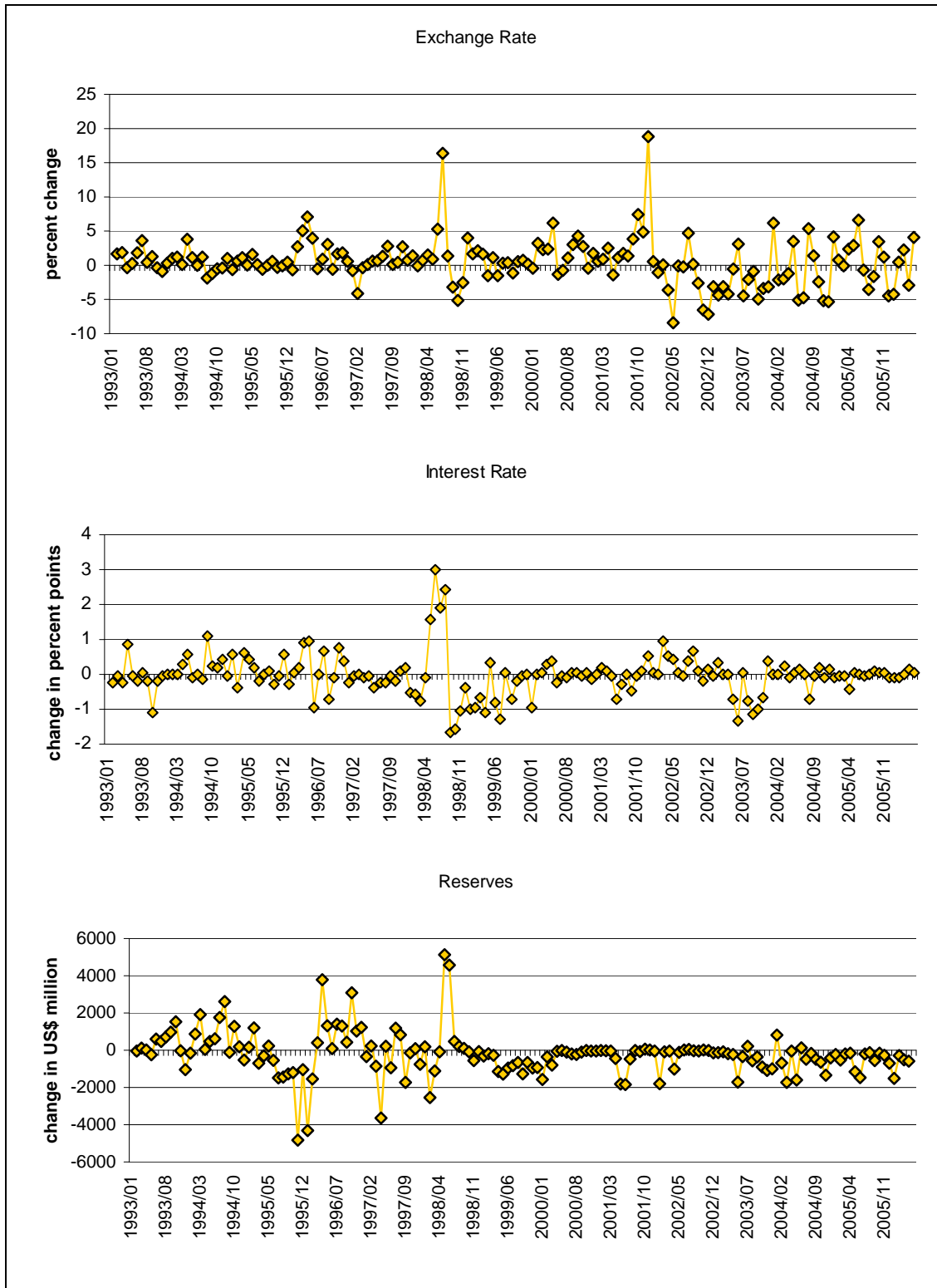
**September-December 2001:** Between September and end of December 2001 the Rand depreciated by 26 percent. The Reserve Bank did not intervene in favor of the Rand. Potential explanations of the depreciation are for example the acceleration in money growth in 2001, the delay of the privatization of the telecom service provider, the continued policy of drawing down the net open forward position of the Reserve Bank (intervention against the domestic currency), Reserve Bank's announcements to tighten the enforcement of exchange controls in October, contagion from political and social trouble in Zimbabwe, and a crisis in Argentina.<sup>13</sup>

<sup>11</sup> Source: Aron, Muellbauer (2000, pp. 16-17).

<sup>12</sup> Source: Schaling, Schoeman (2000, pp. 2-5).

<sup>13</sup> Source: Bhundia, Ricci (2005, pp. 156-165).

Figure 1:  
EMP data

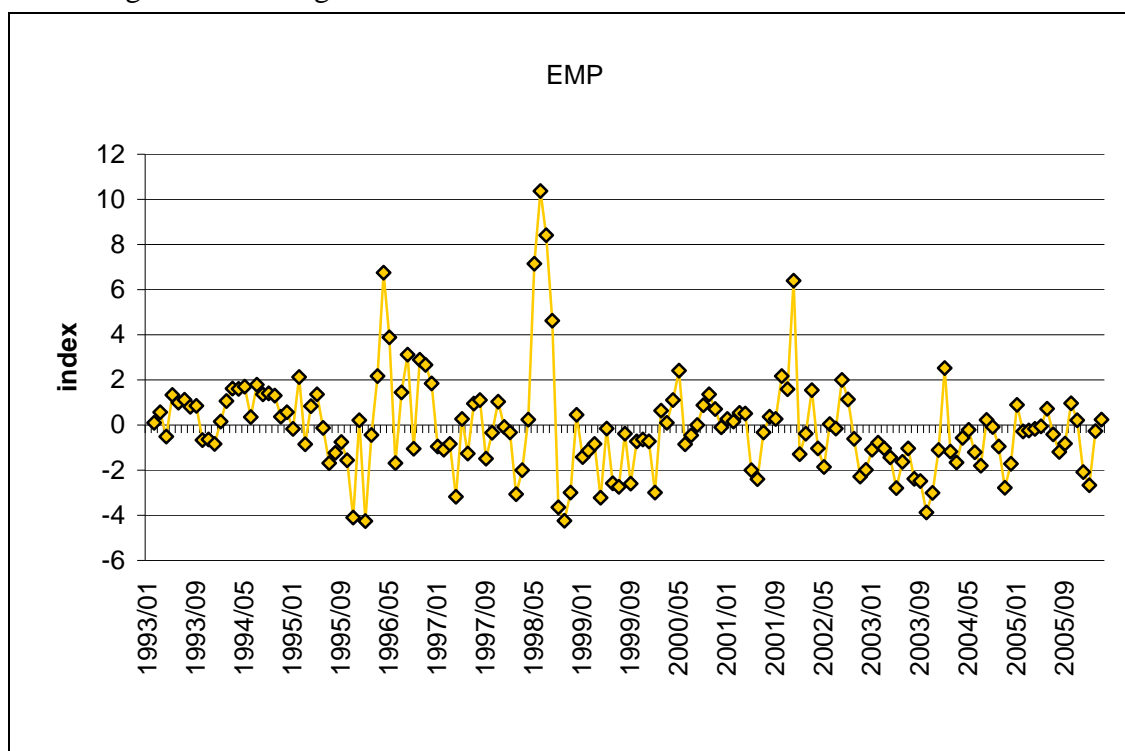


Source: SARB (2006), own calculations.

In order to capture all potential currency crises in South Africa the analysis considers monthly data of the South African Reserve Bank (SARB) beginning at 1993/1 to the latest available data, 2006/5. The time series include in particular “rand cent per US\$” (KBP5339M) which will be called exchange rate in this paper, “discount rates on 91 days treasury bills” (KBP1405W) called interest rates and the “international liquidity position” or “net reserves” (KBP5277M) called reserves. Since the interest rate measure is only available on a weekly basis, the monthly average is calculated. Figure 1 shows the percentage changes in the exchange rate (a positive sign indicates a depreciation), the change in interest rates (a positive sign indicates an increase in interest rates) and the change in reserves (a positive sign indicates decreasing reserves). Note that in contrast to the above-described framework it is not possible to use percentage changes of reserves, since the data (the net reserves) is not rationally scaled (i.e. the time series has no definite zero point). It seems however appropriate to use net reserves in the South African case because of the considerable past open forward position.<sup>14</sup>

Using the concept of inverse standard deviations as weights for the components of the EMP, including all three components, yields the EMP time series as shown in figure 2.

