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**Working Paper**

## The early warnings of balance-of-payments problems: Kaminsky and Reinhart revisited

Frankfurt School - Working Paper Series, No. 205

**Provided in Cooperation with:**

Frankfurt School of Finance and Management

*Suggested Citation:* Lang, Michael (2013) : The early warnings of balance-of-payments problems: Kaminsky and Reinhart revisited, Frankfurt School - Working Paper Series, No. 205, Frankfurt School of Finance & Management, Frankfurt a. M.

This Version is available at:

<https://hdl.handle.net/10419/85379>

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**Frankfurt School – Working Paper Series**

**No. 205**

**The Early Warnings of Balance-of-  
Payments problems:  
Kaminsky and Reinhart Revisited**

by Michael Lang

August 2013



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## Abstract

This paper builds upon the model of Kaminsky and Reinhart (1999) and extends it to triple-crises. It applies a new visualisation approach combining elements of an event study analysis and a fan chart technique. This approach illustrates the deviation of fundamentals in the run-up to balance-of-payments problems. The results suggest that both systemic banking crises and deteriorating government finances are highly significant leading indicators. Taking these indicators into account helps build a new early warning system for currency crises. The results are highly significant and robust. The out-of-sample forecasts demonstrate the strong predictive power of the model.

Key words: F30, F31, F34, F41, G01

JEL classification: currency crisis, financial sector vulnerability, early warning system.

ISSN: 14369753

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## 1. Introduction

Over the last years, global markets were hit by a series of severe financial crises. The global banking problems and the subsequent European sovereign debt crisis have caused serious turbulences on the foreign exchange markets. Bussière et al. (2012) find that currency turmoil results in permanent output loss relative to trend, which is estimated to range between 2 and 6 percent of GDP. Reliable leading indicators and credible early warning systems would allow policy makers to adopt preventive measures in the run-up to currency crises, also referred to as balance-of-payments problems. This could help avoid the crises or at least limit their potential adverse effects on the economy.

Both policy makers and the private sector have been working on early warning systems around the turn of the millennium following the Southeast Asian Crisis. Although financial crises share certain common features, no two are the same. Existing models are able to explain crises *ex post* but they were not successful in predicting crises *ex ante*. Early warning systems have utterly failed so far, and therefore were neglected in recent years. Despite numerous research activities and all the efforts to design a credible model for prediction of currency crises, existing early warning systems are not accurate enough and should only be used complementary to other vulnerability indicators (Andrew Berg, Borensztein, and Pattillo 2005).<sup>1</sup>

One of the most important and influential contributions to this research area has been published more than a decade ago by Kaminsky and Reinhart (1999). Their seminal paper on twin-crises is still ranked among the most cited publications in economic literature and forms the basis for most of later research in this field. Kaminsky and Reinhart (1999) examine the evolution of fundamentals in the run-up to currency and banking problems and show that financial crises follow economic recessions, credit growth, rising fiscal deficits and currency overvaluation. Although they find strong evidence that banking and currency crises are closely linked, Kaminsky and Reinhart (1999) do not control for banking crises in their model for balance-of-payments problems. Moreover, their model does not account for balance-of-payments items.

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<sup>1</sup> Publicly known early warning systems can potentially reduce their own accuracy in the real world. Having received an early warning, policy makers adopt preventive measures. Successfully adopted measures may help to avoid the crisis but cause false alarms in the application of the model (in other words, the model predicts crises which do not occur if the preventive measures are successful).

To the author's knowledge, even today interdependencies are examined only for so-called 'twin-crises', i.e. combinations of two different forms of financial crises. The interdependencies are not analyzed for simultaneously occurring currency, banking and sovereign debt crises. Most studies use rather small samples and focus on specific geographic regions or groups of similar countries. As most previous crises occurred in emerging markets, most of the recent studies do not consider mature economies which form the setting of recent financial turbulences.

The goal of this paper is to review and validate existing indicators. It illustrates the evolution of fundamentals around a typical currency crisis and identifies additional leading indicators of balance-of-payments problems. The central contribution of this paper is the enhancement of existing research on so-called 'triple-crises'. Using the framework outlined in Kaminsky and Reinhart (1999), it examines the interaction of different forms of financial crises and highlights the influence of both banking crises and deteriorating government finances on the likelihood of balance-of-payments problems.

Although the results are similar to those of Kaminsky and Reinhart (1999), there are important differences which are highlighted and discussed below. The indicators identified here could be used complementary to existing early warning systems for currency crises and enhance their predictive power. Besides, they have been used to build a new early warning system for prediction of potential currency crises. This early warning system is presented in this paper. Its predictive power is strong for both in-sample and out-of-sample forecasts.

In contrast to earlier studies that utilize cross-sectional design, panel data is used here to control for country-specific characteristics. The paper presents a new visualisation method which combines the advantages of an event study analysis and a fan chart technique. This method is applied to illustrate the deviation of potential leading indicators from the norm in the run-up to currency crises. Country fixed logit regression estimates are used to calculate the average partial effects of indicators on the likelihood of crises. The robustness check proposed by Sala-I-Martin (1997) and out-of-sample prediction results complement the study. The analysis covers 70 economies and the Euro area representing ca. 95 percent of the world output, including both mature and emerging markets.

The structure of this paper is as follows. Section 1 is introduction. Section 2 reviews the theoretical framework and empirical work on currency crises, and highlights some potential limi-

tations which this paper addresses. Section 3 examines empirical methodology and data. The results are summarized and discussed in section 4. A concluding section follows. Detailed description of data including the country list and sources is provided in the data appendix.

