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# EARLY WARNING SYSTEMS OF FINANCIAL CRISES - IMPLEMENTATION OF A CURRENCY CRISIS MODEL FOR UGANDA

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*Abstract:*

The objective of this paper is to implement a prototype of a currency crisis model as part of an early warning system framework for Uganda. The financial systems of developing countries like Uganda are especially vulnerable and therefore robust instruments to predict crises are needed. Our model is based on the signals approach developed by Kaminsky, Lizondo and Reinhart (1998) and Kaminsky and Reinhart (1999). The basic idea of the signals approach is to monitor several indicators that tend to exhibit an „unusual" behaviour in the periods preceding a crisis. When an indicator crosses a threshold, then it is said to issue a „signal" that a currency crisis may occur within a given period. We implemented this signals approach for Uganda. One of the main challenges in this connection is that Uganda during the analyzed periods had no currency crisis. Therefore, we modified the model in a way that it estimates some of the performance measures based on empirical studies to obtain usable results. The outcomes of our calculations performed well and were economically validated.

*Key words:* Currency crises, Uganda, early warning systems, balance of payment crises, crisis prediction, vulnerability indicators, signals approach

*JEL-classification:* F31; F47

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# 1 Introduction

This paper describes the development of a prototype of a currency crisis model as part of an early warning system framework implemented at the Bank of Uganda by Bankakademie International. The Early Warning System project is part of the GTZ/Sida funded Financial System Development Programme at the Bank of Uganda. Although Uganda has never experienced a currency crisis, it is of utmost importance to monitor early signals to prevent them from occurring. The high amounts of official development assistance, the open capital account and the growing financial market as well as the favourable returns that have been offered by government securities may have adverse effects on the Uganda Shilling and thus become a challenge for the central bank. The model described should contribute to the financial stability in Uganda and enable Bank of Uganda to continue their successful monetary policies.

Kaminsky, Lizondo and Reinhart (1998) propose a nonparametric approach, called the signals approach, to predict banking and currency crisis. This paper focuses on the approach of modelling currency crisis. The signals approach involves the monitoring of several indicators that tend to behave differently or to exhibit an „unusual" behavior in periods preceding a crisis compared to their „normal" behavior. This „unusual" behaviour is identified for each indicator by crossing a threshold. These thresholds are calculated as percentiles of the empirical distribution of observations to minimize the noise-to-signal ratio. The resulting signals are used to calculate a composite index, which is then transformed into conditional probabilities of the appearance of a currency crisis within the signalling window.

The implementation of this model consists of three steps. The first step is to operationalize the term „currency crisis" using an index of exchange market pressure. The second step covers the choice, calculation and interpretation of the indicators. In the third step a composite index is build based on the resulting signals from step two.

The paper is organized as follows. Section 2 gives some background information about Uganda. Section 3 briefly discusses some related literature. Sections 4 to 6 present the implementation of the steps described above. Section 7 presents the conclusions of the paper and discusses possible further work.

The authors would like to thank Graciela Kaminsky and the colleagues from the Research and Supervision Function at Bank of Uganda, namely Benon Mutambi, John Atenu, Enoch Matovu, Richard Byarugaba, Ivan Amagaragariho, Alfred Kurong, Augustin Mwanje, Solome Lumala and the participants at the Second Early Warning System Conference for useful comments and suggestions. The authors would also like to thank the staff and management of the GTZ/Sida FSD Programme for their support and fruitful discussions.

# 2 Background Information

## 2.1 Country

Since Uganda became independent from the British Empire on 9th October 1962, Uganda experienced at least three politically and economically critical phases: Initially the relatively inexperienced and communistically oriented Milton Obote, then the reign of Idi Amin from 1971 – 1979 and finally the second presidency of Milton Obote from 1980 – 1986. Since the take over of today's president Yoweri Kaguta Museveni the economic and political development of Uganda has been generally positive.[1] However, the troubles with the rebels in the North and East of the country have still had adverse impacts on the development.

Apart from big personal sacrifices, which had to be borne by the Ugandan people, during the crises periods, most industrial and agricultural capital stock was destroyed, which negatively affected Uganda's ability to generate export income and led to a fiscal crisis. Europeans and Asians had dominated the industry sector. Thus, the expulsion of the Asians in 1972 and the following emigration of Europeans had a tremendous impact on economic recovery of the country. Since those days, there had been a lack of experienced managers and a technological vacuum (Bibangambah, 2001, p. 38 f.).

In 1986 President Museveni had to face a completely ran down country. Since then the World Bank, the International Monetary Fund, and other international official and private development aid organisations assist the Government of Uganda in their efforts to achieve sustainable economic growth and to fight poverty.[2] The support showed promising results and given its sound record of economic growth, Uganda qualifies as one of the first countries HIPC debt relief. During 1998 to 2000 debt amounting USD 1 billion were relieved.

In 2003, the GDP per Capita was only USD 259.00. The GDP per Capita or per capita income can be seen as a proxy for the wealth of a country.[3] Uganda's GDP per Capita has been rather stable for the past ten years (see Figure 1).

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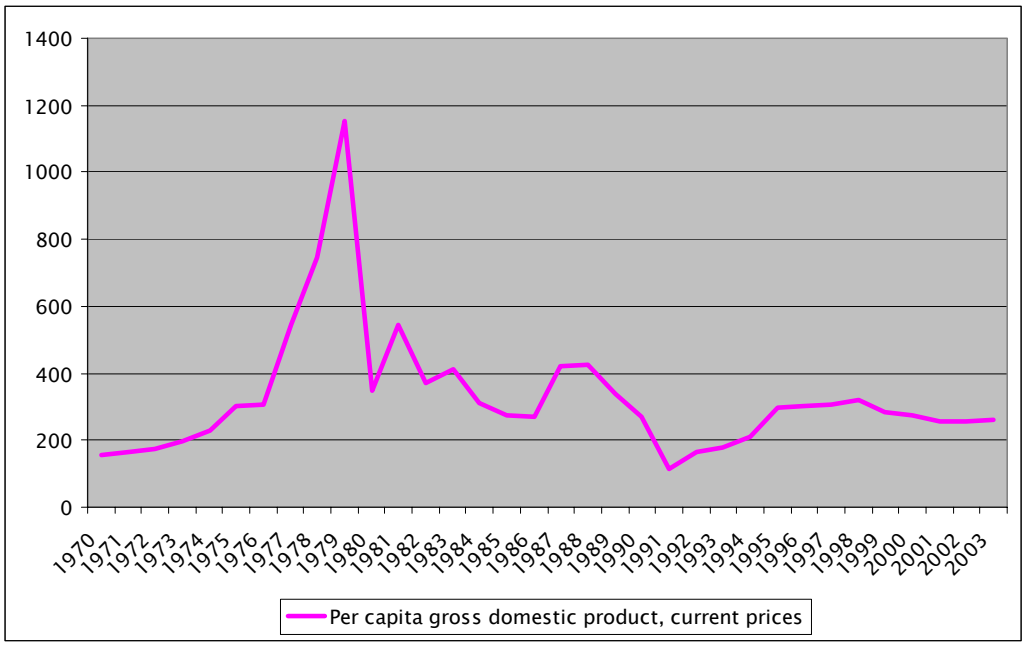
[1] For further analysis of Uganda's political and economic development between 1986 and 1996, see Mugaju (1999).

[2] Reinikka and Colliere (2001) provide an analysis of the micro- and macro-economic level based among others on the 1999/2000 household survey.

[3] This measure of people's wealth has several conceptual and statistical shortcomings. There are three general issues, which can be identified. In developing countries the non-monetary sector (i.e. the subsistence economy) can play an important role. Thus any income measure would not capture the actual income generated within one period. The population statistics might also be not reliable, which may significantly influence the ratio given the relatively small size in USD terms of the developing economies. Last but not least there is the conversion of the domestic currency into „internationally comparable currency". For a more detailed discussion of the GDP per capita as a measure of development, see Hemmer (2002, p. 9 ff.). A thorough introduction on development economics provides e.g. Stern (1989).

*Figure 1: Per Capita Gross Domestic Product in USD*




*Source: Authors' calculations based on World Economic Outlook data.*

Other indicators, which e.g. are used to determine UNDP's Human Development Index[4] (see Table 1), to reflect the wealth or poverty of the country are among others life expectancy, literacy ratio, and the child mortality. In 2001 the population of 24.75 million had a life expectancy of only 43 years (1990 it was 47 years), whereas in Germany the life expectancy is 78 years. The main causes of deaths are HIV/AIDS and Malaria. The child mortality for children up to the age of five is 8.79% (in Germany 0.43%). The literacy ratio for adults was 67% in 2001 (1990 56%), and for teenager it was already 79% (1990 70%) thanks to the efforts spend on primary school education.[5]

[4] The Human Development Index shall provide more holistic assessments of the development progress of countries. For a detailed description see UNDP, 2004, p. 258 ff..

[5] The 2003/2004 Budget estimate assigns 23% or 529.91 billion UGX (approximately 215 million EUR) of Uganda's Budget for education.

*Table 1: Human Development Indicator (HDI) 2004*

| HDI rank | Gross enrolment ratio for schools in %, 2001/2002[6] | Life expectancy index | Education index | GDP index | HDI value 2002 |
|---|---|---|---|---|---|
| 1 Norway | 98 | 0.9 | 0.99 | 0.99 | 0.956 |
| 19 Germany | 88 | 0.89 | 0.95 | 0.94 | 0.925 |
| 146 Uganda | 71 | 0.34 | 0.7 | 0.44 | 0.493 |
| | | | | | |
| Sub-Saharan Africa | 44 | 0.35 | 0.56 | 0.48 | 0.465 |
| OECD | 87 | 0.87 | 0.94 | 0.92 | 0.911 |
| High-income OECD | 93 | 0.89 | 0.97 | 0.95 | 0.935 |
| High human development | 89 | 0.87 | 0.95 | 0.92 | 0.915 |
| Medium human development | 64 | 0.7 | 0.75 | 0.63 | 0.695 |
| Low human development | 40 | 0.4 | 0.5 | 0.41 | 0.438 |
| High income | 92 | 0.89 | 0.97 | 0.94 | 0.933 |
| Middle income | 71 | 0.75 | 0.84 | 0.68 | 0.756 |
| Low income | 51 | 0.57 | 0.59 | 0.51 | 0.557 |
| World | 64 | 0.7 | 0.76 | 0.73 | 0.729 |
| | | | | | |
| **HDI rank** | **1985** | **1990** | **1995** | **2002** | |
| 146 Uganda | 0.395 | 0.395 | 0.404 | 0.493 | |

*Source: Human Development Report 2004*

Although the overall performance of Uganda is promising, the economy still suffers from the dramatic economic drawbacks in the 1970s and 1980s. In 1996, only 500 enterprises employed more than 20 employees.[7] Small and smallest enterprises alone cannot contribute enough to the economic development because they cannot establish the capital stock, which is necessary for a sustainable economic development.[8] Most Ugandan households live from subsistence smallholdings, which only generated an income equivalent on the level of the early 1970s in 1999.

The economic development has been constantly positive with the agricultural sector being the most dominant. The agricultural goods are produced mainly for local consumption. Industrially produced and processed products are sugar, brewery products, tobacco, cotton, textiles and cement. The main export goods are coffee, tea, fish, gold, cotton, flowers and tobacco.

[6] Gross enrolment ratio for primary, secondary and tertiary schools (%) 2001/2002.
[7] Bibangambah (2001) provides a detailed analysis of Uganda's development.
[8] See Hemmer (2002, p 171 ff) for a more detailed description.

The dependency on agriculture may be the rational choice of a resource rich country, where human labour costs are relatively cheap. Nevertheless, apart from the obvious direct link of the success of any harvest on the weather conditions, one should consider two other facts, when assessing the dependence of a country from agriculture and commodity prices. Prices of primary commodities in general do not show trends but a high variance, are highly positively correlated and despite several sharp upward spikes, commodity prices are mean reversing and its distribution is positively skewed (Deaton, 1999). They also show a statistically significant long-term downward trend in the ratio of primary products to those of manufacturers (Bleaney and Greenaway, 1993). Due to technical progress industrial countries can compete with developing countries although cheaper labor and richer natural resources should indeed favor developing countries.[9] Whether this will change in the foreseeable future can be questioned, because the real prices of commodities cannot rise as long as there is an unlimited supply of labor at subsistence level (Deaton, 1999, p.30).

In order to lower further the dependency of Uganda from the donor support, the Government of Uganda and international donors are highly interested in a sustainable increase in the (industrial) capital stock, which should enable Uganda to continue its overall successful economic development.

The outlook for growth is generally favourable, with increased diversification from traditional exports such as coffee. The annual growth rate is expected to average 5% over the medium term. However, with fiscal expenditures almost doubling revenues, the economy remains dependent on donors for the financing of almost half of Uganda's Budget. Whether this is a sustainable, highly depends on the political developments and last but not least on the continuation of good relations with donors.[10]

Since political parties are seen as divisive and as a risk to the stability, the Movement system does not allow political parties. The legality of this ban on multipartyism has been questioned recently by a constitutional court. Most donors have welcomed this ruling and have been encouraging the development of multipartyism. A referendum on the issue is likely to be held in 2005. President Museveni's ability to seek a further term in office after 2006, which is theoretically possible if the constitution is changed, will be important for the Ugandan outlook.

[9] See Deaton (1999) and Deaton and Laroque (2002) for recent explanations of this puzzle, which was originally described by Arthur Lewis 1954.

[10] See Collier and Gunning (1999) for a general analysis of the economic performance of African countries.

## 2.2 Financial Sector

A stable financial sector is a necessary condition for a sustainable positive development and one of its safeguards is usually the country's central bank. A close link exists between the maintenance of price stability and financial sector stability. This link is theoretically embedded in the various theories on transmission mechanism, which highlight effective monetary policy implementation modalities. Thus, financial sector stability is regarded as a key prerequisite for the efficient conduct of monetary policy by central banks.

Whereas economist can agree on a common definition for price stability, no commonality on the clarity of the definition for financial stability can be professed. Most economists find it more convenient to define financial instability instead of its positive counterpart, financial stability. Thus, a financial crisis is seen as a disruption to financial markets in which adverse selection and moral hazard problems predominate, with the result that financial markets are unable to efficiently channel funds to their most productive uses. On the other hand, financial stability is characterized as a situation in which the financial system is capable of: (1) allocating resources efficiently between activities and across time; (2) assesses and manages financial risks, and (3) absorbs shocks. A stable financial system is thus one that enhances economic performance and wealth accumulation and prevents shocks from having adverse structural impacts on the financial sector.

A financial sector has various participants depending on the particular economy. After the independence of Uganda was declared, only foreign owned banks were active in Uganda: Barclays, Standard, ANZ Grindlays and Bank of Baroda. The latter had also been the central banking function for some time. Over the years, those four banks were nationalized and again partly privatized. When President Museveni came into power, new commercial banks were founded and an independent central bank, the Bank of Uganda was established. The Bank of Uganda regulates and supervises the commercial banks. In the 1990s the Government of Uganda started its financial liberalization process, which implied the devaluation of the Uganda Shilling (UGX), liberalization of the foreign exchange markted and of the capital market. The formerly fixed interest rates were also abandoned and influences on the credit policies of commercial banks ceased to be applied.

However, commercial banks are reluctant to grant loans to privately owned enterprises and private businessmen. Instead of concentrating on the credit business, commercial banks have been investing in government securities. The reluctance can be partly explained by the experience with the credit policies of the former governmentally owned and market dominating banks. Loans were usually not repaid, because they were regarded as government grants or gifts (Bibangambah, 2001, p. 91). Conducive to this perception were respective comments and descriptions by the government.

Against this background, it might not be surprising that the former biggest bank, the Uganda Commercial Bank, had to classify more than 80% of its outstanding loans as non-performing. The portfolio of the second state bank, the Co-operative Bank, was as bad. Nevertheless, both banks collected more than 50% of all deposits in Uganda and they owned 90% of all branches in the country. All other banks concentrated their business on the financial and political centre Kampala.

Until end of 2003, there were only short-term government securities, which showed high real interest rates. Thus it was usual for commercial banks to invest in those. Smallest and small entrepreneurs have not been services as necessary. This segment is fortunately serviced by microfinance institutions (MFIs). Uganda's microfinance culture is internationally well know and regarded as a leading example of the success of microfinance. The refunding possibilities for MFIs are restricted because they are not allowed to mobilize deposits from the public. However, MFIs are allowed to accept savings from members of mutualist institutions and mandatory savings.

Currently, there are 15 commercial banks, 7 credit institutions, which are regulated and supervised by the Bank of Uganda. Among the unsupervised financial services providers, there are more than 1000 SACCOs/credit unions, which are registered with the Registrar of Co-operatives, and more than 1000 outlets of MFIs, which serve more than 600000 borrowers and 800000 savers.[11]

Given the importance of the MFIs for the financial sector, it was decided to integrate some MFI into the formal regulated financial sector. The rationale for the regulation and supervision of the so called Tier-3 MFIs shall ensure (1) the sound development of the financial sector; (2) the safety of public deposits and the ability for its withdrawal. The regulation of Tier-3 MFIs also requires minimum capital requirements and capital adequacy ratios similar to those of the other financial institutions in Uganda.