Figure 2:  
EMP weighted according to inverse standard deviation

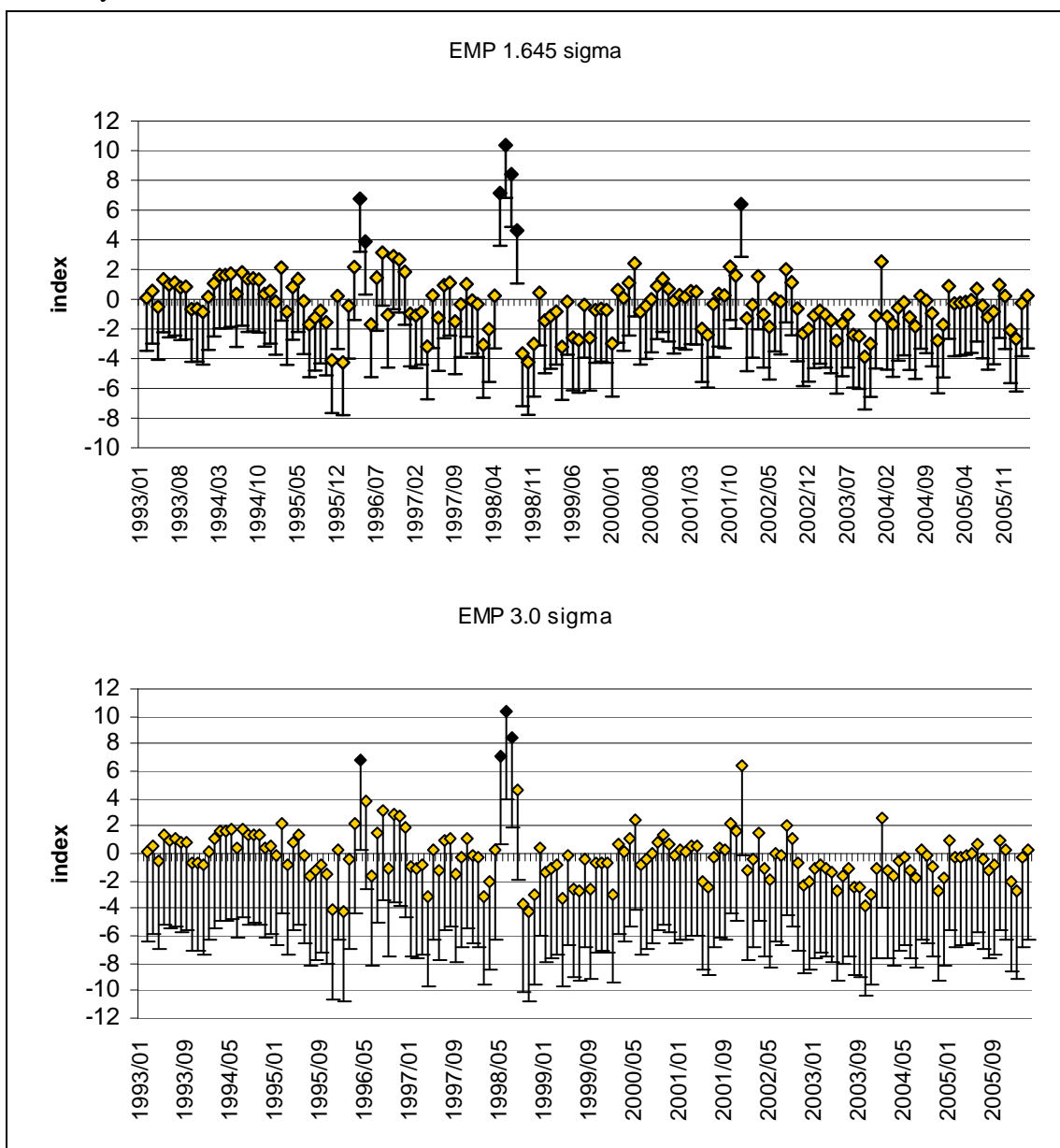


Source: own calculations based on SARB (2006).

<sup>14</sup> See e.g. *Bhundia, Ricci* (2005, p. 157).

Higher values of the EMP index indicate higher exchange market pressure. In order to identify crises periods a definition of the crises threshold is needed. Figure 3 shows two versions of crises thresholds used in the literature (more can be found in the table in the appendix). The figure shows the values of the EMP index in each year and the different threshold interval. All data points whose threshold-intervals lie completely above the zero line are called crises months (indicated by a black dot). In all cases the thresholds consist of the mean of the times series plus a varying multiple of the standard deviation ( $\sigma$ ).

Figure 3:  
Currency crises in South Africa



Source: own calculation based on SARB (2006).

Figure 3 shows that indicated crises months decline with the increasing threshold. While in circumstances where the threshold is set at the mean of the EMP time series plus 1.645 times the standard deviation indicates seven crises months, namely April and March 1996, May to August 1998, and December 2001. The increase of the threshold to 3.0 times the standard deviation leads to “losing” March 1996, August 1998, and December 2001 as crises months.

Using a 25 percent annual depreciation of the exchange rate as an additional condition for currency crises, the crisis months would diminish to July and August 1998 and December 2001; furthermore 1996 would not be a crisis year any more. If the strict rule of 25 percent annual depreciation is combined with the “three sigma”-threshold condition, only one month is identified as a crisis month during the period of observation: July 1998. Table 1 shows the depreciation of the exchange rate in percent of the pre-years value for the above identified potential crises months.

Table 1:

Annual depreciation of the rand/US\$ exchange rate in selected months

Potential crises month	1996/4	1996/5	1998/5	1998/6	1998/7	1998/8	2001/12
Depreciation	16.8%	23.6%	14.0%	19.2%	37.0%	35.0%	51.2%

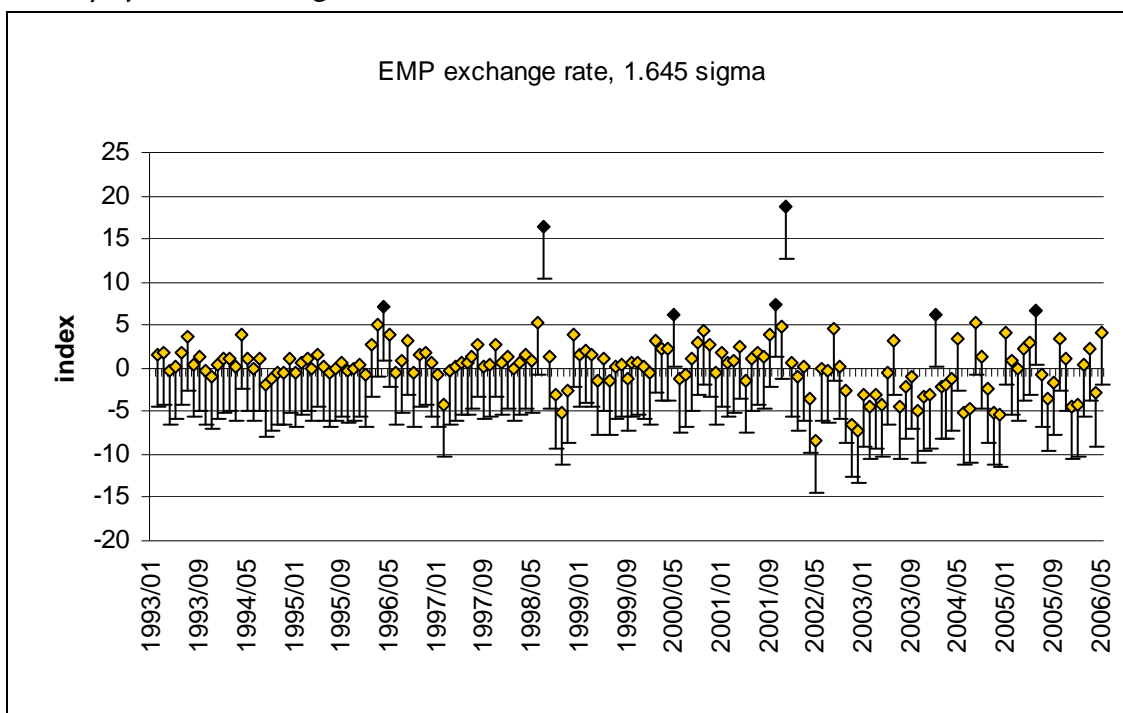
Source: SARB (2006), own calculations.

The above stated shortcomings concerning the precision weights for measuring currency crises in the case of fixed exchange rates can be translated into the South African case. In this case it can be criticized that the more current crises, namely in the period after the decision of the treasury and the SARB in 2000 not to intervene in the case of speculative pressure on the rand, may lead to an underestimation of currency crises. This can be expected because these later crises are supposed to just affect the exchange rate and not the policy instruments of interest rates and reserves.<sup>15</sup> Thus, if interest rates and reserves used to be relatively stable, their weight in the EMP may be relatively high. Since interest rates and reserves are not responding to exchange rate developments, their variations may overlay depreciation episodes which would otherwise be called currency crises. However, interest rates may not be adjusted to counteract speculative pressure but may be adjusted to avoid rising inflation due to increasing import prices. Thus, a forward-looking monetary policy-maker may still react in the case of expected depreciation of the rand by increasing interest rates. Thus, it seems to be appropriate to calculate two other versions of the EMP, one setting the weight on reserves ( $\gamma$ ) to zero and another

<sup>15</sup> South Africa saw a change in the exchange rate policy from exchange rate smoothing between the times of SARB governors *Stals* (1999) and the introduction of an inflation targeting regime in 2000 (*Mboweni* 2000). In 2001 governor *Mboweni* (2001) noted with regard to exchange rate volatility: „... we have to live with it – sit tight, grit out teeth and suffer in silence“.

setting the weights of reserves and interest rates ( $\beta, \gamma$ ) to zero. Figure 4 shows the case of an EMP just consisting of percent changes in the exchange rate.

Figure 4:  
EMP,  $\beta, \gamma = 0$ , 1.645 sigma threshold



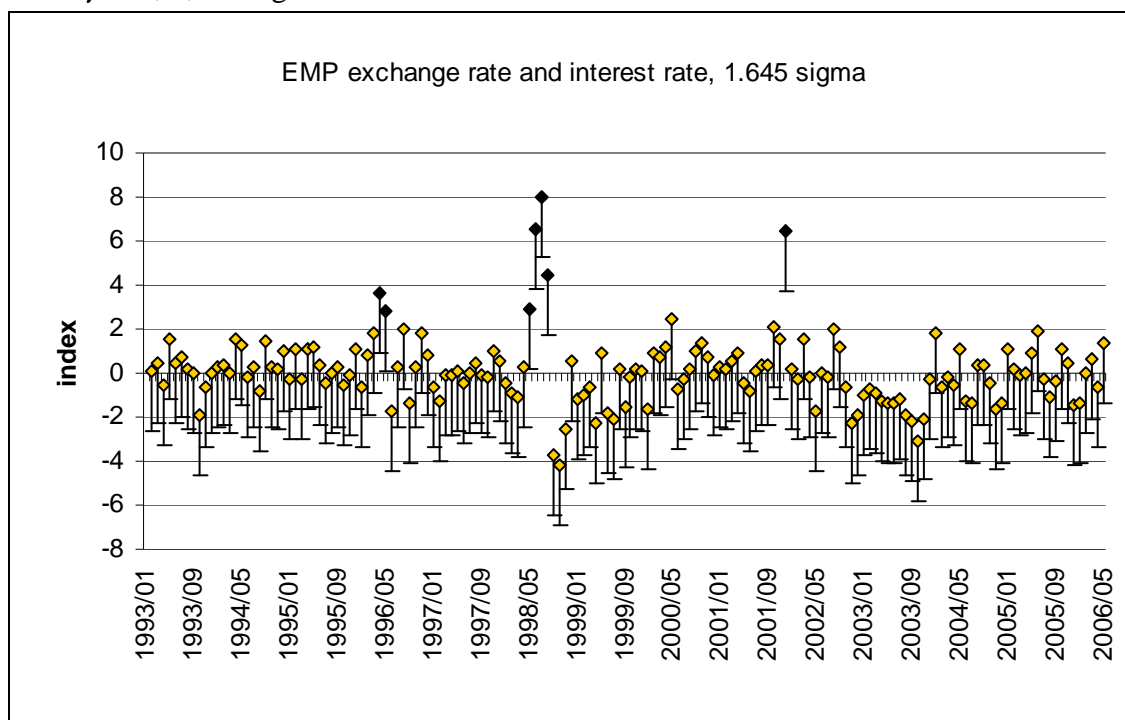
Source: own calculations based on SARB (2006).

With this measure seven crisis months are identified, which are however not in all cases identical with the above identified ones. The crisis months similar to the above analysis are April 1996, July 1998, December 2001, i.e. all major crises are indicated by this method as well, though the crisis duration is shorter. Additionally the method indicates crises in May 2000, October 2001, January 2004, and June 2005. It is not surprising that more crises are indicated for the last couple of years because of the above-mentioned change in policy. This version of the EMP index, including the exchange rate, can be employed using different thresholds. The results can be seen in the Annex. Two crisis months are left using the highest threshold of three times sigma plus the mean, which are July 1998 (again) and December 2001. Figure 5 shows the case where just ( $\gamma$ ), the weight on reserves is set zero.

The premise saying that interest rates may indicate current events as being in crises, since they may not react to the exchange rate developments but to expected inflation could not be confirmed. The so-constructed EMP indicates well-known months as crisis months. The only exception is May 1996, which is indicated as a crisis month here and

has not been identified as such before. This may be due to a late reaction of interest rates responding to inflationary pressure in the aftermath of the March/April crisis of 1996.

Figure 5:  
EMP  $\gamma = 0$ , 1,645 sigma threshold



Source: own calculations based on SARB (2006).

Crises during the times of the interventionist approach of the SARB may not have resulted in large changes in the exchange rate but may have been covered by interventions in foreign exchange markets. To detect them figure 6 shows an EMP index including just reserves.

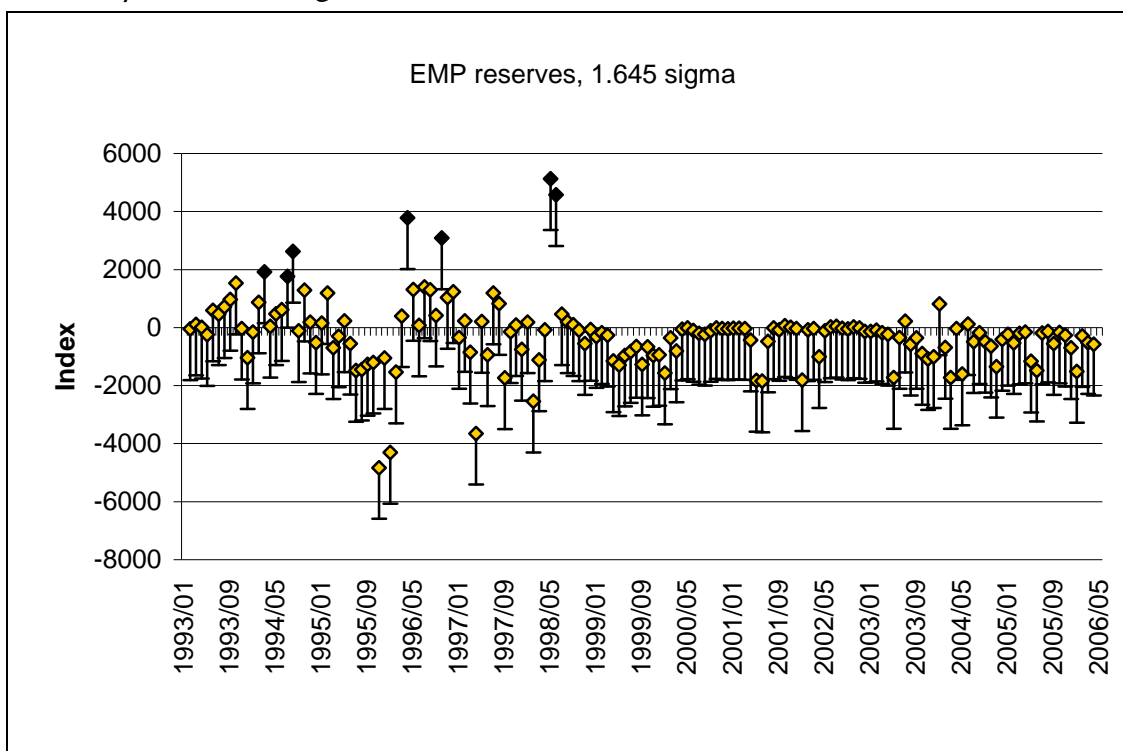
As expected the so-detected currency crisis months are concentrated in the first part of the sample. The picture shows that there have been crisis-significant interventions in March, July and August 1994, which were not followed by significant depreciations and have therefore not been detected by the broader EMP approaches. However, these months are not called a crisis if the threshold is increased to 2.5 times sigma (as can be seen from the table in the appendix). In 1996 there have been interventions during April (a month already detected as a crisis month) and October, a month so far seen as a point after the 1996 crisis. The indications in 1998 are again in line with what has already been detected. After June 1998 no significant intervention could be observed.