Since those requirements are difficult to meet for most MFIs, and because effective and cost-effective supervision requires sufficient capacity for the Bank of Uganda as well as the MFIs, only those MFI which have a significant scale of operations and the institutional capacity to achieve compliance with the regulatory requirements shall become regulated Tier-3 institutions, i.e. Micro Finance Deposit-taking Institutions (MDI). The vast majority of MFIs, especially those credit-only and small member-based institutions will not be

The approach chosen by Bank of Uganda provides a gradual approach for MFIs, which do not immediately qualify for an MDI license, can gradually develop into an MDI. The MDI license is no must for every MFI. However, transition of unregulated

[11] The savings are mandatory and voluntary although not legal.

(large) MFIs into MDIs is highly welcomed. Thus, all MFI with significant outreach should be regulated and supervised as far as the overall financial stability approach is concerned. The failure of any institution, which provide financial services functions such as investments and savings, affects its stakeholders and depending on its size, it might also have an effect on the whole sector.

In addition to sound and well regulated and supervised financial institution a stable macroeconomic environment is also conducive for a stable financial system, therefore appropriate policies are necessary and if possible tools, which enable the responsible authorities to take appropriate actions well in advance to avoid adverse economic situations.

# 3 Literature Review

Over the course of time, different models were developed which aim at predicting currency crises. One usually differentiates three model generations to describe the explanatory approaches for currency crises respectively balance-of-payment crises.

Krugman (1979) developed one of the most prominent of the first generation of models in the light of the crises in Latin America in the 1960s and 1970s. Krugman focused on the impact of the fiscal and monetary environment on the balance-of-payment crises. A balance-of-payment crisis is a speculative attack on the central bank during the final moments of a peg. Krugman found that a weak economic environment contributes to speculative attacks on a fixed exchange rate. Against the background of an expansive monetary policy and a growing credit volume, a stable exchange rate could only be maintained if the central bank sold reserves. Since international reserves are limited, speculators, who anticipate an abandonment of the fixed exchange rate, cause a currency crisis by exchanging domestic for foreign money in order to avoid capital losses.

Flood and Garber (1984) developed a linear version of the Krugman model. It is based on a deterministic, continuous time monetary model of a small economy in which the size of a country's financial liabilities relative to its short-run ability to foreign exchange or a sustained real appreciation from domestic price level inflation should signal an increasing likelihood of a crisis.[12] Since it is a deterministic model, attacks are predictable, which is actually not possible.[13]

The second-generation models were developed after the currency crises in the European Monetary System 1992/1993 and the crisis in Mexico 1994/1995. They explicitly accounted for authorities' policy options to defend the exchange rates and its related costs. Models of this generation are closely linked with the seminal work of Obstfeld (1986), who introduces the impact of rational expectations of investors into his approach. It implies that a market can reach an equilibrium with favourable as well as adverse economic fundamentals depending on the expectations of investors and their respective actions (i.e. multiple equilibria are possible). The monetary and fiscal policies are assumed to be exogenously set. Unfortu-

[12] See Mark (2001) for a more detailed description of the deterministic model, who also extends it to a stochastic environment which provides the conditional probability of an speculative attack on the currency.

[13] Krugman (1979) himself saw the restrictions of his model: „The first (model) is based on a highly simplified macroeconomic model. (…) In a more we would have to allow for the possibility of other policies to stabilize the exchange rate, such as an open market sales of securities or intervention in the forward market." (Krugman 1979, p 324). However, these models allow us to understand the main causes of a balance-of-payment or currency crisis.

nately, the reasons for expectations shifts are not fully explained by this model generation, except that they are based on economic fundamentals.[14]

The models of the third generation were developed after the 1994/1995 Tequila crisis and the Asian crisis in 1997/1998. Apart from the acknowledgment that the behavior of market participants influences also the decisions of policymakers, the main characteristics of those models are the integration of moral hazard, information asymmetries, herding and contagion effects. The extensions of the second generation models were necessary because the fundamentals, which had been monitored until then, could not explain the causes of the crises. The combination of booming economies with currency crises was not expected. This also caused the research to focus on excessive booms, asset prices, international capital flows and institutional framework conditions (such as banking regulation and supervision) as causes and contributing factors for crises, respectively.

Whereas policymakers would appreciate a common set of factors, which might cause currency crises, recent empirical research showed, that the causes of crises are not equal (Kaminsky, 2003). However, Kaminsky (2003) showed that „most of the crises are characterized by multitude of weak economic fundamentals, suggesting that it would be difficult to characterize them as „self fulfilling" crises" (Kaminsky 2003, p. 16). Therefore, it should be attempted to develop early warning models to detect such weaknesses in advance to allow policymakers to take appropriate steps.

The empirical test of the various approaches and its application in early warning systems follow three methodological model approaches: i) the leading indicator approach, ii) the linear-dependent variable approach, iii) the discrete-dependent variable approach, iv) other new approaches, apart from the three aforementioned ones, like artificial neural networks, latent variable threshold models, autoregressive conditional hazard models or Markov regime switching models. An overview over those newer approaches is provided by Abiad (2003).[15]

Sachs, Tornell and Velasco (1996) e.g. use the linear-dependent variable approach. In their paper, they analyse the Mexican crisis in 1994/1995 (the so called Tequila Crisis) and its aftermaths. Their model uses three explanatory variables in a linear regression to determine whether a country is vulnerable for a crisis: the percentage changes of i) the real depreciation of the exchange rate, ii) the ratio of the size of claims of the banking sector on the private sector to GDP as a proxy for the resilience and weakness of the banking sector, respectively, and iii) the reserve adequacy measured as M2 to the stock of foreign exchange reserves. As

[14] See Diamond and Dybvig (1983) for a similar reasoning for banking runs, which are also recognized by Obstfeld, whose links to currency crises he however does not identify, yet.

[15] Abiad (2003) also provides overviews over the various crisis definitions, coverages and „standard" methodology models in the empirical literature after 1997.

dependent variable, a crisis index is used, which is a weighted average of the devaluation of the exchange rate against the US-Dollar and the percentage change in foreign exchange reserves. The linear regression returns a steady dependent variable and even small changes in the independent variables are captured. However, non-linearities are not captured. The authors conclude for their empirical work that the combination of overvalued exchange rates, recent lending booms and low reserves relative to short-term commitments of the central bank are conducive for crises. However, they also found that the current account data, capital flows and fiscal policies do not provide further explanatory power.

The most widely used approaches in the empirical literature on currency crises are the first two approaches. In the leading indicator approach, signals are extracted from a set of indicators. It has traditionally been used to predict business cycle turning points.[16] The seminal paper of this approach for currency crises is Kaminsky and Reinhart (1996), followed by Kaminsky, Lizondo and Reinhart (1998), Kaminsky and Reinhart (1999), Goldstein, Kaminsky and Reinhart (2000) and Edison (2000) are papers, who apply this approach. Authors who use the second methodological approach are among others Eichengreen, Rose and Wyplosz (1995), Berg, Borensztein, Milesi-Feretti, and Patillo (1999) as well as Bussiere and Frantzscher (2002).

Edison (2000) carries on mainly the work of Kaminsky, Lizondo, Reinhart (1998) by using a wider range of countries, adding explanatory variables, testing for regional differences as well as applying their model for one specific economy (Mexico) without using information from other countries. The performance of his model is mixed. He concludes that there are to many false alarms[17], which are mostly due to the fact there are too few crises in the sample, and therefore further research would be necessary.

Bussiere and Frantzscher (2002) use another type of model, which allows for statistical tests. For a sample of 32 emerging market economies with monthly data from 1993 to 2001, they use a multinomial logit model to predict currency crises within a 12months window. The multinomial logit model was chosen because it enabled them to distinguish between three phases for each country and thereby to avoid post-crisis bias in their analysis. Unlike most other studies, they take into consideration the significant difference of the behaviour of the indicators during the tranquil pre-crisis period, and the crisis and post-crisis phase, respectively.[18] The application of the multinomial logit model enabled them to improve predictive power of their model.

[16] See Diebold and Rudebusch (1989) for a formal probability assessment of composite leading indicators for the aggregate US economic activities.
[17] The signals approach does not allow for common statistical significance tests.
[18] The pre-crisis and the post crisis phases cover the preceding 12 months before a crisis and the 12 months following a crisis.

A recent overview over the performance of various currency crises models, which were tracked by the International Monetary fund is provided by Berg, Borensztein and Patillo (2004). They compare the models from the IMF's Developing Country Studies Division and Kaminsky, Lizondo, Reinhart (1998), which have long signalling windows, with the three private sector models from Goldman Sachs, Credit Suisse First Boston and Deutsche Bank, which have short signalling windows. Out of the five models, the Kaminsky, Lizondo and Reinhart model performed best in the relevant out-of-sample test. The private sector models performed poorly out-of-sample. The authors conclude, that their „results reinforce the view that EWS models are not accurate enough to be used as the sole method to anticipate crises" (Berg, Borenzstein and Patillo, 2004, p.30). Nevertheless, „(t)he advantage of EWS models lie in their objective, systematic nature" (Berg, Borenzstein and Patillo, 2004, p. 30).

# 4 Step 1: The Index of Exchange Market Pressure

This section describes the definition of a currency crisis using an index of exchange market pressure and describes how this index is calculated.

## 4.1 Methodology

It is not trivial to define a currency crisis: „There is no generally accepted formal definition of a currency crisis, but we know them when we see them".[19] Nevertheless, to build a quantitative or econometric model it is necessary to operationalize the term „currency crisis".

In this paper a currency crisis is defined as a period or a situation in which an attack on the currency leads to a sharp depreciation of the currency, or to substantial losses in international reserves, or to both. This definition of a currency crisis has the advantage that it is comprehensive to include successful and unsuccessful attacks on the currency because it takes into account the reserve losses, i.e. the cost of an unsuccessful speculative attack. It also captures different exchange rate regimes, including fixed exchange rates, crawling pegs or exchange rate bands.[20]

According to Goldstein, Kaminsky and Reinhart (2000) and Edison (2000) we define an index of currency market turbulences as an weighted average of the rate of change of the exchange rate, $\delta e_t$, and the rate of change of the reserves, $\delta R_t$.[21] The weights are chosen in a way that the two components of the index have equal sample volatilities.

Let $e_t$ denote the exchange rate at time $t$ (defined as units of domestic currency per US dollar), $R_t$ the international reserves at time $t$ (international reserves, measured in US dollars), $\sigma_{\delta e}$ the standard deviation of the rate of change of the exchange rate and $\sigma_{\delta R}$ the standard deviation of the rate of change of reserves, respectively. Then the index of exchange market pressure *EMPI* is defined as follows:

$$EMPI_t = \delta e_t - \left( \frac{\sigma_{\delta e}}{\sigma_{\delta R}} \right) \bullet \delta R_t, \quad where \;\; \delta e_t = \frac{e_t - e_{t-1}}{e_{t-1}} \;\; and \;\; \delta R_t = \frac{R_t - R_{t-1}}{R_{t-1}}$$

Since changes in the exchange rate are positively and changes in the reserves negatively related to the index of exchange market pressure, a crisis is said to occur when the index of exchange market pressure is more than $m$ standard deviations above the mean. Let $\mu_{EMPI}$ denote the mean and $\sigma_{EMPI}$ the standard deviation

[19] See Krugman (2000), p.1.
[20] However, the Ugandan shilling floats free to the USD.
[21] See Goldstein, Kaminsky and Reinhart (2000), p. 19, and Edison (2000), p. 10.

of the index of exchange market pressure, $m \in IR_+$, a currency crisis is formally defined as follows:

$$Crisis\ in\ t = \begin{cases} 1, & if\ EMPI_t > \mu_{EMPI} + m\sigma_{EMPI} \\ 0, & otherwise \end{cases}$$

Kaminsky and Reinhart (1999), Kaminsky, Lizondo and Reinhart (1998) and Goldstein, Kaminsky and Reinhart (2000) modify this index for countries with hyperinflation. Since Uganda has no hyperinflation, these modifications are not necessary for our research.

### 4.2 Exchange Rates

To implement this index of exchange market pressure for Uganda some decisions about the underlying data have to be made. The international reserves are provided by the Bank of Uganda (hereafter BoU) as complete time series. The next question to answer is about which exchange rate should be used.[22] The BoU provides, among others, time series for the following types of exchange rates:

- Official Middle Rate
- Forex Bureaux Rate
- Real Effective Exchange Rate (REER)
- Nominal Effective Exchange Rate (NEER)

#### 4.2.1 Official Mid-Rate

In Uganda the official mid rate is the average of the weighted buying and selling rates in the inter-bank foreign exchange market. The Ugandan commercial banks submit their rates and transaction volume three times a day (at the opening of the market, midday and at the closing of the market) via Reuters to the Bank of Uganda. For each bank, the three submitted rates are averaged and then weighted according to the transaction volume of the reporting bank. The weighted averages for all the banks are thereafter summed up to get a single value, for the weighted buying or selling rates.

At the end of a business day, the commercial banks submit the rates, which they intend to use during the following business day. Thus, when a business day starts,

[22] Kaminsky and Reinhart (1999) and Kaminsky, Lizondo and Reinhart (1998) use the real exchange rate; see Kaminsky and Reinhart (1999), p. 479.

Bank of Uganda already has the official mid rate to be used that day. The official mid-rate is the rate that the Bank of Uganda uses in their policies. For non-policy transactions, e.g. if the Bank of Uganda purchases a computer in South Africa, it uses the weighted buying or selling rate respectively.

### 4.2.2 Foreign Exchange Bureaux Rate

The computation for the foreign exchange bureau (forex) bureaux rate is the same as that of the inter-bank mid rate, only that in this case, it is the forex bureaux' rates that are used.

### 4.2.3 Nominal Effective Exchange Rate

In contrast to the nominal exchange rate, which shows how many Uganda Shilling can purchase one unit of a foreign currency, the nominal effective exchange rate (NEER) is an index measure, which shows the changes of the Uganda Shilling relative to other currencies. The composition of the basket of other currencies used for the NEER reflects the importance of Uganda's trading partners expressed by the country's export trade weight.

$$\text{NEER} = \prod_{i=1}^{k} e_i^{\alpha_i}$$

Where k = number of trading partners;

$e_i$ = the exchange rate of the Uganda Shilling against the trading partner i's currency;

$\alpha_i$ = the export trade weight of country i and

$$\sum_{i=1}^{k} \alpha_i = 1$$

### 4.2.4 Real Effective Exchange Rate

The real exchange rate (REER) of a country is the nominal effective exchange rate adjusted for inflation differentials among the countries it trades with. It gives an

indication for a country's ability to sell abroad. Therefore the REER is often regarded as an indicator of competitiveness in the foreign trade of a country.

According to the classic definition of the purchasing power parity (PPP), the real exchange rate is defined in the long run as the nominal effective exchange rate, e, that is adjusted by the ratio of the foreign price level, $P_f$, to the domestic price level, $P_{UG}$. In Uganda's case, the underlying consumer price index (CPI) is used as proxy for domestic prices. Mathematically, it can be shown as

$$REER = e\frac{P_f}{P_{UG}}$$

In terms of this definition, the decline in the REER can be interpreted as the real appreciation of the exchange rate; the reverse is true in the case of an increase.

There are several approaches to include foreign price levels in the REER. In Uganda, the foreign prices as used in the REER are indices of CPI, or wholesale price indices (where available) of Uganda's trading partners, weighted by the trade shares.

$$\mathrm{P_f} = \prod_{i=1}^{k} \rho_i^{\alpha_i}$$

Where k = number of trading partners;

$\rho$ = the (wholesale or consumer) price index of the country i; and

$\alpha_i$ = the export trade weight of country i with Uganda and

$$\sum_{i=1}^{k} \alpha_i = 1$$

Therefore, the REER can be expressed as

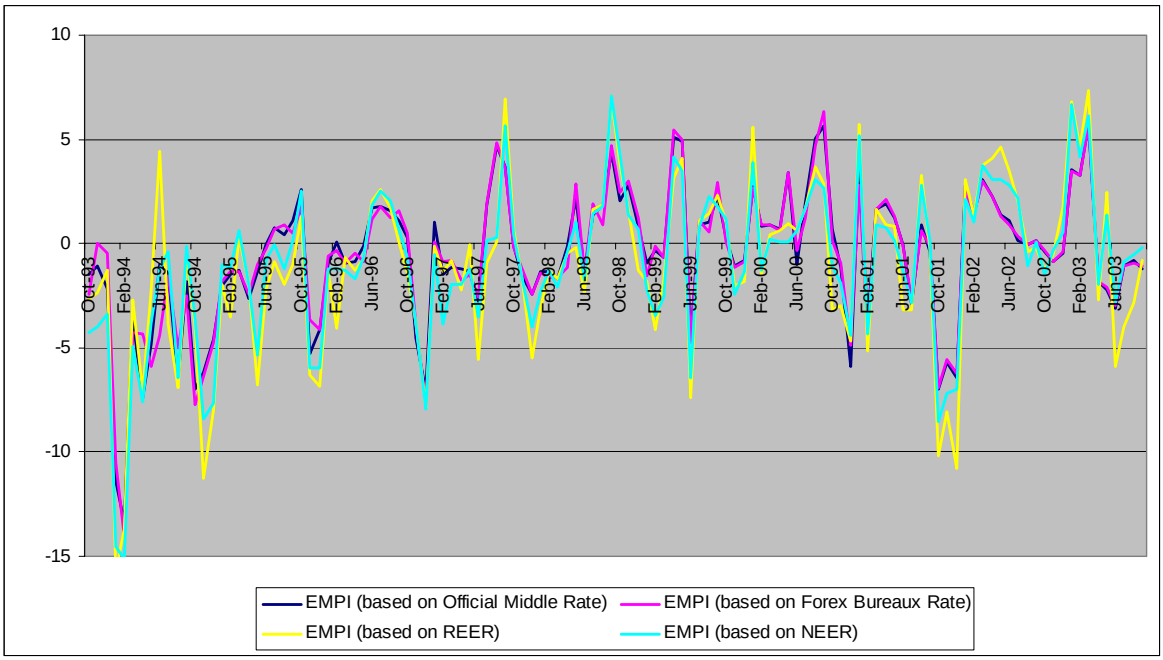
$$REER = \prod_{i=1}^{k} e_i^{\alpha_i} \cdot \frac{P_i^{\alpha_i}}{P_{UG}}$$

It has to be acknowledged that the mixture of wholesale and consumer price indices reflects two different methodologies of measuring price changes. Whereas the wholesale prices cover prices charged at the first stage of the bulk distributions, the consumer price index relates to a basket of goods and services bought by households. However, data restrictions beyond the influence of Bank of Uganda require using different measures of price changes.

## 4.3 Implementation

Figure 2 displays the indices of exchange market pressure based on the exchange rates mentioned above. As we can see, almost all indices are very close together and show nearly the same peaks and minima.

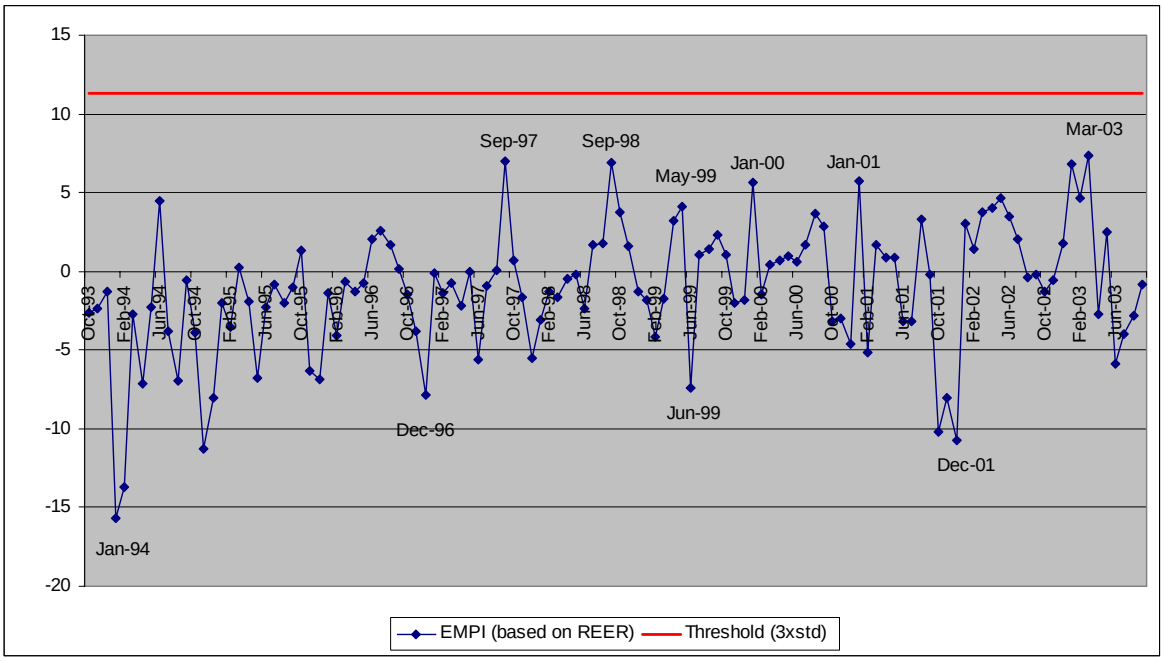
*Figure 2: Indices of Exchange Market Pressure*




*Source: Authors' calculations.*

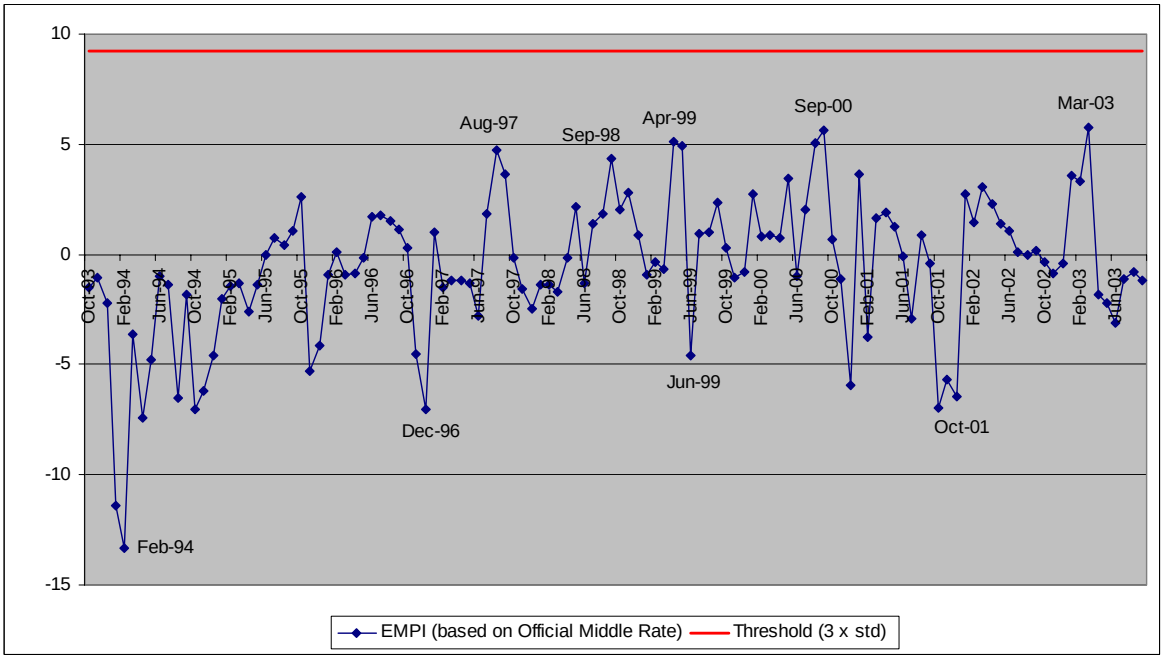
Figure 3 and Figure 4 displays the index of exchange market pressure based on the real effective exchange rate and the index of exchange market pressure based on the official middle rate, respectively. The thresholds are calculated according to Kaminsky, Lizondo and Reinhart (1998) as the mean plus three times the standard deviation, i.e. $m = 3$, in the formula above.

*Figure 3: Index of Exchange Market Pressure (based on REER)*




*Source: Authors' calculations.*

*Figure 4: Index of Exchange Market Pressure (based on Official Middle Rate)*




*Source: Authors' calculations.*

If we compare the results of both indices in Figure 3 and Figure 4 we see that the highest peaks as well as the local minima go hand in hand. The main differences

occurred in June 1994, where the EMPI based on the real effective exchange rate shows a higher peak and in the month January 2000 and January 2001, where the EMPI based on REER shows clearer peaks than the EMPI based on the official middle rate. On the other hand, the index based on the official middle rate shows a peak in September 2000 that was not so strong reflected in Figure 3.

What all the indices have in common is that they are far away from reaching the threshold. This actually reflects the economic situation of Uganda, because there was no currency crisis observed in Uganda during the monitored time. Because this index is used as a benchmark for calculating the performance of the indicators, this fact will lead to several adjustments in section 4.

Nevertheless, we want to validate the indices displayed above. Since it is not possible to validate the indices on currency crisis of the past, we had some talks with several experts from BoU. In line with these experts we refer our validation on the index showed in Figure 4.[23] The coffee boom reaching its maximum within these periods can explain the local minimum in January/February 1994. The peaks in the periods from August 1997 to April 1999 can be identified as those periods where some banks in Uganda got bankrupt and therefore can be described as banking crisis.[24] Between 1993 and 2003, Bank of Uganda intervened in ten commercial banks and credit institutions.[25] The peak of the Ugandan banking crises is usually set between 1998 and 1999, when four banks were closed (Caprio and Klingebiel 2003):

- International Credit Bank Ltd.,
- Greenland Bank Ltd.,
- The Co-operative Bank Ltd., and
- Trust Bank.

The EMPI peak in March 2003 can be explained by the middle-east crisis and the war in Iraq. Therefore, even if there was no currency crisis occurring in the past, we could validate the calculated indicators.

[23] The reason for concentrating on the EMPI based on the official middle rate is quite practical: For the practical use as benchmark it is necessary to calculate this index as soon as possible. Since the data of the official middle rate is accessibly with only one month time lag and the data of the real effective exchange rate has a time lag of approximately six month, we focus on the first one. As shown above, the differences are very small and the EMPI based on REER is in practice calculated when the data is provided.

[24] This shows also the phenomenon of twin crisis, meaning that banking crisis and currency crisis are often strongly connected; see Kaminsky and Reinhart (1999) for further details.

[25] Teefe Trust Bank Ltd., Sembule Investment Bank Ltd., Nile Bank Ltd., The Co-operative Bank Ltd., International Credit Bank Ltd., Trust Bank Ltd., Greenland Bank Ltd., Uganda Commercial Bank Ltd., TransAfrica Bank Ltd., and Interstate Finance Company Ltd.

# 5 Step 2: The Indicators

## 5.1 Choice of Indicators

In the literature on EWS there are discussed a variety of different indicators. In their comprehensive paper Kaminsky, Lizondo and Reinhart (1998) analyze 105 indicators regarding to their ability to predict currency crises and identify several categories of indicators. Based on this research Kaminsky and Reinhart (1999) use 15 selected and high-performing indicators. These indictors can be grouped into four major categories: current account indicators, capital account indicators, real sector indicators, and financial indicators. A list of the variables considered is given below in Table 2.[26]

*Table 2: Categories and corresponding Indicators*

| Category | Indicator | Comments[27] |
|---|---|---|
| Current account indicators | Real exchange rate | Real exchange rate overvaluations and a weak external sector are a part of a currency crisis. They add to the vulnerability of the banking sector since a loss of competitiveness and external markets could lead to a recession, business failures, and a decline in the quality of loans. Thus, large negative shocks to exports, the terms of trade, and the real exchange rate and positive shocks to imports are interpreted as symptoms of financial crises.[28] |
| | Exports | |
| | Terms of trade | |
| | Imports | |
| Capital account indicators | International reserves | High world interest rates may anticipate currency crises as they lead to capital out-flow. Capital account problems become more severe when the country's foreign debt is large and capital flight increases since it may raise issues of debt „unsustainability".[29] |
| | M2 / international reserves | |
| | Domestic/foreign real interest rate differential | |
| Real sector indicators | Real output | Recessions and the burst of asset price bubbles precede financial crises.[30] |
| | Equity prices (excluded) | |

[26] Definitions of the indicators are given in Appendix B.
[27] The comments are based on Kaminsky (1999) and Kaminsky and Reinhart (1999).
[28] See Dornbusch et al. (1995).
[29] As discussed in Kaminsky and Reinhart (1999), a currency crisis may in turn deepen the banking crisis.
[30] See Gorton (1988) and Calomiris and Gorton (1991).

*Table 2 (continued)*

| Category | Indicator | Comments[31] |
|---|---|---|
| Financial sector indicators | M2 multiplier | Both banking and currency crises have been linked to rapid growth (boom-bust) in credit and the monetary aggregates.[32] |
| | Domestic credit / nominal GDP | |
| | Real interest rate on deposits | High real interest rates could be a sign of a liquidity crunch leading to a slowdown and banking fragility. An increase in the lending/deposit ratio in the domestic economy can capture a decline in loan quality. |
| | Ratio of lending interest rate to deposit interest rate | |
| | Excess real M1 balances | Loose monetary policy can fuel a currency crisis.[33] |
| | Bank deposits | Currency crises (as well as banking crises) can be preceded by bank runs.[34] |

## 5.2 Calculating the Indicators

In order to adjust the model of Kaminsky and Reinhart (1999) to Uganda we choose the indicators shown in Table 2. After screening the data and the economic situation for Uganda we excluded the equity prices, since until September 2004, there were only five companies listed at the relatively young Uganda Securities Exchange, of which two are cross listed from the Nairobi Stock Exchange:

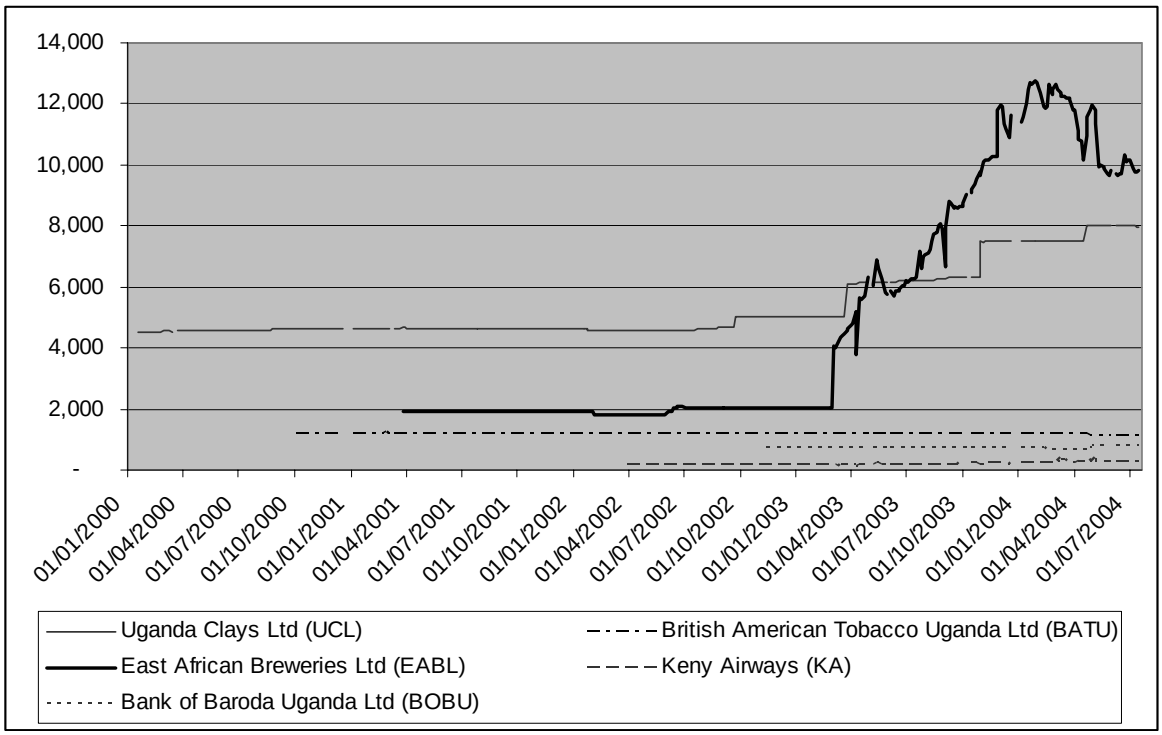
- UCL, Uganda Clays Ltd – listed in January 2000
- BATU, British American Tobacco Uganda Ltd – listed in October 2000
- EABL, East African Breweries Ltd – listed in March 2001
- KA , Kenya Airways Ltd – listed in March 2002
- BOBU, Bank of Baroda Uganda Ltd – listed in November 2002

There is no significant turnover on the two trading days per week, therefore the market has to be considered illiquid and in contrast to the fixed income market not yet significantly attractive for portfolio investments. However, when the equity mar-

[31] The comments are based on Kaminsky (1999) and Kaminsky and Reinhart (1999).
[32] See McKinnon and Pill (1996).
[33] See Krugman (1979).
[34] See Goldfajn and Valdes (1995).

ket liquidity grows and becomes attractive for foreign investors equity prices should be taken into account as an indicator for the model.