Using the 25 percent annual depreciation criterion as an additional condition for an event to be called a currency crisis, the respective months are marked by an exclamation mark in the annex. Of the, so far, detected potential crises months, October 1996, July



and August 1998, as well as December 2001 show depreciations of the exchange rate of above 25 percent compared to the pre-year month.

Figure 6:  
EMP,  $\alpha, \beta = 0$ , 1.645 sigma threshold



Source: own calculations based on SARB (2006).

As a final measure for determining currency crises the simple method of requiring a certain current depreciation of the exchange rate is used. Brüggemann & Linne (2002) use the criterion of 20 percent depreciation within ten trading days. According to this criterion only one day during the period of observation would be called a crisis: 20<sup>th</sup> of December 2001, 21.30 percent.<sup>16</sup>

To sum up, the results drawn from the different currency crisis identification frameworks depicted in the table in the appendix show that there is just one crisis month, indicated as such by all versions of the EMP, and that is April 1996. This month, however, is not detected as a crisis month with use of all the thresholds. April 1996 is surrounded by two months that show some indications for crises. Also in October there have been significant interventions due to ongoing depreciation. Other prominent months are May and June 1998 (not detected by the EMP including exchange rates only) and July 1998 (not detected by the EMP with including reserves only) as well as December 2001 (ob-

<sup>16</sup> The daily exchange rate data is provided by Datastream.

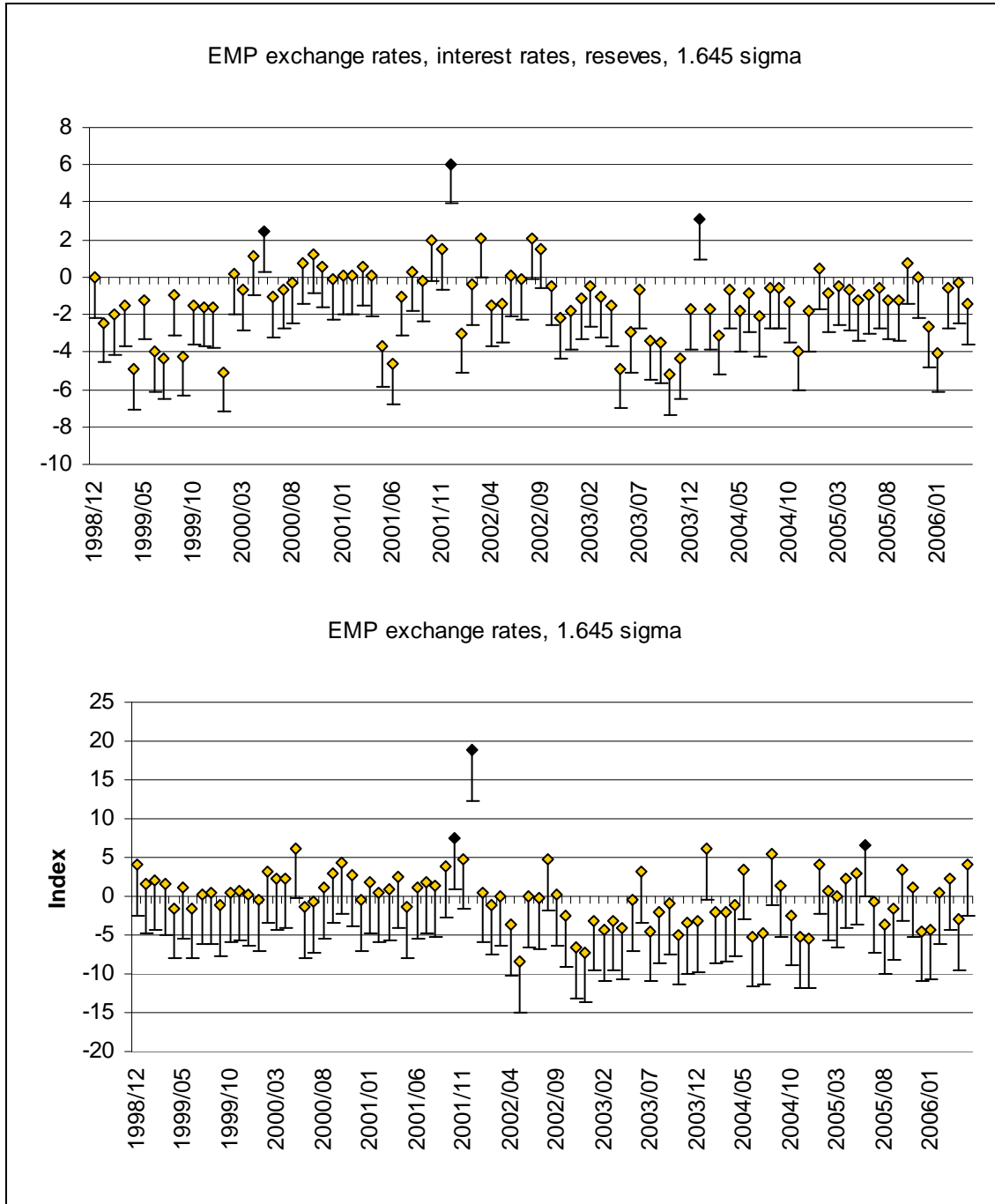
viously not detectable by the EMP including reserves only). The 1998 event is centered on June and July but surrounded by two months that show some indication for currency crises. In 2001 the episode focuses very much on December with some indications in October. The three events of April 1996, June/July 1998 and December 2001 can, with the backing of the above analysis, be called currency crises.

It is somewhat more questionable whether the 1994, the 2000, 2004, and 2005 episodes can be called crises. The 1994 event shows some depreciation, which is low compared to the 1996, 1998, and 2001 events. Interest rates had been rising as well, but the increases of up to 1.1 percent points have been relatively low. Only the reserves measure shows a severe reaction of the Reserve Bank with changes in reserves of above what we observed e.g. in August 1998. The impression from these figures is that the reaction of the Reserve Bank has been successful in order to prevent a more serious depreciation and therefore a currency crisis. The successfully held elections in 1994 may have added to the stop of the depreciation episode. The episodes of 2000, 2004, and 2005 are more difficult to evaluate. The main concern is the policy switch, which can clearly be seen at the reserves chart in figure 1. After the 1998 crisis there have been no interventions by the SARB that came close to the previously seen figures. As stated above, the SARB opted against intervention in currency markets further on. Figure 7 shows an EMP index including exchange rates, interest rates and reserves calculated with data from 1998/12 onwards.

The figure shows that limitation of the sample period leads to two newly detected crisis months using the EMP index including all three measures: April 2000 and January 2004. When taking out the more extreme events of the 1990s the chart leads to an identification of events as crises that were formerly hidden by those events. However, the second chart of figure 7 shows that the increased volatility in exchange rates (see also figure 1) leads to fewer detected crises by the exchange rate alone EMP as compared to figure 4 (the 2004 event is not detected as crisis here). What is also evident from the above figures is that May 2006, the last dot in the charts, is not identified as currency crises month even though it was discussed as being a serious event (the June 2006 data is still not available at the time of writing).