*Figure 5: Equity Prices at the Uganda Securities Exchange since 2000*




*Source: Authors' calculations.*

According to Kaminsky, Lizondo and Reinhart (1998) for most of the variables the monthly value of the indicator was defined as the 12-month percentage change in the level of the variable with respect to its level a year earlier. This filtering provides the following advantages: The units are comparable across countries, i.e. it reduces the „noisiness" of working with monthly data, and the transformed variables are stationary, with well defined moments, and free from seasonal effects. This filter was not used for: the deviation of the real exchange rate from trend, the „excess" of real M1 balances and the three variables based on interest rates. Table 3 provides information about the transformation used and the frequency of the data.

*Table 3: Transformation and Data Frequency of Indicators*

| Indicator | Transformation | Data frequency |
|---|---|---|
| Real exchange rate | Deviation from trend | monthly |
| Exports | 12-month growth rate | monthly |
| M2 / international reserves | 12-month growth rate | monthly |
| Real output | 12-month growth rate | monthly |
| Excess real M1 balances | Level | monthly |
| International reserves | 12-month growth rate | monthly |
| M2 multiplier | 12-month growth rate | monthly |
| Domestic credit / nominal GDP | 12-month growth rate | monthly |
| Terms of trade | 12-month growth rate | monthly |
| Real interest rate on deposits | Level | monthly |
| Imports | 12-month growth rate | monthly |
| Domestic/foreign real interest rate differential | Level | monthly |
| Ratio of lending interest rate to deposit interest rate | Level | monthly |
| Bank deposits | 12-month growth rate | monthly |

To realize the advantages of the 12-month percentage changes it is necessary to have monthly data. Since not all data is provided monthly, we estimated some monthly values. For example the GDP is provided as annual data from BoU.[35] Therefore, we use a linear spline-interpolation to calculate the monthly values of the GDP.[36]

### 5.3 The Signal-extraction Method

The objective is now to obtain signals from the indicators presented above. Each indicator is analyzed separately within this univariate approach to predict a cur-

[35] We will refer to this in section 4.6

[36] This is appropriate since the linear trend of the annual GDP data has a coefficient of determination $R^2$=0.9966 and the interpolated GDP data provides a value of $R^2$=0.9976, i.e. the difference is less or equal than 0.001.

rency crisis. Hence each indicator is monitored to identify when a variable deviates from its „normal" behavior beyond a certain threshold. If an indicator crosses this threshold it is said to issue a signal. We define the signal formally as follows. Let $X$ denote the vector of the $n$ indicators (here $n$ = 14), i.e. $X_{t,j}$ denotes the value of indicator $j$ in period $t$. Hence, the **signal** of indicator $j$ in period $t$ is defined as

$$S_{t,j} = \begin{cases} 1, & if \quad X_{t,j} \quad crosses \quad the \quad threshold \\ 0, & otherwise \end{cases}$$

Note that for some of the indicators the rise above the threshold value indicates an increase of the probability of a currency crisis, while for other indicators the decline below the threshold indicates an increase of the probability of a currency crisis. These threshold crossings are summarized in Table 4.

*Table 4: Direction of relevant Threshold Crossings*

| Indicator | Relevant Threshold |
|---|---|
| Real exchange rate | Lower |
| Exports | Lower |
| M2 / international reserves | Upper |
| Real output | Lower |
| Excess real M1 balances | Upper |
| International reserves | Lower |
| M2 multiplier | Upper |
| Domestic credit / nominal GDP | Upper |
| Terms of trade | Lower |
| Real interest rate on deposits | Upper |
| Imports | Upper |
| Domestic/foreign real interest rate differential | Upper |
| Ratio of lending interest rate to deposit interest rate | Upper |
| Bank deposits | Lower |

## 5.4 Performance of Indicators – Methodology

To determine the threshold value of each indicator and to measure the performance of the indicators it is necessary to define some further terms.

The **signalling window** is the period within each indicator would be expected to show ability for anticipating currency crisis. Kaminsky, Lizondo and Reinhart (1998) set this signalling window for currency crisis a priori at 24 months preceding a crisis. This determination of the signalling window seems to be somewhat arbitrary, but it is consistent with other papers and performed well in the researches of Kaminsky and Reinhart (1999), Kaminsky, Lizondo and Reinhart (1998) and Goldstein, Kaminsky and Reinhart (2000). The sensitivity analysis done by Goldstein, Kaminsky and Reinhart (2000) showed quite similar results for a signalling window of 18 month and proved the 12-month signalling window to be too restrictive.

In practice, shorter signalling windows are usually found in private sector models, which are used by e.g. investment banks (Berg, Borensztein and Patillo 2004). However, longer signalling windows are more conducive for policy makers because they enable them to adjust their policies and to take appropriate steps in order to avoid signalled crises from happening.

With this definition of a signalling window, we can measure the performance of each indicator. If an indicator issues a signal as defined above within this signalling window preceding a crisis it is called a **good signal**. If a signal is not followed by a crisis in the next 24 month it is called a **false signal** or **noise**. The ratio of false signals to good signals is called **noise-to-signal ratio** and plays an important role in the further work. A formal definition is given below.

The outcome of each indicator can be considered in terms of the two by two matrix given in Table 5.

*Table 5: Matrix of Indicator Signals*

| | Crisis (within 24 month) | No Crisis (within 24 month) |
|---|---|---|
| Signal was issued | A | B |
| No signal was issued | C | D |

This matrix is calculated for each indicator separately. The meaning of the contents of the cells is as follows:

- A = number of month in which the indicator issued a good signal, i.e. the indicator crosses its (upper or lower) threshold within the crisis window
- B = number of month in which the indicator issued a bad signal or noise

- C= number of month in which the indicator failed to issue a (good) signal
- D = number of month in which the indicator refrained to issue a (bad) signal

A perfect indicator would only produce entries in cells A and D. Therefore with this matrix we can calculate several measures of performance for each indicator. The main concepts used by Goldstein, Kaminsky and Reinhart (2000) are the unconditional probability of a crisis, P(Crisis) = (A+C)/(A+B+C+D), the probability of a crisis conditional on a signal, P(Crisis | S) = A/(A+B), the marginal predictive power, P(Crisis | S ) – P(Crisis) and the noise-to-signal ratio, which is the ratio of false signals to the ratio of good signals.[37]

The results of the indicators depending on these performance measures are very stable in the research of Kaminsky and Reinhart (1999), Kaminsky, Lizondo and Reinhart (1998), Edison (2000) and Goldstein, Kaminsky and Reinhart (2000), i.e. if you rank the indicators according to the different performances measures these rankings do not vary very much. Hence we focus in our research on the noise-to-signal ratio. The noise-to-signal ratio is formally defined as follows:

$$noise-to-signal\ ratio = \frac{B/(B+D)}{A/(A+C)}$$

The smaller the value of this ratio, the better is the ratio of false signals to good signals. An indicator with a noise-to-signal ratio of unity issues as many false alarms as good signals.

An overview of the results of the performance measures of some related papers is given in Table 6. The indicators are ordered by decreasing marginal predictive power.[38]

[37] Mulder, Perelli and Rocha (2002) propose the noise-to-signal balance defined as ((A/C)–(B/C)). This ratio has the advantage that it can be easily interpreted. In case all crises are detected correctly, the ratio is 1 and -1 if only wrong signals are given. They argue that the noise-to-signal ratio would not properly distinguish between models, which identify e.g. 90% of crises correctly and 10% wrong and those which signal 9% correct and 1% wrong. Oka (2003) provides an overview of some additional measures of efficiency.

[38] As mentioned before, this type of ranking goes almost hand in hand with the other performance measures, see Kaminsky and Reinhart (1999), Kaminsky, Lizondo and Reinhart (1998) and Goldstein, Kaminsky and Reinhart (2000) for details.

*Table 6: Performance of Indicators*[39]

| Indicator | Noise-to-signal ratio | | | Marginal predictive power |
|---|---|---|---|---|
| | KLR (1998) | Edison (2000) | GKR (2000) | GKR (2000) |
| Real exchange rate | 0.19 | 0.22 | 0.22 | 35.2 |
| Exports | 0.42 | 0.52 | 0.51 | 15 |
| M2 / international reserves | 0.48 | 0.54 | 0.51 | 14.9 |
| Real output | 0.52 | 0.57 | 0.57 | 12.5 |
| Excess real M1 balances | 0.52 | 0.6 | 0.57 | 12.3 |
| International reserves | 0.57 | 0.57 | 0.58 | 12.2 |
| M2 multiplier | 0.61 | 0.89 | 0.59 | 11.6 |
| Domestic credit / GDP | 0.62 | 0.63 | 0.68 | 8.3 |
| Terms of trade | 0.77 | n.a. | 0.74 | 6.5 |
| Real interest rate on deposits | 0.77 | 0.69 | 0.77 | 5.5 |
| Imports | 1.16 | 1.2 | 0.87 | 2.9 |
| Domestic/foreign real interest rate differential | 0.99 | 1.2 | 1 | -0.1 |
| Ratio of lending interest rate to deposit interest rate | 1.69 | 2.3 | 1.32 | -4.8 |
| Bank deposits | 1.2 | 1.05 | 1.32 | -5.2 |

Using the definition of the noise-to-signal ratio, it is possible to determine the thresholds for the indicators. For each indicator a grid search is performed over all countries in the sample to find that threshold value that minimizes the noise-to-signal ratio, i.e. the noise-to-signal ratio is calculated for a range of (potential) threshold values and the value that minimizes the noise-to-signal ratio is chosen as the threshold for that indicator. Note that these thresholds are defined as percentiles of the empirical distribution of the indicator of all countries, e.g. the grid search produces as result an optimal threshold of 0.1 (the $10^{th}$ percentile). The threshold value for each country is calculated as the $10^{th}$ percentile of the empirical distribution of the indicator for this country. Therefore, the actual threshold

[39] The abbreviation KLR (1999) stands for Kaminsky, Lizondo and Reinhart (1998); GKR (2000) means Goldstein, Kaminsky and Reinhart (2000).

value of an indicator varies across countries, but the percentile is the same for each country.

Following Kaminsky, Lizondo and Reinhart (1998) the objective to define the threshold in this way is to divide the distribution of an indicator into a region that is considered „normal" and a region that is considered aberrant or unlikely. This can be easily put into a context of a statistical hypothesis test. Let the null hypothesis ($H_0$) be that a crisis occurs (within the signalling window) and the alternative Hypothesis ($H_A$) be that no crisis occurs. In the terms of the matrix above $H_0$ is equal to A+C and $H_A$ is equal to B+D. Then the type I error and type II error are defined according to standard hypothesis tests as follows:

$$Type\ I\ error = \alpha = P\left(reject \quad H_0 \mid H_0 \quad is \quad true\right) = \frac{C}{A+C}$$

$$Type\ II\ error = \beta = P\left(not\ reject\ H_0 \mid H_0\ is\ false\right) = \frac{B}{B+D}$$

The choice of an optimal threshold should now be in a way that it strikes a balance between the risk of having many bad signals and the risk of missing many crises. Or in terms of a hypothesis test: The threshold should give a balance between minimizing type I error and type II error.[40] Therefore it seems to be a promising approach to minimize the term $\beta/(1-\alpha)$, since the term $\beta/(1-\alpha)$ decreases if $\alpha$ and/or $\beta$ are small.[41] Minimizing this term is nothing else than minimizing the noise-to-signal ratio:

$$\frac{\beta}{1-\alpha} = \frac{B/(B+D)}{1-(C/(A+C))} = \frac{B/(B+D)}{A/(A+C)} = noise-to-signal\ \ ratio$$

Hence for each indicator the threshold defines the size of the rejection region. In other words, if the indicator crosses the threshold, i.e. issues a signal, this means that the indicator enters the rejection region.

### 5.5 Performance of Indicators – Implementation

As mentioned above, Uganda never had a currency crisis. Therefore it does not make sense to calculate the thresholds using the matrix shown in Table 4, since the matrix would have only entries in cells B and D. Referring to the definitions of

[40] As we know from probability theory it is in general not possible to minimize type I error and type II error separately at the same time.

[41] Note that $\alpha, \beta \in [0,1]$.

performance measures of indicators shown in the previous section it would not be possible to calculate these measures.

Therefore, we decided to estimate the values of the thresholds and the noise-to-signal ratios from the research of Kaminsky and Reinhart (1999), Edison (2000) and Goldstein, Kaminsky and Reinhart (2000). These papers include a variety of different industrial and developing countries.[42] Table 7 gives an overview of the calculated threshold values, the type of the threshold (upper or lower) and shows the mean of the three threshold values.

*Table 7: Threshold Values of Indicators*[43]

| **Indicator** | **Threshold** (expressed as percentile of the empirical distribution) | | | | |
|---|---|---|---|---|---|
| | **Type** | **KR (1999)** | **Edison (2000)** | **GKR (2000)** | **Mean** |
| Real exchange rate | lower | 0.1 | 0.1 | 0.1 | 0.10 |
| Exports | lower | 0.1 | 0.1 | 0.1 | 0.10 |
| M2 / international reserves | upper | 0.13 | 0.1 | 0.1 | 0.11 |
| Real output | lower | 0.11 | 0.12 | 0.1 | 0.11 |
| Excess real M1 balances | upper | 0.06 | 0.1 | 0.11 | 0.09 |
| International reserves | lower | 0.15 | 0.1 | 0.1 | 0.12 |
| M2 multiplier | upper | 0.14 | 0.15 | 0.11 | 0.13 |
| Domestic credit / GDP | upper | 0.1 | 0.1 | 0.12 | 0.11 |
| Terms of trade | lower | 0.16 | n.a. | 0.1 | 0.13 |
| Real interest rate on deposits | upper | 0.12 | 0.15 | 0.12 | 0.13 |
| Imports | upper | 0.1 | 0.1 | 0.1 | 0.10 |
| Domestic/foreign real interest rate differential | upper | 0.11 | 0.1 | 0.11 | 0.11 |
| Ratio of lending interest rate to deposit interest rate | upper | 0.2 | 0.2 | 0.12 | 0.17 |
| Bank deposits | lower | 0.1 | 0.1 | 0.15 | 0.12 |

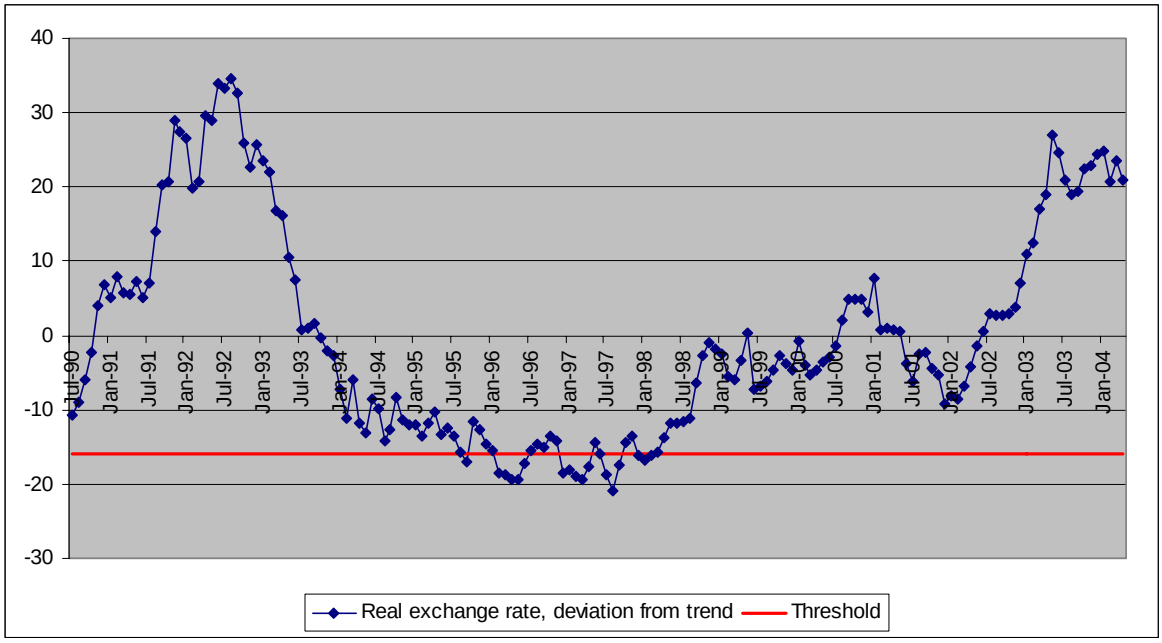
[42] For example, the research of Kaminsky and Reinhart (1999) includes 5 industrialized countries and 15 developing countries, the sample period spans the 1970's through 1995 and they analyzed 76 currency crises. Countries, which showed no crisis, were not included in the sample.

[43] The abbreviation KR (1999) stands for Kaminsky and Reinhart (1999); GKR (2000) means Goldstein, Kaminsky and Reinhart (2000).

Our decision to choose the mean of the empirical results as estimator for the threshold (expressed as percentile) is based on the following three reasons. First, as mentioned above, the papers cover a variety of countries and a variety of currency crises. Second, the results are extremely stable with a very small standard deviation.[44] Third, of course it is possible to choose a more conservative or progressive approach, i.e. choosing the minimum or the maximum to enlarge or to reduce the size of he rejection region. A sensitivity analysis has shown that the resulting composite indices do not vary significantly.