It can be concluded that for no post-1998 event, except for the episode in 2001, there has been enough evidence for it to be called a currency crisis. In the following sections the events of 1996, 1998 and 2001 are considered as currency crises. The remainder of this section discusses shortcomings and criticisms of detecting currency crises by the methods employed above.

Figure 7:  
EMP (1998/12 to 2006/5) 1.645 sigma threshold



Source: own calculations based on (SARB 2006).

If it is assumed that the data points of the time series can be described as normally distributed, the calculation of crises thresholds will almost certainly lead to the identification of some events as currency crises, depending on the heights of the threshold. The version prominently used in the graphical analysis above was a threshold of the mean of

the time series plus 1.645 its standard deviation. That threshold is used, in line with e.g. Bhundia and Ricci (2005: 157) and Caramazza et al. (2000), because it will identify five percent of the months as crises months (outlying of a one-sided 95 percent confidence interval) if the time series is normally distributed. Obviously discrete changes in the threshold lead to more, or less, detected crises. It is also for that reason that the crisis identification by this measure is largely method dependent. As seen above, the crisis detection is also dependent on the sample period and the weights of the three measures in the index. Additional conditions, such as an additional annual depreciation criterion, counteract the potential identification of crises in periods where there have not been any serious events. However, depending on the threshold of this criterion, more or less crises are identified and the criterion may let crises, in which the depreciation has been held in check by interventions in money or foreign exchange markets undetected. Thus, the technical analysis of EMP index figures cannot be a substitute for careful economic analysis of events. It may also be worthwhile to look at the impact of episodes on currency markets on other macroeconomic aggregates such as inflation and economic growth, which may be closer to economic wealth and can therefore be a better indicator of a certain events being a crisis or not.

The results of the analysis above are still used in the remainder of the paper, since the findings are in line with what has already been detected as currency crises in the literature.

## 4 Signaling currency crises – a literature review

The theoretical literature on currency crises is centered on the paradigm of the three generations of currency crises models. The first generation, owed to Krugman (1979) and Flood & Garber (1984), described currency crises as speculative attacks which result from monetary or fiscal policies that were not in line with a fixed exchange rate target. The run on foreign currency reserves occurred because market participants could foresee the depreciation and tried to avoid losses. The models described the currency crises of the 1970s and 1980s in Latin America. The second generation, based on Obstfeld (1986), stresses the trade-off between the central banks intentions to target a fixed exchange rate and to follow other policy targets, e.g. to achieve low levels of unemployment. If speculators assume that the policy response could be devaluation, the event may become self-fulfilling without (in contrast to first generation models) worsening economic fundamentals. The models addressed, for example, the EMS crises in Europe. Third generation models stress the connection between banking and currency crises, and address problems such as contagion of crises and herd effects. These models were developed in response to the Asian crises of 1997/1998.

The empirical literature on signaling or forecasting currency crises is based on the theory transmission processes described above, but approaches vary with regard to the employed techniques. Standard approaches are bivariate Logit/Probit-models and signals approaches as developed by Kaminsky & Reinhart (1996, 1998).<sup>17</sup> Logit/Probit-models use the bivariate variable crisis/no crisis as endogenous variable and estimate the impact of different sets of explanatory variables.<sup>18</sup> Signals approaches are non-parametric approaches that examine the behavior of potential explanatory variables prior to the detected crises and compare it with non-crises periods. If some of the variables pass a certain threshold their changes are used as crisis signals.<sup>19</sup> Besides these two techniques, further concepts are outlined in the literature. These include artificial neural networks (ANN), whose advantage is the reflection of complex interaction between the variables;<sup>20</sup> value-at-risk models, exposing several factors of risk to the ability of central

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<sup>17</sup> For a more detailed survey on Early-Warning Systems presented in this section see *Abiad* (2003).

<sup>18</sup> Examples include *Berg, Pattillo* (1999b); *Kamin, Schindler, Samuel* (2001), and *Kumar, Moorthy, Perraudin* (2002).

<sup>19</sup> See *Brüggemann, Linne* (2002). Other examples include *Berg, Pattillo* (1999b), and *Edison* (2000).

<sup>20</sup> E.g. *Nag, Mitra* (1999); *Peltonen* (2006).

banks to target a fixed exchange rate;<sup>21</sup> restricted VAR models;<sup>22</sup> and Markov-switching approaches, which do not depend on an a priori definition of crises.<sup>23</sup>

This paper largely follows the signals approach as developed by Brüggemann & Linne (2002), which is generally based upon Kaminsky & Reinhart (1996, 1998). The signals approach is used, because of its simple applicability and because it was found to outperform alternatives.<sup>24</sup> The remainder of this section is devoted to the used method, which is used in the subsequent section to calculate the country specific currency crisis signals in South Africa.

The first step in employing a signals approach is to define currency crises in the period of observation. This has been undertaken in the previous section. The second step is to identify potential explanatory variables, which may send signals for currency crises. These variables should be derived from theories about currency crises. Variables, which may have an influence on the occurrence of currency crises in South Africa, are identified in the next section. The third step is to generate appropriate time series, as well as to decide on a sample period and data frequency. The fourth step is to decide on the crises window, i.e. the time prior to a crisis in which the variables are expected to send their signals. The literature uses different sample periods and data frequencies; most common are sample periods starting in the 1980s or 1990s and monthly data frequency.<sup>25</sup> The time-window spans from 18 months to 24 months.<sup>26</sup>

The fifth step is to calculate individual crisis thresholds for each variable, which cuts tranquil periods from crises periods. The difficulty lies in the problem that the threshold should neither be too high (and probably not detecting crises) nor too low (and probably give false alarm). The instrument to detect the optimal threshold has to minimize the noise-to-signal ratio:<sup>27</sup>

$$\omega_j = \frac{B/(B+D)}{A/(A+C)} \quad (4)$$

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21 E.g. *Blejer, Schumacher* (1998).

22 E.g. *Krkoska* (2001).

23 E.g. *Abidad* (2003). The author provides further examples of techniques of Early warning systems.

24 *Abidad* (2003, p. 3).

25 *Abidad* (2003, p. 9).

26 See for example *Brüggemann, Linne* (2002, p. 9), and *Kaminsky, Lizondo, Reinhart* (1998, p. 17) respectively.

27 See *Brüggemann, Linne* (2002, p. 10).

Whereby  $A$  is the number of months a good signal was sent (a crisis is correctly signaled),  $B$  is the number of months a false alarm signal was sent,  $C$  is the number of months in which no signal was sent but a crises followed,  $D$  is the number of months in which no signal was sent and no crises followed. In other words, the noise-to-signal ratio is the ratio between false alarms as part of non-crises followed months and good signals as part of crises followed months. The noise-to-signal ratio is calculated with different crisis thresholds ranging from 5 to 30 percent or 70 to 95 percent of the distribution, depending on the expected impact of the variable, for each measure. The thresholds yielding the best-fit or lowest noise-to-signal ratios are used in the further calculation of the signals approach. Indicators which produce more false alarms than good signals, i.e. those having a noise-to-signal ratio of above one, are excluded from further analysis.

The sixth step is the calculation of a composite indicator. Following Brüggemann & Linne (2002) the signals approach is extended by introducing a second threshold in order to discriminate weak from strong signals, and by considering the timing of a signal (i.e. more current signals are higher weighted in the composite indicator). The weighting of the single indicators according to their prognostic quality is in line with standard literature.

The three stages of calculation are conducted by first calculating the second threshold, which is done by halving the percentile of the frequency distribution which was calculated for the first threshold. If a single indicator remains below its first threshold it takes the value of zero, if it passes the first threshold its value is defined as one, if it passes the second threshold its value is defined as two:

$$I_t^j = \begin{cases} 0 & I_t^j < T_1^j \\ 1 & \text{for } T_1^j \leq I_t^j < T_2^j \quad j = 1, \dots, k. \\ 2 & I_t^j \geq T_2^j \end{cases} \quad (5)$$

Second, a moving 18- or 24-months window is calculated, depending on the time-window defined before, to calculate geometrically weighted signal of each indicator:

$$Z_t^j = \sum_{i=1}^l \frac{I_{t+1-i}^j}{i} \quad l = \begin{cases} 18 \\ 24 \end{cases}, \text{ for } t \geq \begin{cases} 18 \\ 24 \end{cases}. \quad (6)$$

Third, these so-calculated Z-signals of each variable are combined by accounting for their prognostic quality i.e. by then dividing them by their respective noise-to-signal ratio.

$$CI_t = \sum_{j=1}^k \frac{Z_t^j}{\omega_j}. \quad (7)$$

The procedure yields a composite indicator of currency crises.

## 5 Signaling currency crises in South Africa

As derived above, April 1996, June/July 1998 and December 2001 are considered as crises months. A set of variables in the style of those that have been found to be useful in signaling currency crises in previous studies as extracted by Brüggemann & Linne (2002) are used. These variables include: (1) growth of industrial production, (2) the ratio of budget deficits to GDP, (3) the appreciation of the real exchange rate, (4) the change in the international liquidity position, (5) growth rate of merchandise exports, (6) growth rate of merchandise imports, (7) growth rate of ratio of domestic credit to GDP, (8) the growth rate of the ratio of M2 to currency reserves, (9) the domestic interest rate, (10) the interest rate differential to the US, (11) growth rate of bank deposits of individuals, (12) growth rate of foreign debt of the government, (13) the ratio of lending rates to deposit rates. The Commission of Inquiry into the rapid depreciation of the exchange rate of the rand and related matters, the so-called Myburgh Commission (2002), was officially established to investigate the 2001 currency crisis in South Africa. The commissions report indicates variables, which may contribute to the explanation of currency crises in South Africa. Some of them are already included in standard set of variables, such as the open forward position of the SARB which is reflected in the international liquidity position. Additionally, from this report variable (14), the inflation differential to the US is included. Other “weak” factors found to explain part of the 2001 depreciation, such as privatizations and negative sentiments could not be included due to a lack of computable data. Additionally, another factor mentioned in the literature as explaining factor to currency crises in South Africa (15) the change of the price of gold is included.<sup>28</sup>

January 1993 to the latest available data is the period of observation. Using more current data follows that strand of literature which uses data from 1990s onwards only. The use of this time period is also justified by the general change in the nature of currency crises and the opening of the capital account in the 1990s in South Africa. The paper uses monthly data; if monthly data is not applicable monthly time series are constructed by averaging weekly data or by interpolating moving averages from quarterly data. All data is sign-adjusted, in order to generate time series indicating increasing pressure when their value rises. Data sources are predominantly the SARB or the Federal Reserve Bank and Bureau of Labor Statistics in the US. A 24-months crisis window is chosen in the analysis and an 18-months crisis window is used to test for the robustness of the result. Data from up to August 2004 is used for the calculation of the noise-to-signal ratio, since it is unknown whether the time after that date may be followed by a crisis or not.

- (1) As industrial production variable the growth rate of gross value added at basic prices of secondary sector (KBP6633D) is used and monthly data is generated by

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<sup>28</sup> E.g. Aron, Muellbauer (2005, p. 30).



interpolation. The measure shows a minimal noise-to-signal ratio at a threshold of 25 percent, which takes a value of 2.32. Thus, industrial production sends more false alarms than good signals and is not considered in the composite index.

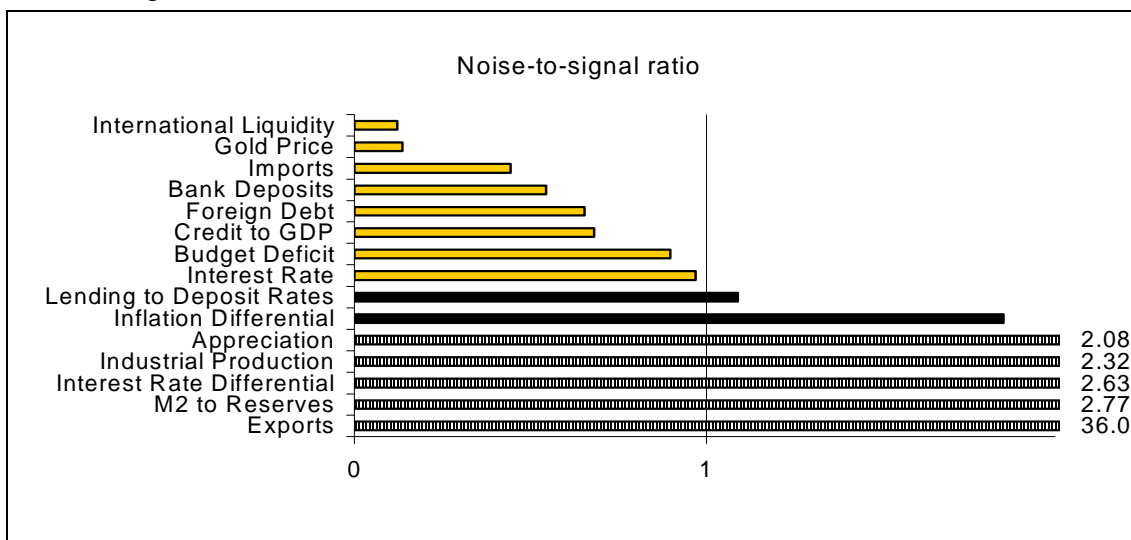
- (2) The ratio of budget deficits to GDP (KBP4420K) is constructed by interpolation from quarterly data and a calculation of the annual change. The indicator shows some more good than false signals; the noise-to-signal ratio is 0.90.
- (3) The appreciation of the real exchange rate is measured as annual change of real effective exchange rate of the rand consistently, excl. Zimbabwe (KBP5367M). The measure shows the lowest noise-to-signal ratio at the 30 percent threshold and takes a value of 2.08, which signifies that the measure is not a useful indicator.
- (4) The change in the international liquidity position (KBP5339M) is a good indicator with a minimal noise-to-signal ratio of 0.12 at the 5 percent threshold.
- (5) The growth rate of merchandise exports (KBP5000K) is calculated by interpolation from quarterly data and sends just one good signal at the 30 percent threshold. The noise-to-signal ratio of 36.0 is out of reach for any use as indicator. It was expected that falling exports increase the probability of a crisis, since investors may expect problems in serving foreign debt if exports earnings shrink and withdraw.
- (6) Also the growth rate of merchandise imports (KBP5003K) is calculated by interpolation from monthly data. At a 25 percent threshold the noise-to-signal ratio is 0.44, showing that rising imports are a good indicator for currency crises in South Africa.
- (7) The growth rate of the ratio of domestic credit to GDP is calculated from credit extension (KBP1368M) and interpolated GDP (KBP6006K) figures. The minimal noise-to-signal ratio of 0.68, at a threshold of 30 percent, shows that the variable is a good indicator for currency crises.
- (8) The growth rate of the ratio of M2 to currency reserves is calculated from M2 (KBP1373M), gold and other foreign reserves (KBP5806M), and the US\$ exchange rate (KBP5339M). The minimal noise-to-signal ratio of 2.77 shows this not to be a useful indicator.
- (9) The change in the domestic interest rate is calculated by subtracting the inflation rate (KBP7032A) from the interpolated discount rate on 91 days treasury bills (KBP1405W). The indicator produces some more good than bad signal; the ratio is 0.97 at a threshold of 10 percent.

- (10) The interest rate differential to the US is calculated by subtracting the inflation corrected discount rate on three months US treasury bills from the domestic interest rate. The variable is not indicating currency crises properly; the noise-to-signal ratio is 2.63 at the 30 percent threshold.
- (11) The growth rate of bank deposits is calculated by the use of bank deposits of resident individuals (KBP1148M). The indicator is useful, showing a ratio of 0.54 at the 5 percent threshold.
- (12) The growth rate of foreign debt of the government is calculated from the total foreign debt of central government denominated in foreign currencies (KBP4451M) time series. The indicator shows more good than bad signals, with a ratio of 0.65 at the 30 percent threshold.
- (13) The ratio of lending to deposit rates is calculated by dividing interest rates on mortgage loans (KBP2012M) by the interest rate on one year fixed deposits (KBP2007M). The measure sent slightly more bad than good signals with a ratio of 1.09 and is therefore no indicator for currency crises.
- (14) The inflation differential to the US is calculated by subtracting US inflation rates from changes in the South African consumer price index (KBP7032A). The noise-to-signal ratio of 1.84 indicates that the variable is not an appropriate indicator for currency crises.
- (15) Changes in the gold price are calculated from London gold price in US\$ (KBP5357M). As expected, the change in gold price is a good indicator for currency crises in South Africa showing a minimal noise-to-signal ratio of 0.14 at the 10 percent threshold.