Figure 6 to Figure 8 displays the three top performing indicators with their thresholds. Figures of the other indicators are given in Appendix A.

*Figure 6: Indicator: Real Exchange Rate (Deviation from Trend) and Threshold*

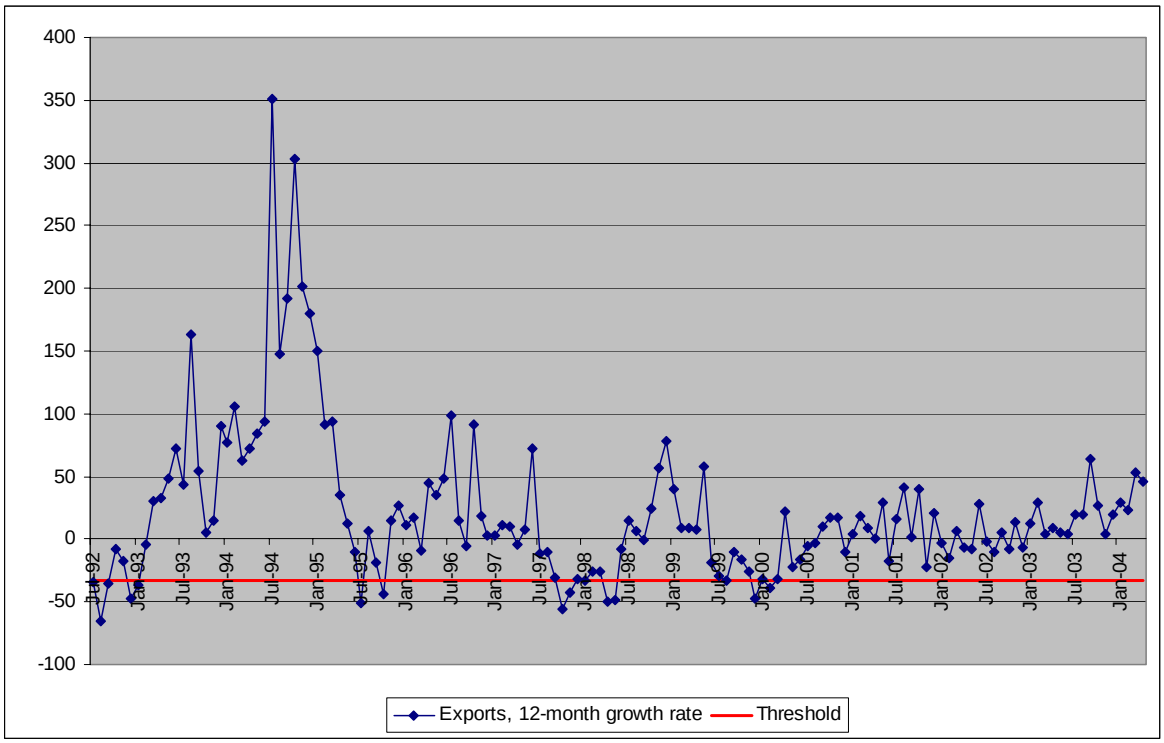



*Source: Authors' calculations.*

A real appreciation of the currency, which occurs in the context of a large current account deficit, is a source of increased vulnerability of the country. The deviation from trend is calculated as the percentage deviation for the linear trend, which is determined by a simple regression covering data from 1990 until April 2004.

[44] See e.g. Edison (2000), p. 19: „Overall, the results reported in Table 5 are similar to those presented in Kaminsky, Lizondo and Reinhart (1998)."

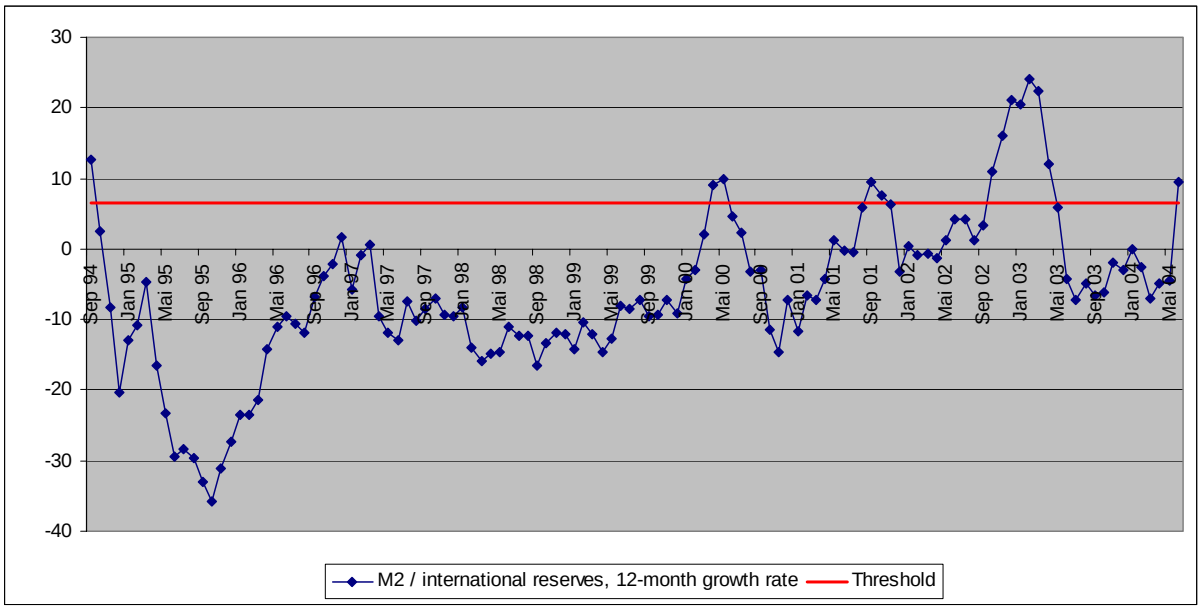
*Figure 7: Indicator: Exports (12-month growth rate)*




*Source: Authors' calculations.*

Ugandan exports are mainly composed by agricultural products, like coffee, cotton, tea, and fish. Uganda's economy is exposed to external shocks, as world prices for agricultural products tend to be volatile. Coffee accounted for almost all Ugandan exports before 1994/1995. However, after the short coffee boom in 1995 its share declined dramatically. This was due to falling world coffee prices, whereas the quantity of exported coffee hardly diminished. In contrast, non-traditional exports like fish and fish products, tobacco, flowers, beans, hides & skins, and maize gained more and more weight in Ugandan exports. Export shares of cotton and tea grew only slightly in the same period. Non-agricultural exports of merchandise are oil re-exports, gold, electricity, and textiles.

*Figure 8: Indicator: M2 / international Reserves (12-month growth rate)*




*Source: Authors' calculations.*

The ratio of M2 to international reserves shows, to what extent the liabilities of the financial system are backed by international reserves. In the event of a currency crisis, individuals may run to convert their domestic currency deposits into foreign currency (deposits). Thus, this ratio reflects (among others) the ability of the central bank to meet those foreign currency demands.

## 5.6 Practical Issues

This section provides some information about the data used for our analysis as well as an overview of the time series. Furthermore, it summarizes some data requirements.

Table 8 contains the indicators and the related input variables for each indicator (column 2), which are provided by BoU. Columns 3 and 4 indicate the beginning and the end of the available time series for each input variable. Column 5 states the maximum time lag until the data is accessible. For example, the CPI has a time lag of 3 months, i.e. the CPI of January 2004 is provided by BoU in April 2004.

*Table 8: Indicators and Input Variables (as at August 2004)*

| Indicator | Input Variables (provided by BoU) | Start | End | Availability (max. time lag) |
|---|---|---|---|---|
| Real exchange rate | Real Effective Exchange Rate (REER) | Jul-90 | Apr-04 | 5 month |
| Exports | Exports | Jul-91 | Apr-04 | 1 month |
| M2 / international reserves | M2 | Sep-93 | Jun-04 | 1 month |
| | International Reserves | Sep-93 | Jun-04 | 1 month |
| | Exchange Rate (Official Middle Rate) | Jul-90 | Jul-04 | No lag |
| Real output | Monthly Index of Industrial Production of Major Manufacturing Establishment | Jan-99 | May-04 | 2-3 months |
| Excess real M1 balances | M1 | Jun-91 | Mar-04 | 1 month |
| | GDP | Dec-97 | Dec-03 | 6 months |
| | CPI (Consumer Price Index) | Sep-89 | Feb-04 | 3 months |
| International reserves | International Reserves | Sep-93 | Jun-04 | 1 month |
| M2 multiplier | Money Multiplier | Jun-93 | Jun-04 | 1 month |
| Domestic credit / nominal GDP | Net Domestic Credit | Jul-93 | Mar-04 | 1 month |
| | GDP | Dec-97 | Dec-03 | 6 months |
| Terms of trade | Terms of Trade | Jan-97 | Apr-04 | 1 month |
| Real interest rate on deposits | Deposit Rates (Saving Deposits) | Jan-96 | May-04 | 1 month |
| | Inflation (Annual % Change) | Aug-90 | Jun-04 | 2 weeks |
| Imports | Imports | Jan-97 | Apr-04 | 1 month |

*Table 8 (continued)*

| Indicator | Input Variables (provided by BoU) | Start | End | Availability (max. time lag) |
|---|---|---|---|---|
| Domestic/foreign real interest rate differential[45] | Interest Rates Uganda (3-month T-Bills) | Jan-93 | Jul-04 | 1 week |
| | Inflation Uganda (Annual % Change) | Aug-90 | Jun-04 | 2 weeks |
| | Interest Rates US (3-month T-Bills), TREASURY BILL RATE, IFS Line 60C | any | any | see IFS |
| | US CONSUMER PRICES, IFS Line 64 | any | any | see IFS |
| Ratio of lending interest rate to deposit interest rate | Lending Rate | Jan-96 | May-04 | 1 month |
| | Deposit Rates (Saving Deposits) | Sep-93 | May-04 | 1 month |
| Bank deposits | Demand Deposits | Jun-93 | Jun-04 | 1 month |
| | Time and Savings Deposits | Jun-93 | Jun-04 | 1 month |

Nearly all input variables state a time lag less than 3 months, which is appropriate for the implementation of an early warning system for currency crises. Thus the effective signalling windows is only 21 months. There are only two input variables with a higher time lag: The real effective exchange rate with 5 months and the GDP with 6 months.

The time lag of the real effective exchange rate is not serious, because of two facts. First, the time lag cannot be influenced by BoU since the calculation of the real effective exchange rate depends on data from other countries. Second, the data frequency of the real effective exchange rate is monthly. Hence the time lag is actually 5 months, e.g. the real effective exchange rate of January 2004 can be provided in June 2004.[46]

The 6-months time lag of the GDP seems to be more serious for practical use in an early warning system for currency crises. In opposite to the real effective exchange rate the data frequency of the GDP is annual. Normally (and naturally) the

[45] The US data are taken from the IFS, the International Financial Statistics provided by the International Monetary Fund.

[46] In opposite to the actual time lag of the GDP, as discussed below.

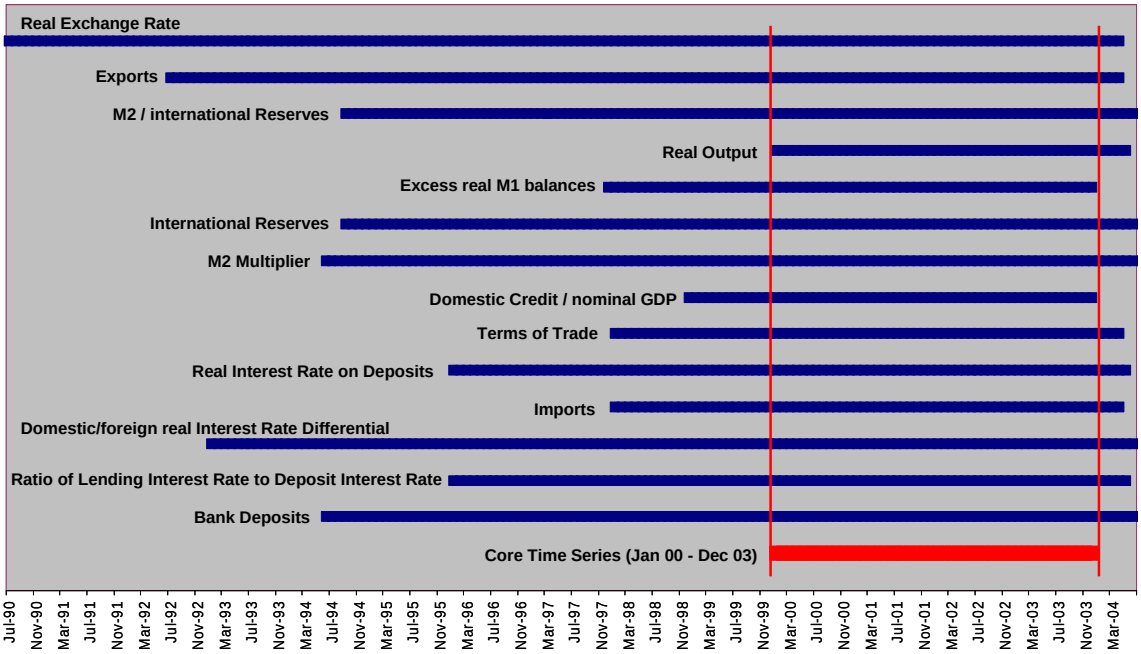
GDP of year x cannot be calculated before the end of year *x*, i.e. the GDP of year x is (spoken in monthly terms) in fact related to December of year *x*. A time lag of 6 month therefore means that the data of the GDP of year x can be provided in June of year *x+1*. Let's have a look on a worst case example: In February 2004 we want to calculate the indicator (and the composite index) referred to January 2004. The (monthly interpolated) value of the GDP of January 2004 can be calculated when the GDP of 2004 is available. As argued above, the GDP of 2004 is (monthly spoken) related to December 2004 and therefore it would still be used in June 2005. Hence to calculate the GDP (and the related indicators) of January 2004, we have to wait until June 2005. This means that the actual time lag is almost one and a half year. Concerning a signalling window of 24 month, an actual time lag of 18 month is not desirable. There are at least two solutions to fix this problem: The first is to increase the frequency of data of the GDP, e.g. to calculate the GDP quarterly.[47]Second, estimate the monthly values of the GDP using a linear trend function. Since the annual GDP data has a coefficient of determination of $R^2$=0.9966. The latter seems to provide an appropriate estimator.

To visualize the lengths of the different time series as well as the data availability of the indicators we transformed the data of starts and ends of the time series of the input variables (columns 3 and 4 in Table 8) into the starts and ends of the available time series of the indicators.[48] The results are displayed in Figure 9.

[47] There is an initiative of the IMF, which aims at enabling the Uganda Bureau of Statistics (UBOS) publishing the GDP figures on a quarterly basis. UBOS officials estimates that this will be possible in mid 2005.

[48] The start of the time series of an indicator is calculated as the maximum of starting points of the time series of the related input variables and the end of the time series of the indicator is calculated as the minimum of ending points of the time series of the related input variables, respectively. Depending on the transformation, given in table 2, one year was added to the start of the time series.

*Figure 9: Available Time Series of Indicators (as at August 2004)*




*Source: Authors' calculations.*

The time series of the available data of the time series of the indicators displayed in Figure 9 are calculated from the time series of input variables from Table 8. The displayed time series of indicators represent the data of indicators, which are available, and not the time series of the input variables, e.g. the export's input variable is available from July 1991 (see Table 8) but the resulting indicator time series starts in July 1992 because of the transformation to the 12-month growth rate, see table 2. The core time series (January 2000 – December 2003) refers to resulting transformed time series of indicators. Hence the start of the core time series is the same as the start of the time series of the real output. The end of the core time series depends on the two indicators „Excess real M1 balances" and „Domestic credit / nominal GDP". Both indicators are based on the GDP; hence the GDP-time series limits these time series and therefore the core time series.

One could now argue that only the data within the periods of the core time series (one year before, respectively) should be used to calculate the indicators and the composite index. We decided to use the given time series for each indicator's input variables to calculate each indicator and its threshold, respectively. This is due to the following reasons. First, it seems to be appropriate to use all available data to enlarge the sample. Second, there were no indications of a structural breakdown during the analyzed periods, e.g. a fundamental break in the Ugandan economic environment. To calculate the composite index we used the data within the core time series, since calculating the composite index without at least one indicator seems to be not adequate.

The last point to mention in this section is to discuss some data requirements. To produce valid and reliable results to predict a currency crisis high-quality data is necessary. High-quality results can only be produced with sound, reliable and consistent data. This is underlined by the following citation: „In view of the data deficiencies that in many cases continue to hamper vulnerability analysis most [IMF] Directors agreed that staff reports should identify more clearly gaps in data…and discuss progress in compiling data needed for vulnerability assessments."[49] Hence, the problem of data quality is well-known and discussed in detail in the literature we focus on some major points.