The noise-to-signal ratios of all variables are summarized in figure 8.

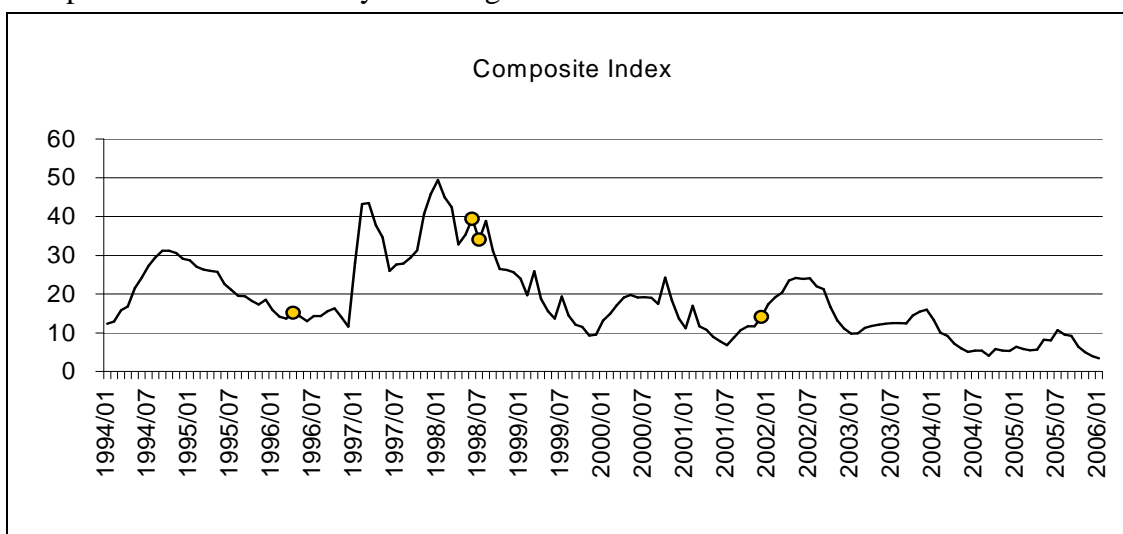
In sum, eight indicators are left for calculating the composite index. As stated above, the area outlying the one-sided confidence interval is halved to calculate the second thresholds. Using equation (5), first and second threshold signals are generated from each indicator. Then the moving time windows for each indicator are calculated (equation (6)) and the Z-values of the indicators according to their inverse noise-to-signal ratio are aggregated to derive a composite indicator (equation (7)). The result is displayed in figure 9. The dots on the line highlight the crises months.

Figure 8:  
Noise-to-signal ratios with 24-months time window:



Source: own calculations.

Figure 9:  
Composite index of currency crises signals



Source: Own calculations.

While the index itself can be used to observe changes in the intensity of currency crisis signals, the level of the index cannot be interpreted. Thus, it is not possible to draw inferences on the probability of currency crises from the index. Therefore, following Brüggemann & Linne (2002) and Edison (2000) conditional probabilities for currency crises are calculated:

$$P(\text{crises}_{t,t+18} | CI_l \leq CI_t < CI_u) = \frac{\sum \# \text{months for } CI_l \leq CI_t < CI_u \text{ and crisis follows}}{\sum \# \text{months for } CI_l \leq CI_t < CI_u} \quad (8)$$

For each interval between a lower and an upper limit (in our case intervals of 10) the conditional probability is calculated. This conditional probability is the probability of a crisis occurring within 24 months under the condition that the indicator ranges between the lower and the upper band. The conditional probabilities are reported in table 2.

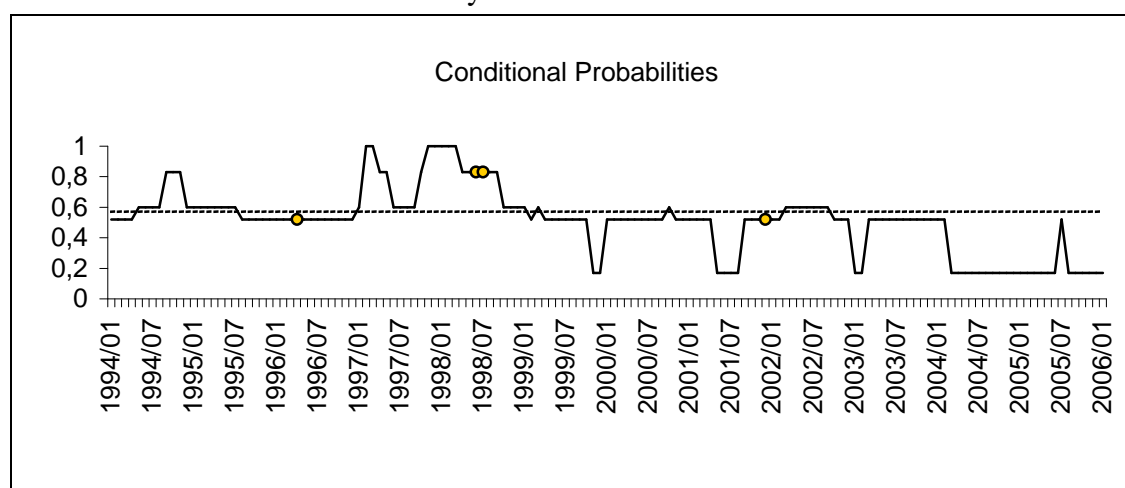
Table 2:  
Conditional probabilities of currency crises in South Africa

Interval	0-10	10-20	20-30	30-40	40-50	Unconditional
Probability	0.17	0.52	0.60	0.83	1	0.57

Source: Own calculations.

For example, the probability of a currency crisis is 0.83 if the index shows a value of between 30 and 40, which is well above the general probability of a currency crisis to occur following any month of the sample (0.57). Figure 10 shows a graph where the probabilities are attributed to the respective months.

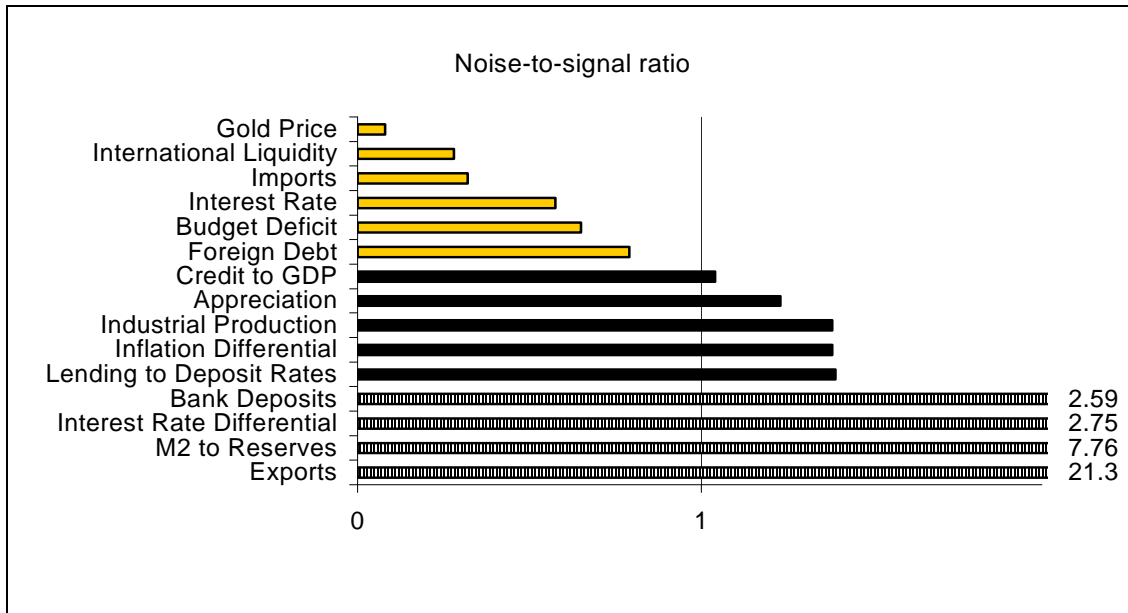
Figure 10:  
Conditional Probabilities of currency crises in South Africa



Source: own calculations. Note: dotted line shows unconditional probability.