Therefore, we state the following minimum requirements. First, the definition of the underlying has to be precise and stable. Second, the whole process of data acquisition and data transformation must be well-defined and transparent.[50] Third, the data should be timely, e.g. with e minimal time lag, and cover a minimum of missing values. Fourth, fast and secure access to the relevant data must be ensured, e.g. this can be realized by the use of a centralized data base. If and only if these data requirements are fulfilled, the proposed model can produce useful information for policy makers in practical use.

In contrast to most academics, we do not use the IFS data but the data available at Bank of Uganda. This ensures a sustainable data feed and it avoids unnecessary time lags. However, this approach also implies that comparisons with other countries would require data harmonisations, which would not be required if IFS data would be used.

[49] International Monetary Fund, 2002, „IMF Executive Board Reviews Data Provision for Surveillance" Public Information Notice No. 02/133 (November 18).

[50] For example, it should not happen that the values of a whole time series change at once without any explanation.

# 6 Step 3: The Composite Index and Probabilities of a Currency Crisis

## 6.1 Composite Index - Methodology

The topic of this section is to construct a composite index to map the time-varying probability of a crisis. The main idea is to combine the information obtained from the individual indicators in a meaningful way. In principle, the greater the number of indicators signalling a future crisis, the higher the probability that such a crisis will actually occur.

A straightforward way of capturing the vulnerability of an economy is to use the signals issued by the indicators. As Kaminsky (1999) has described, there are several different ways to realize this combination of signals. We focus here on the composite index calculated as weighted average of the signals of each indicator, where the inverses of the noise-to-signal ratio are used as weights. Kaminsky (1999) showed that this indicator performed best in their research.

It is formally defined as follows. Let $S_{t,j} \in \{0,1\}$ denote again the signal of variable *j* in period *t* as defined above, i.e. indicator *j* crosses the threshold in period *t* or not. Let $\omega_j$ denote the noise-to-signal ratio of indicator *j*, then the composite index of *n* indicators is defined as

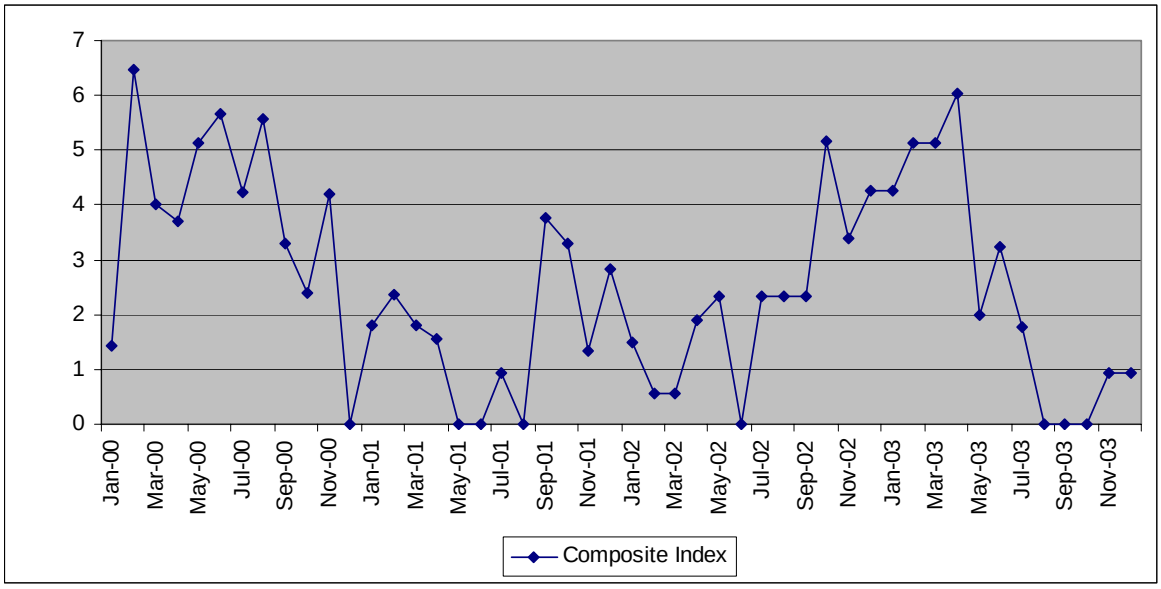
$$S_t = \sum_{j=1}^{n} \frac{1}{\omega_j} S_{t,j}$$

As mentioned above, a smaller value of the noise-to-signal ratio indicates a better performance of an indicator. Hence, using the inverse of the noise-to-signal ratio weights the indicators with a smaller noise-to-signal ration higher.

## 6.2 Composite Index - Implementation

The composite index for Uganda is obtained from our 14 indicators based on the thresholds calculated above. The result is displayed in Figure 10.

*Figure 10: The Composite Index*




*Source: Authors' calculations.*

As argued above in the context of estimating the thresholds for each indicator, it is not possible to calculate the matrix of table 3 directly for Uganda, since there was no currency crisis observed in the past. Hence it is also not possible to calculate the noise-to-signal ratios for each indicator. The same argumentation as of the threshold of indicators holds here for estimating the weights.[51] Table 9 gives an overview of the values of the noise-to-signal ratio of each indicator calculated in the related papers.

In the same way as estimating the thresholds we use the mean as an appropriate estimator for the noise-to-signal ratio and therefore for the weights of the composite index. A sensitivity analysis has shown here as well, that the resulting composite index varies only slightly depending on choosing other similar estimators.

[51] See section 4.5.

*Table 9: Estimating the Weights*[52]

| Indicator | Noise-to-signal ratio | | | |
|---|---|---|---|---|
| | **KLR (1998)** | **Edison (2000)** | **GKR (2000)** | **Mean** |
| Real exchange rate | 0.19 | 0.22 | 0.22 | 0.21 |
| Exports | 0.42 | 0.52 | 0.51 | 0.48 |
| M2 / international reserves | 0.48 | 0.54 | 0.51 | 0.51 |
| Real output | 0.52 | 0.57 | 0.57 | 0.55 |
| Excess real M1 balances | 0.52 | 0.6 | 0.57 | 0.56 |
| International reserves | 0.57 | 0.57 | 0.58 | 0.57 |
| M2 multiplier | 0.61 | 0.89 | 0.59 | 0.70 |
| Domestic credit / GDP | 0.62 | 0.63 | 0.68 | 0.64 |
| Terms of trade | 0.77 | n.a. | 0.74 | 0.76 |
| Real interest rate on deposits | 0.77 | 0.69 | 0.77 | 0.74 |
| Imports | 1.16 | 1.2 | 0.87 | 1.08 |
| Domestic/foreign real interest rate differential | 0.99 | 1.2 | 1 | 1.06 |
| Ratio of lending interest rate to deposit interest rate | 1.69 | 2.3 | 1.32 | 1.77 |
| Bank deposits | 1.2 | 1.05 | 1.32 | 1.19 |

## 6.3 Probabilities of a Currency Crisis - Methodology

Based on the obtained composite index we now want to infer from its values the likelihood that Uganda will experience a currency crisis. To convey information on the dynamics of the process, it is convenient to link the composite index to the implied probabilities of a crisis. „The idea is to analyze the empirical distribution of the composite indicator jointly with the occurrences of crises and to estimate probabilities of crises conditional on different values of the composite indicator."[53]

[52] The abbreviation KLR (1999) stands for Kaminsky, Lizondo and Reinhart (1998); GKR (2000) means Goldstein, Kaminsky and Reinhart (2000).
[53] See Goldstein, Kaminsky and Reinhart (2000), p. 65.

This probability can be calculated as follows:

$$P\left(Crisis_{t,t+h} \mid S_{lower} < S_t < S_{upper}\right)$$
$$= \frac{\sum months\ with\ S_{lower} < S_t < S_{upper}\ \ given\ a\ crisis\ occurs\ within\ h\ months}{\sum months\ with\ S_{lower} < S_t < S_{upper}}$$

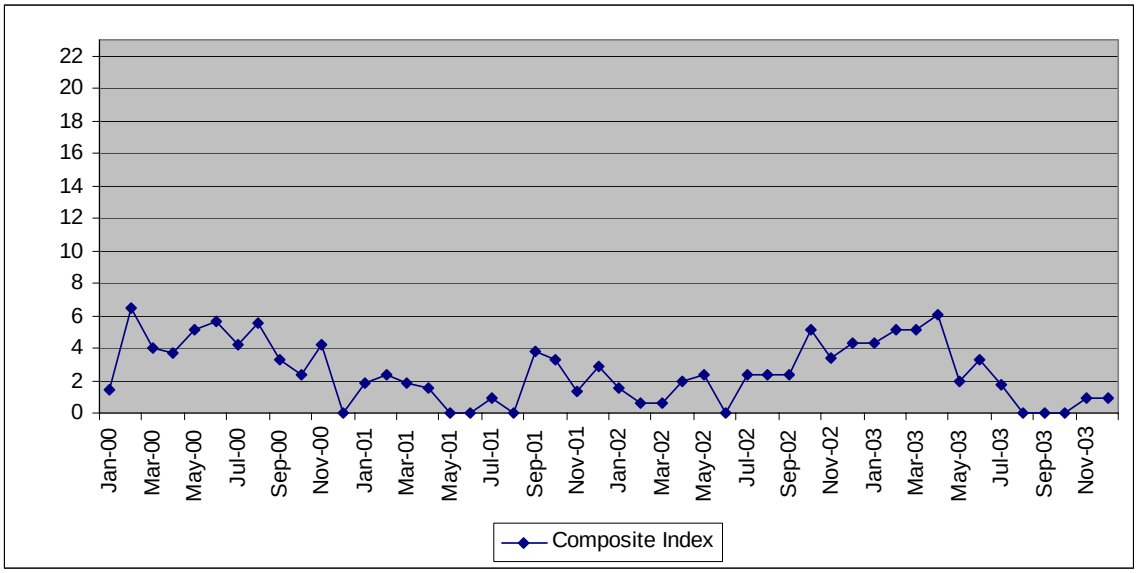
where *P* denotes probability, $Crisis_{t,t+h}$ is the occurrence of a crisis in the interval *[t,t+h]*, *h* is the signalling window (24 months), $S_t$ is the weighted index and $S_{lower}$ and $S_{upper}$ denote lower and upper intervals for the composite index. $P(Crisis_{t,t+h} | S_{lower} < S_t < S_{upper})$ denotes the probability that a crisis will occur within *h* months at time *t*, given that the composite indicator $S_t$ falls within the interval $[S_{lower}, S_{upper}]$.

### 6.4 Probabilities of a Currency Crisis - Implementation

Kaminsky (1998) and Goldstein, Kaminsky and Reinhart (2000) calculate the conditional probabilities of a currency crisis for their huge sample. Analogous to the argumentation above it is not possible to calculate these conditional probabilities directly from our sample. Hence, we estimated the probabilities using a linear transformation of the intervals analyzed by Kaminsky (1998) and Goldstein, Kaminsky and Reinhart (2000).

The theoretical maximum of our composite index is the sum of all the weights, i.e. $S_{t,j} = 1$ for all $j = 1,\ldots,n$ and a fixed *t*. This theoretical maximum equals 23.05 in our Ugandan sample. A rescaled graph of the composite index is given in Figure 11.

*Figure 11: The rescaled Composite Index*



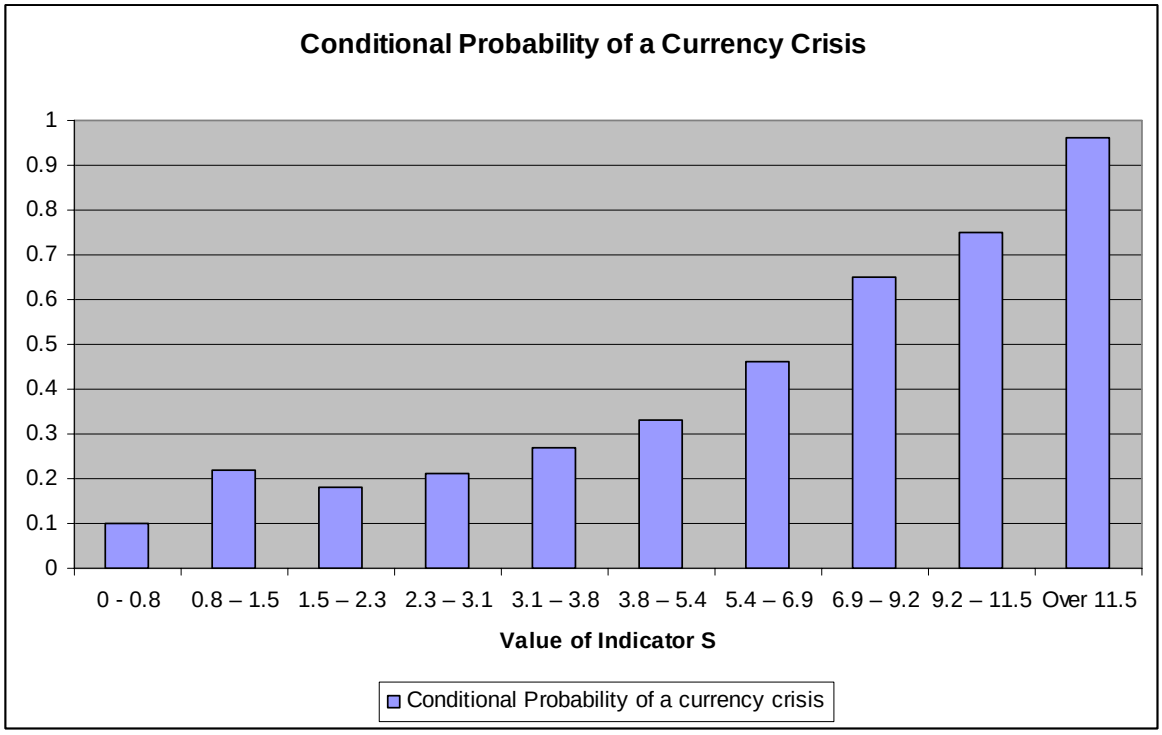

*Source: Authors' calculations.*

The objective is now to transform the range of the composite indicator via linear transformation to the conditional probabilities of Kaminsky (1998) and Goldstein, Kaminsky and Reinhart (2000). The results of the linear transformation are given in Table 10 and visualized in Figure 12.

*Table 10: Conditional Probabilities of a Currency Crisis*

| Value of Indicator S | Conditional Probability of a currency crisis |
|---|---|
| 0 – 0.8 | 0.10 |
| 0.8 – 1.5 | 0.22 |
| 1.5 – 2.3 | 0.18 |
| 2.3 – 3.1 | 0.21 |
| 3.1 – 3.8 | 0.27 |
| 3.8 – 5.4 | 0.33 |
| 5.4 – 6.9 | 0.46 |
| 6.9 – 9.2 | 0.65 |
| 9.2 – 11.5 | 0.75 |
| Over 11.5 | 0.96 |

*Figure 12: Conditional Probabilities of a Currency Crisis*




The results of Table 10 and Figure 12 provide only very rough estimators of the corresponding probabilities of a currency crisis. The probability values should be treated carefully and they should not be considered as fixed and exact. Rather the results should give us an idea of the different ranges of the composite index and the corresponding orders of probabilities. Hence, the exact values of the conditional probability should be handled with care. Nevertheless, the mapping given in Table 10 supports the understanding, the assessment and the interpretation of the composite index.

# 7 Conclusions and possible Extensions

The presented model is a quantitative model, which produces quantitative results. The qualitative interpretation of the results must be done by a person with expertise of the economic situation of Uganda. The model should not be understood as an automatic tool, rather it should be understood as a supporting instrument. The economic policy challenges due to among others the donor flows large amounts of official and unofficial development assistance, the poverty reduction agenda of Uganda and the fast development of the financial system should always be taken into consideration and they make human judgement mandatory. Thus, it is suggested to use the model complementary to other standard country and market surveillance.

This section covers some ideas how the described model can be extended and which points to pay attention when transforming this prototype into a diagnostic tool for operational use.

To extend the model there are a variety of options. First, it could be interesting to analyze not only currency crises but banking crises as well. Following Kaminsky and Reinhart (1999) this could enhance the performance of the model, since it takes the phenomenon of twin crises into account. Second, it would be promising to enlarge the sample, i.e. to do a (Sub-Saharan) Africa wide research. Especially the integration of data from Tanzania and Kenya would be interesting because of their close economic links. The integration of other African developing countries with comparable economic structures could also enrich the model, since it would be possible to include some currency crises of the past to calculate the matrix of table 4. In the case that these assumptions do not hold for several countries, one can analyze some contagion factors for these countries. Third, it could be useful to add some other annual indicators to the model. Goldstein, Kaminsky and Reinhart (2000) analyze several annual indicators which partly could be useful for Uganda.

For practical use of the model, the following points seem to be important to us. Especially the problem of the annual provision of the GDP that leads to an actual time lag of one and a half year should be solved. It is understood that the Uganda Bureau of Statistics works on increasing the frequency and that within 2005, GDP figures shall be published on a quarterly basis. As discussed above in the meantime a solution could either be a quarterly collection and provision of the data or an estimation based on the linear trend.

In order to ensure sustainability of the operational model, it is necessary to build a central database containing all the required data in an appropriate quality. Then it is possible to update the model monthly, which seems to be indispensable to improve the quality of further decisions.

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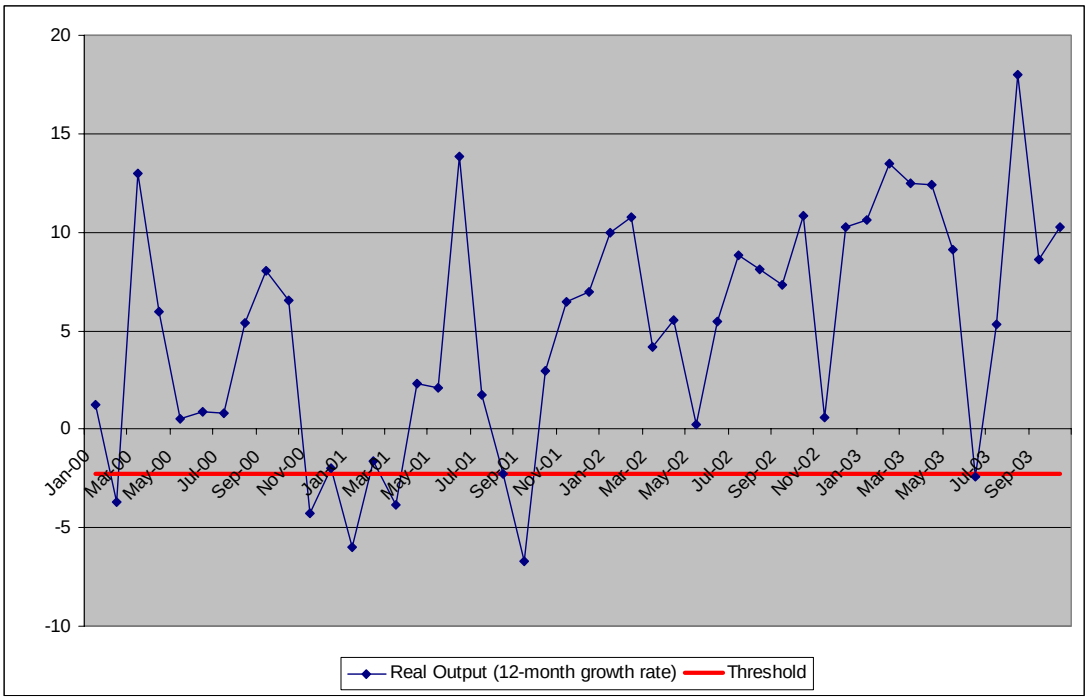
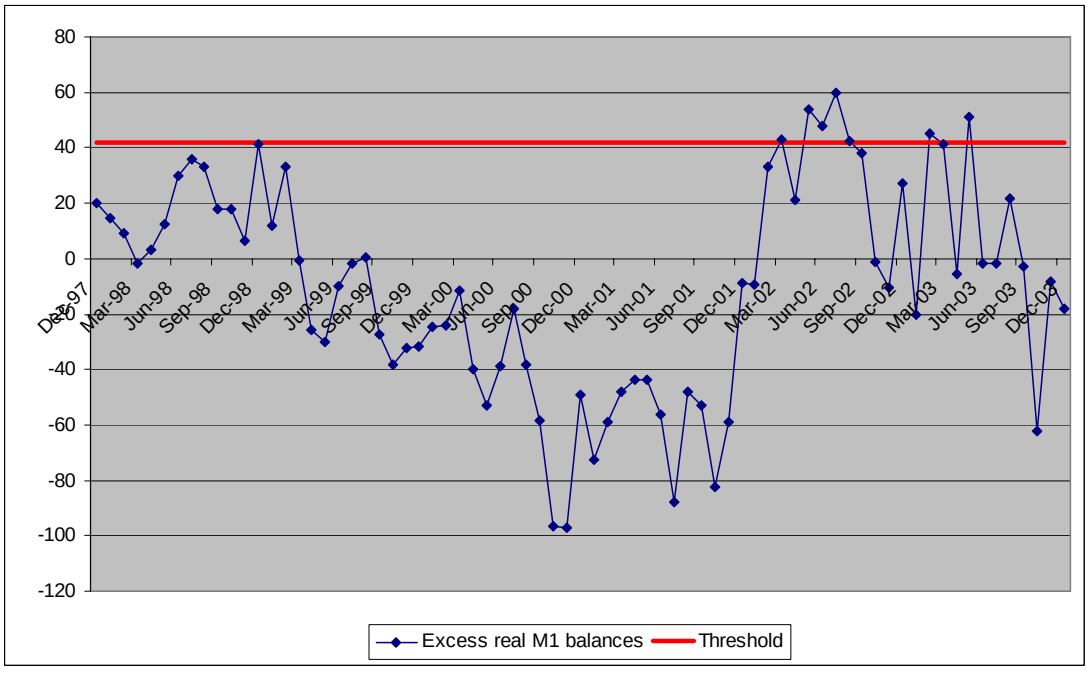
# Appendix A. The Indicators