To test for the robustness of the composite indicator of currency crises, as derived by the signals approach, the procedure is repeated for the case of an 18-months time window. The noise-to-signal ratios are reported in figure 11. Notable is the change in the relevant indicators. Only six indicators sending more positive than false signals are left, credit to GDP and bank deposits are not considered in the 18-months case.

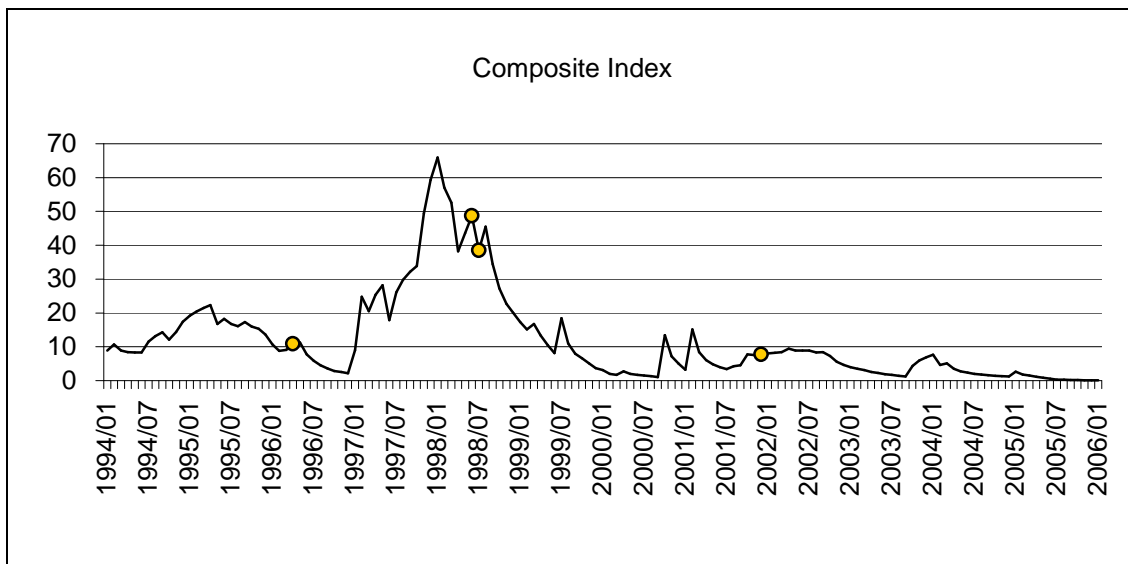
Figure 11:  
Noise-to-signal ratios with 18-months time window



Source: Own calculations.

The respective composite index is shown in figure 12.

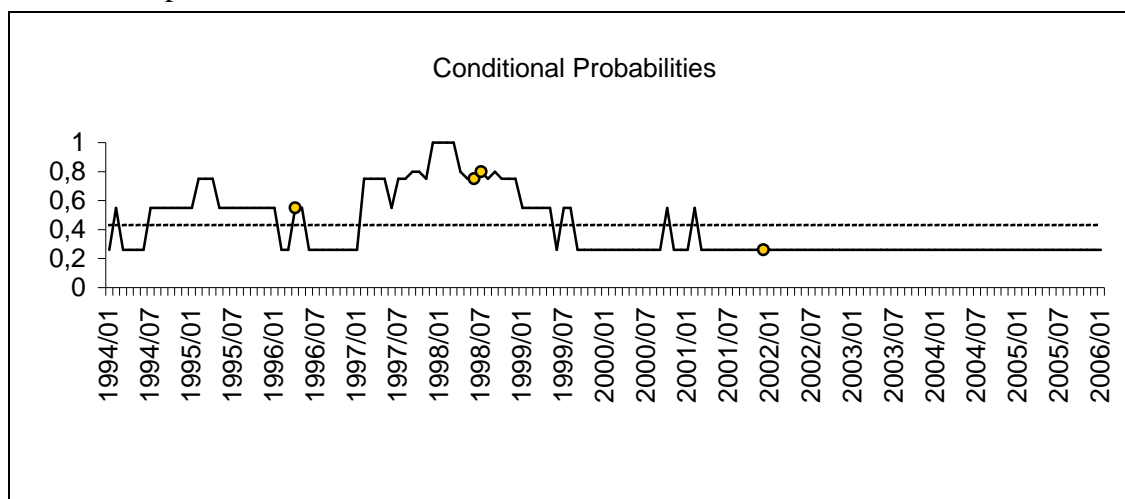
Figure 12:  
Composite indicator with 18-months time window



Source: Own calculations.

The conditional probabilities for the 18-months time window case are shown in figure 13.

Figure 13:  
Conditional probabilities with 18-months time window



Source: Own calculations. Note: Dotted line shows unconditional probability.

While some difference between the composite indices and the respective conditional probabilities can be observed, the general picture remains the same after changing the time window. While the index provides indications of the 1996 and in particular the 1998 crises, it fails to clearly indicate 2001 as a crisis. For the time after 2001 there exists no indication of extraordinary risk of currency crises. However, as the figure of the unconditional probabilities for currency crises shows, the overall risk that any month of the period of observation is followed by a crisis within 24 or 18 months is 0.57 or 0.43 respectively. Thus, the risk of currency crises is there and the change in policy in South Africa resulted in less indicated crisis probability due to less risk or to lesser indication of risk.

## 6 Conclusions

The evaluation of the risk of currency crises in South Africa by the use of a signals approach, considering the crises episodes of 1996, 1998 and 2001 as reference, indicates low current risk for currency crises. The approach leads to a correct prediction of the currency crises of 1996 and 1998, but fails to predict the currency crisis of 2001. The changing nature of currency crises and the change in exchange rate policy of the SARB suggest that crises of the 2001-type are more likely to occur in future than crises of the 1996/1998-type. The crisis indicator, as developed above, must therefore be treated with caution and should be updated permanently. A shift in the period of observation can lead to the detection of new crises, previously not considered as crises and also to a failure of detecting events previously called a crises. The changing volatility of potential signal variables may lead to different signal thresholds and to the inclusion or exclusion of variables in the composite index and may therefore change not only the index itself but also the calculated conditional probabilities of crises. Further research on South African currency crisis risk should also consider the use of other methods as has been mentioned in section 4.

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Crises month	EMP method including exchange rates, interest rates, and reserves						EMP method including exchange rates only						EMP method including exchange rates and interest rates						EMP method including reserves only					
	1.5	1.6 45	1.7 5	2.0	2.5	3.0	1.5	1.6 45	1.7 5	2.0	2.5	3.0	1.5	1.6 45	1.7 5	2.0	2.5	3.0	1.5	1.6 45	1.7 5	2.0	2.5	3.0
1994/03																			X	X	X			
1994/07																			X	X				
1994/08																			X	X	X	X		
1996/03	X	X	X																					
1996/04	X	X	X	X	X	X	X	X	X				X	X	X	X			X	X	X	X	X	X
1996/05													X	X										
1996/10																			X!	X!	X!	X!	X!	
1998/05	X	X	X	X	X	X							X	X					X	X	X	X	X	X
1998/06	X	X	X	X	X	X							X	X	X	X	X	X	X	X	X	X	X	X
1998/07	X!	X!	X!	X!	X!	X!	X!	X!	X!	X!	X!	X!	X!	X!	X!	X!	X!	X!						
1998/08	X!	X!	X!	X!									X!	X!	X!	X!	X!							
2000/05							X	X																
2001/10							X	X	X	X														
2001/12	X!	X!	X!	X!	X!		X!	X!	X!	X!	X!	X!	X!	X!	X!	X!	X!	X!						
2004/01							X	X																
2005/06							X	X	X															