*Figure 13: Indicator: Real Output (12-month growth rate)*



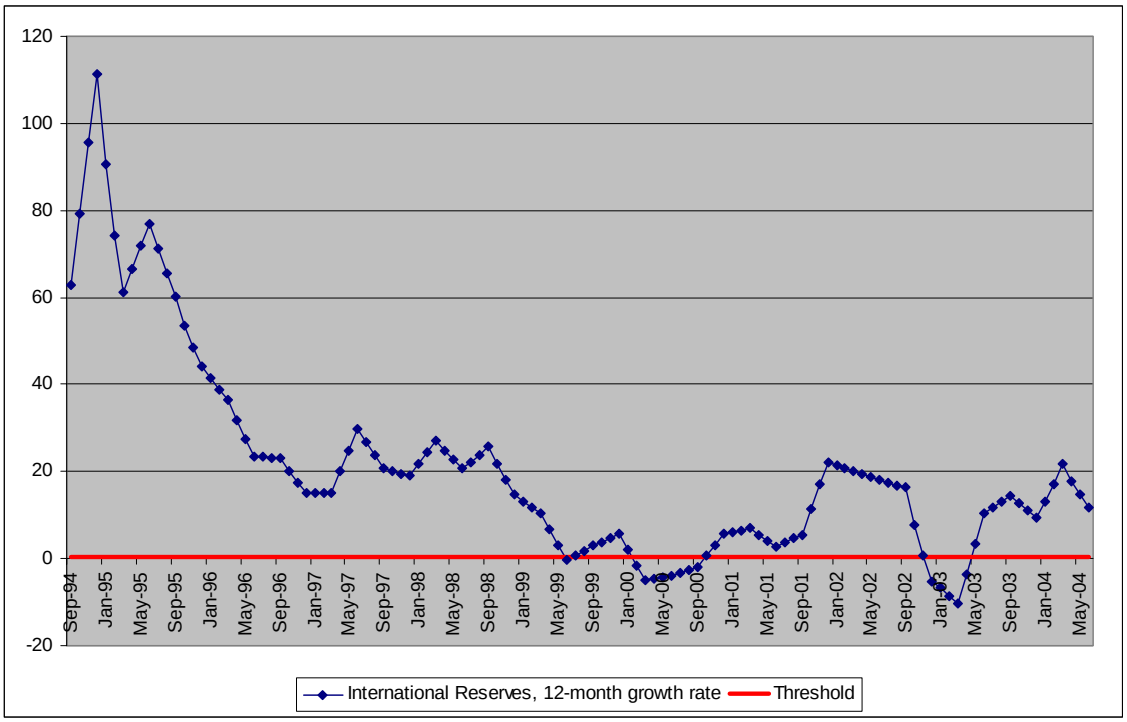

*Source: Authors' calculations.*

*Figure 14: Indicator: Excess Real M1 Balances*



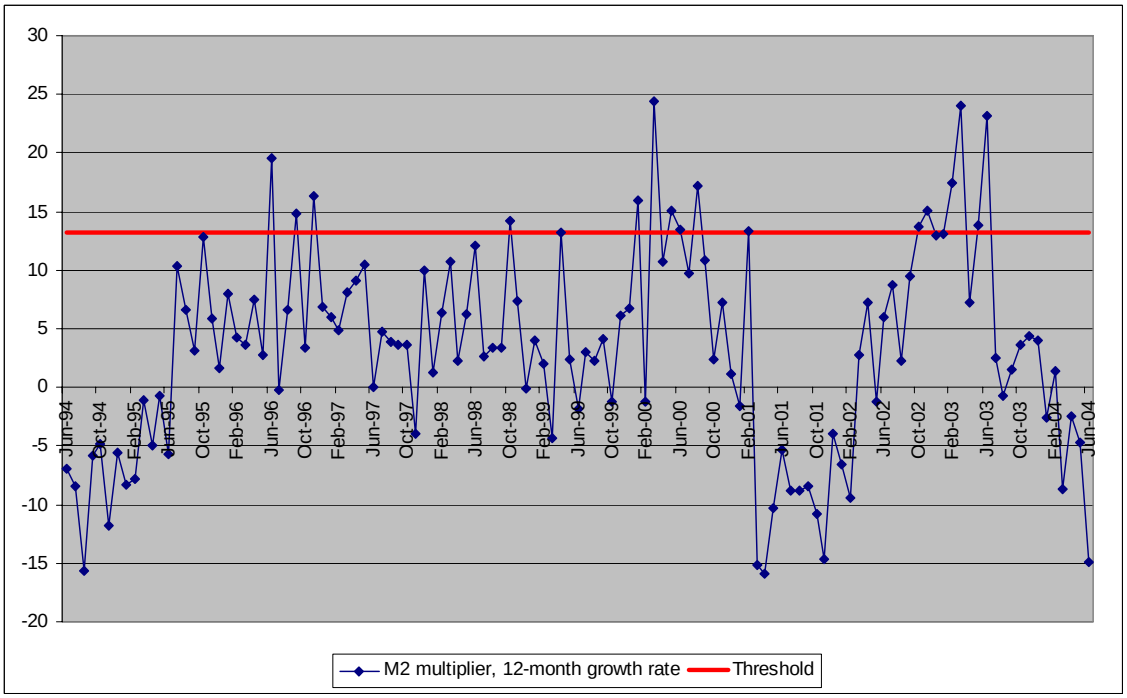

*Source: Authors' calculations.*

*Figure 15: Indicator: International Reserves (12-month growth rate)*



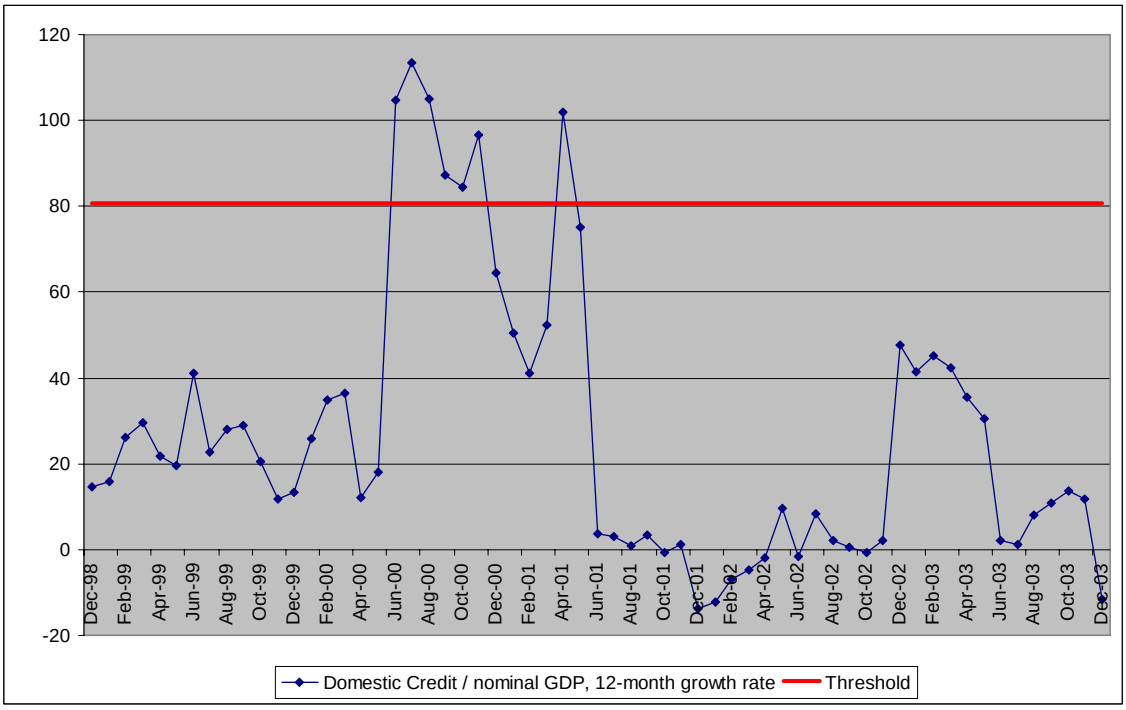

*Source: Authors' calculations.*

*Figure 16: Indicator: M2 Multiplier (12-month growth rate)*



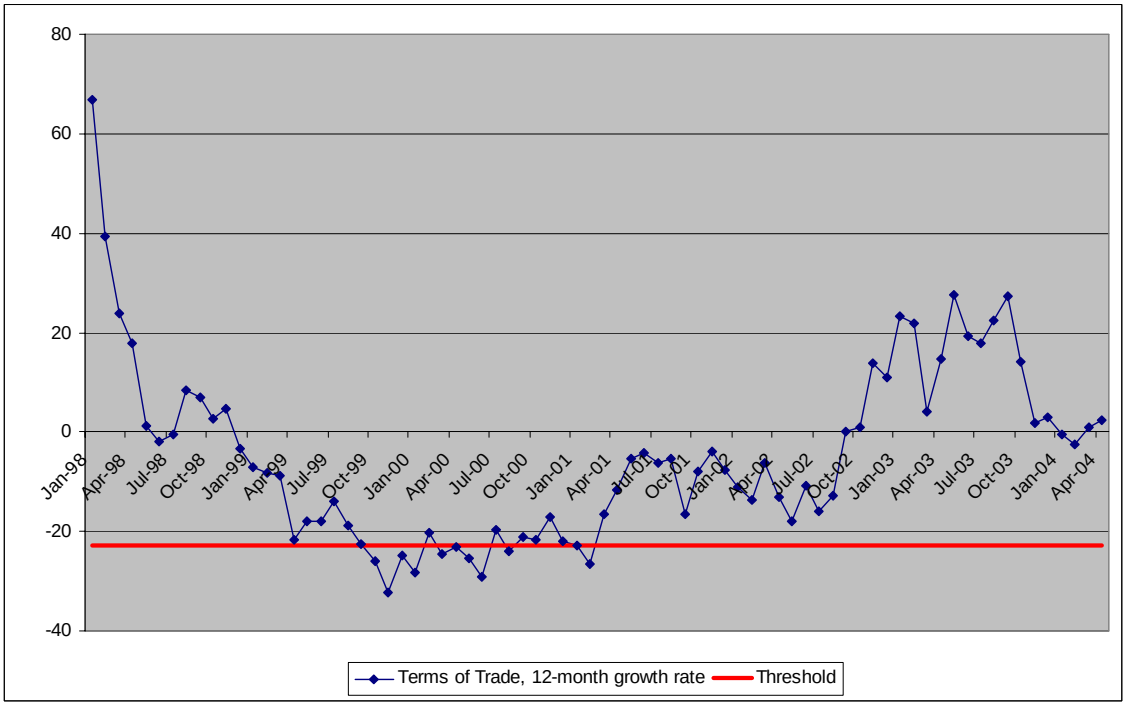

*Source: Authors' calculations.*

*Figure 17: Indicator: Domestic Credit / nominal GDP (12-month growth rate)*



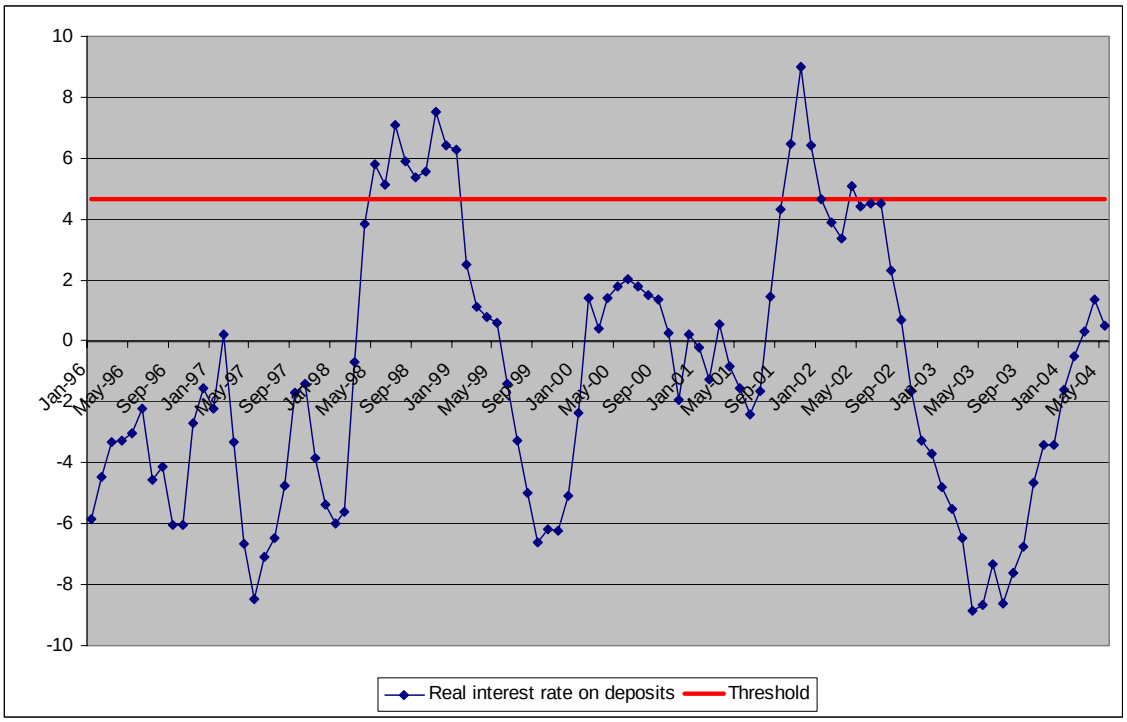

*Source: Authors' calculations.*

*Figure 18: Indicator: Terms of Trade (12-month growth rate)*



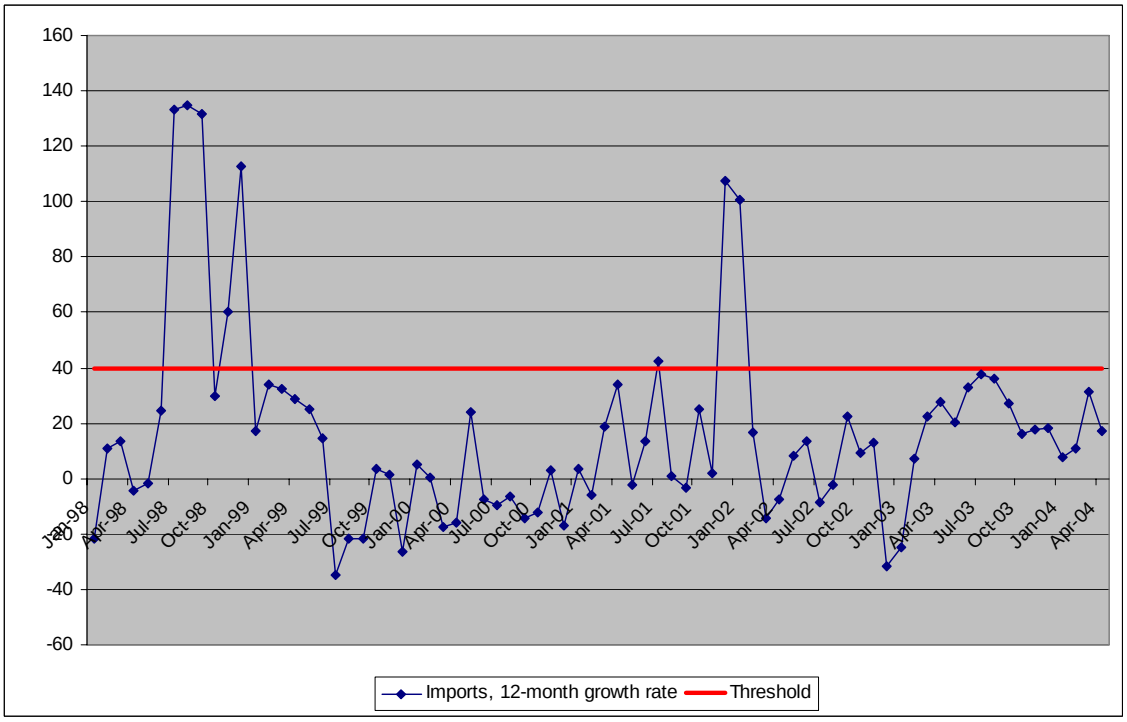

*Source: Authors' calculations.*

*Figure 19: Indicator: Real Interest Rate on Deposits*



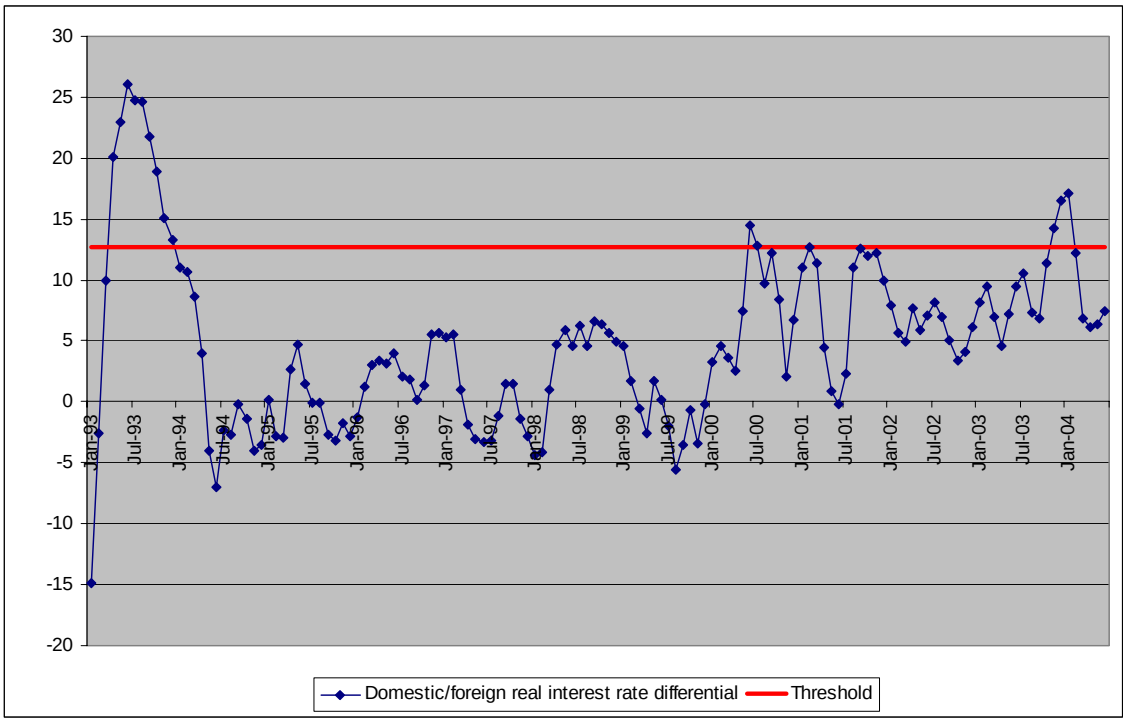

*Source: Authors' calculations.*

*Figure 20: Indicator: Imports (12-month growth rate)*



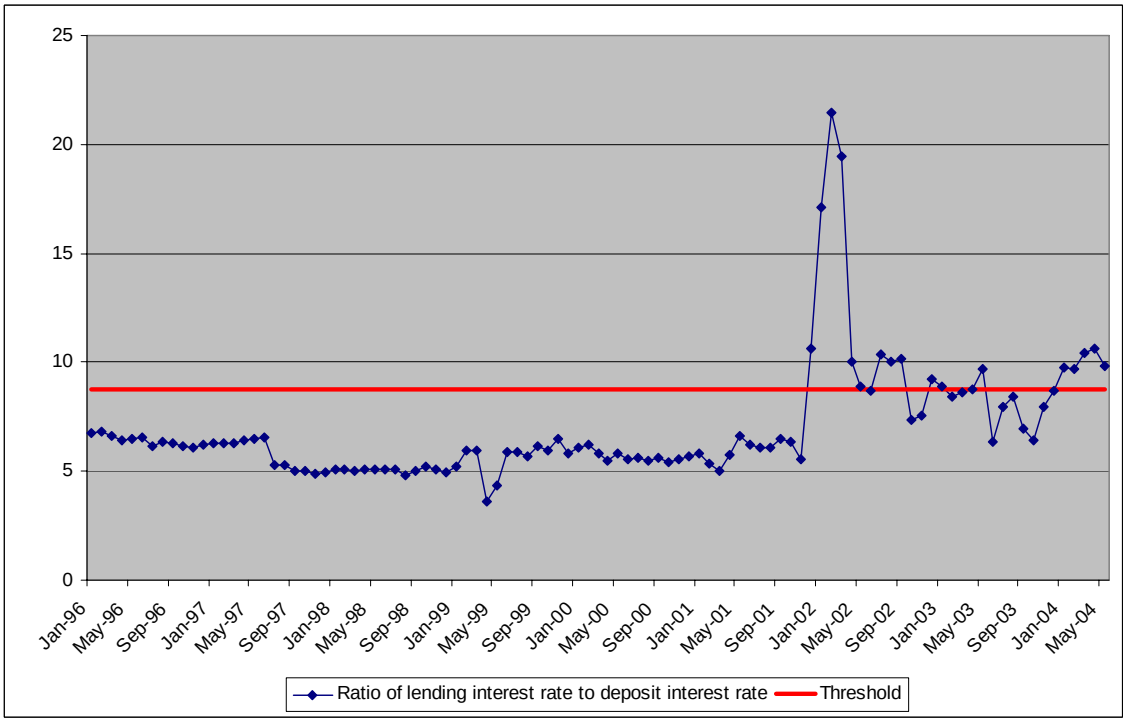

*Source: Authors' calculations.*

*Figure 21: Indicator: Domestic/foreign Real Interest Rate Differential*



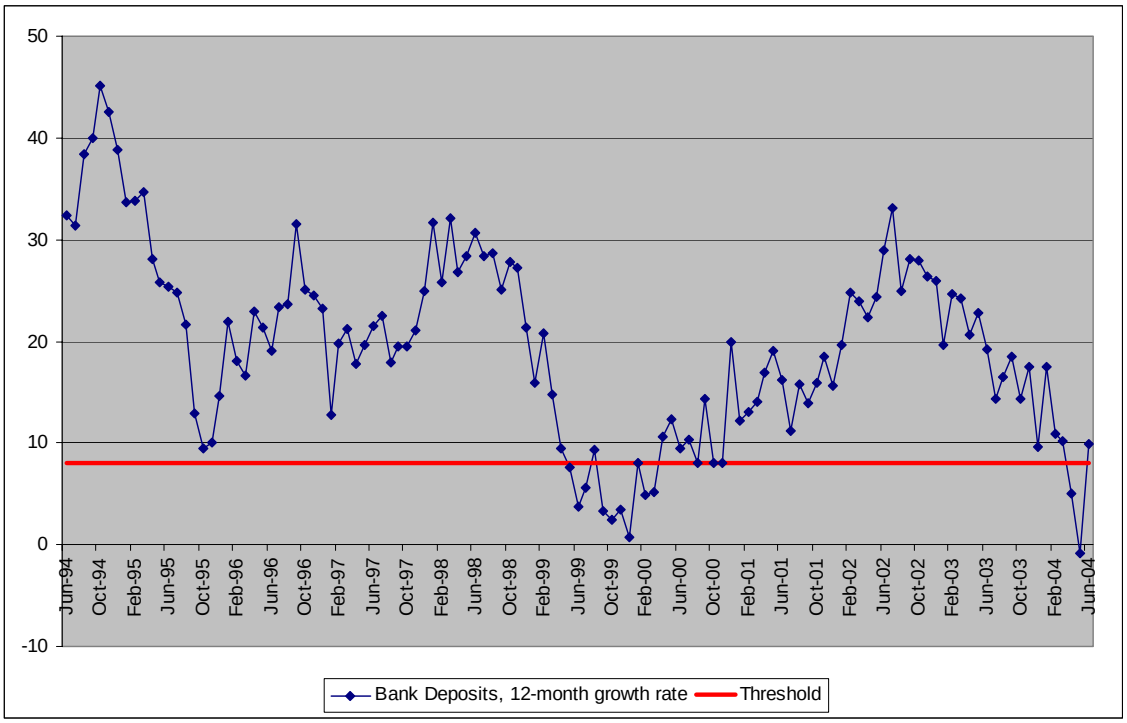

*Source: Authors' calculations.*

*Figure 22: Indicator: Ratio of Lending Interest Rate to Deposit Interest Rate*




*Source: Authors' calculations.*

*Figure 23: Indicator: Bank Deposits (12-month growth rate)*




*Source: Authors' calculations.*

# Appendix B. Data Definitions

*Table 11: Data Definitions*

| Indicator | Definition (based on GKR, 2000) | Definition (based on nomenclature provided by BoU) |
|---|---|---|
| Real exchange rate | Based on consumer price indices (IFS line 64) and defined as the relative price of foreign goods (in domestic currency) to the price of domestic goods. The trend was specified as, alternatively, log-linear, linear and exponential; the best fit among these was selected on a country-by-country basis. | *Real Effective Exchange Rate* (REER). The trend was specified as linear, which provided the best fit. |
| Exports | IFS line 70 | *Exports* (USD) |
| M2 / international reserves | M2 (in US dollars) / reserves (in US dollars): IFS lines 34 plus 35 converted into dollars using IFS line ae) divided by IFS line 1L.d. | *Money M2* (in shs) converted into dollars using the *Official Middle Rate* divided by linear interpolated (quarterly) *International Reserves* (USD) |
| Real output | For most countries, industrial production (IFS line 66). However, for some countries (the commodity exporters) an index of output of primary commodities is used (IFS line 66aa) | *Monthly Index of Industrial Production of Major Manufacturing Establishments* (1997/98 = 100) |
| Excess real M1 balances | (IFS line 34) deflated by consumer prices (IFS line 64) less an estimated demand for money. The demand for real balances is determined by real GDP (interpolated IFS line 99b), domestic consumer price inflation and a time trend. Domestic inflation was used instead of nominal interest rates, as market determined interest rates were not available during the entire sample for a number of countries; the time trends (which can enter log-linearly, linearly or exponentially) is motivated by its role as a proxy for financial innovation and/or currency substitution | *Money M1* (shs) deflated by *Composite Consumer Price Index*, Uganda (1997/98 = 100) less an estimated demand for money. The demand is calculated by linear interpolated (annual) *GDP* (shs), domestic *Inflation* (monthly % change) and a linear time trend. |
| International reserves | IFS line 1L.d. | *International Reserves* (USD), provided as quarterly data, hence linear interpolated |

*Table 10 (continued)*

| Indicator | Definition (based on GKR, 2000) | Definition (based on nomenclature provided by BoU) |
|---|---|---|
| M2 multiplier | Ratio of M2 to base money (IFS lines 34 plus 35) divided by IFS line 14 | *Money Multiplier* |
| Domestic credit / nominal GDP | IFS line 52 (MH: 32) divided by IFS line 99b (interpolated). Monthly nominal GDP was interpolated from annual or quarterly data | *Net Domestic Credit* (shs) divided by nominal *GDP* (shs). Monthly GDP was linear interpolated from annual data |
| Terms of trade | The unit value of exports (IFS line 74) over the unit value of imports (IFS line 75). For those developing countries where import unit values (or import price indices) were not available, an index of prices of manufactured exports from industrial countries to developing countries was used | *Terms of Trade*: Export Unit Value (USD) over the Import Unit Value (USD) |
| Real interest rate on deposits | IFS line 60L, monthly rates deflated using consumer prices (IFS line 64) expressed in percentage points | *Depositrates* (Saving Deposits) deflated using *Inflation* (Annual % Change), which is based on the *CPI* |
| Imports | IFS line 71 | *Imports* (USD) |
| Domestic / foreign real interest rate differential | Monthly rates in percentage points (IFS line 60L). Interest rates in the home country are compared with interest rates in the US if the domestic central bank pegs the currency to the dollar. | Real treasury bill rate, i.e. *91d Treasury Bill rates* (in %) deflated using *CPI* of Uganda, over the real treasury bill rate of the US, i.e. IFS Line 60C deflated by IFS Line 64 |
| Ratio of lending interest rate to deposit interest rate | IFS line 60p divided by IFS line 60L was used instead of differentials to ameliorate the distortions caused by the large percentage point spreads observed during inflation. In levels. | *Lending Rate* divided by *Depositrates* (Saving Deposits) |
| Bank deposits | IFS line 24 plus 25 | *Demand Deposits* plus *Time and Savings Deposits* |

Further definitions::

- Money Multiplier = M3 / Base Money
- M1= Currency In Circulation+Private Demand Deposits
- M2 = M1 + Private Time and Savings Deposits
- M2A = M2 + Certificate of Deposit
- M3 = M2A + Foreign Exchange Accounts
- Base Money = Cash in Circulation + Transaction balance of operating banks

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