## **2. Existing theories and empirical evidence**

Balance-of-payments problems play a key role in financial crisis theories. As of today, there are three major generations of currency crisis theories. The traditional approach is to be attributed to Krugman (1979) who views currency crises in pegged exchange rate regimes as a result of unsustainable policies or fundamental imbalances affecting the viability of an exchange rate regime. In a country which maintains a fixed exchange rate and runs expansionary monetary policy to finance the excessive fiscal deficits, a sudden speculative attack will exhaust the foreign reserves and force the policy makers to float the currency resulting in currency devaluation. Flood and Garber (1984) modify Krugman's canonical model to the reference form for so-called first generation models. Later Krugman's model has been extended to crawling pegs (Connolly 1986) and currency bands (Krugman and Rotemberg 1991). These models have been used to explain both sovereign debt and currency crises in developing and emerging countries in Latin America in the 1970s and the beginning of 1980s but were able to predict neither the near-collapse of the European Monetary System in 1992/93 nor the sudden devaluation of the Mexican Peso in 1994.

As a consequence, the theoretical framework for currency crises has been revised and extended. Second-generation models go back to Obstfeld (1986; 1996) and Krugman (1996). While first-generation theories view currency crises as a consequence of weak economic fundamentals, second-generation theories assign them to abrupt shifts in investors' confidence (Pesenti and Tille 2000). Obstfeld (1986) shows that interaction between the actions of policy makers and the expectations of investors can result in multiple equilibriums leading to "self-fulfilling balance-of-payments problems". The equilibrium is determined by the investors' expectations concerning the policy makers' willingness to maintain a peg or to float the currency.

The later Asian Crisis in 1997/98, however, was different from previous crises. It was not characterized by weak economic fundamentals or abrupt shifts in investors' confidence. In contrast to most previous episodes of currency turmoil, this crisis was marked by inadequate supervision of the financial sector following the liberalization of capital markets. This led to

serious financial sector vulnerability. The domestic real sector was highly leveraged. Having pegged their currency to the U.S. Dollar, heavily relying on foreign denominated debt and running huge current account deficits, Southeast Asian economies were highly dependent on foreign investors. In the light of the economic upswing and the favourable outlook,<sup>2</sup> the Southeast Asian economies have attracted high foreign capital investments. Most investors and policy makers were taken by surprise when the currency crisis started in Thailand and spread over the entire region as foreign investors suddenly withdrew their funds.

Following the Asian Crisis, third-generation models highlight the adverse effect of the financial sector's vulnerability (Chang and Velasco 2000). Pesenti and Tille (2000) summarize the main issues of these theories. Explicit or implicit government guarantees, including a currency peg, and anticipation of a government bailout in case of financial distress create false incentives for the financial sector and give rise to moral hazard. The financial intermediaries will engage in excessively risky projects and neglect currency risks. Financial sector vulnerability is in particular characterized by inadequate supervision of the financial sector in liberalized capital markets, heavy dependence on foreign financing, and currency and maturity mismatch of assets and liabilities. The government's rescue operations for the financial system impose a severe burden for the public sector. Moreover, third-generation theories pay attention to so-called 'contagion' – the transmission of crises through different channels, in particular trade links and international capital flows.

Obviously, the public sector, the banking sector and the foreign exchange market are closely linked with each other. While first- and second-generation theories of currency crises focus on the interaction of foreign exchange markets and public finance, third-generation theories emphasize the importance of financial sector. Different currency crisis theories do not contradict but complement each other. An advanced analysis of currency crises should therefore cover the financial, external, real and fiscal sectors.

Currency crisis theories and structural models have been transformed into empirical models combining the elements of all three generations of currency crises. Both policy makers and the private sector have been working on early warning systems and used them to predict potential crises. The most popular early warning systems were designed by Kaminsky, Lizondo

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<sup>2</sup> i.a. The World Bank (1993) and OECD Economic Outlook (1997)



and Reinhart (1998), Berg and Pattillo (1999), and the IMF's Developing Country Studies Division (Borensztein et al. 2000). They form the basis for many other models related to different forms of financial crises, including the early warning system for balance-of-payments problems designed by Bussiere and Fratzscher (2006) who consider the current account, and the early warning system for sovereign debt crises provided by Ciarlone and Trebeschi (2005).

Theoretical considerations imply that systemic banking distress highlights the financial sector vulnerability. Excessive fiscal deficits characterise the deterioration of government finances and increase the likelihood of a sovereign debt crisis. Empirical evidence – particularly emphasizing the importance of twin-crises – suggests an allowance for interaction between different forms of financial crises. Kaminsky and Reinhart (1999) illustrate the interdependencies between balance-of-payments and banking crises, and show that the likelihood of a currency crisis is significantly higher when an economy experiences a banking crisis<sup>3</sup>. Bauer et al. (2007) demonstrate that differentiation between pure currency crises, pure debt crises and twin currency and debt crises significantly improves the efficiency of early warning systems. Thus far, little research has been conducted to examine the interdependencies between currency, banking and sovereign debt crises.

To bridge this gap, this paper extends existing research on so-called 'triple-crises'. The following section provides the definition of balance-of-payments problems and discusses the evolution of potential leading indicators in the run-up to currency crises.

### **3. Methodology and data**

#### **3.1. Definition of currency crises**

Balance-of-payments problems are characterized by severe pressure on the foreign exchange market. Under a floating exchange rate regime, the exchange market pressure can be measured as the actual depreciation. However, in a pegged exchange rate regime the pressure on the foreign exchange market is not always and not necessary reflected in the change of exchange rate. Monetary authorities can set higher official interest rates or intervene in the foreign exchange market, partly offsetting depreciation tendencies. Foreign exchange market interventions, i.e. the support of the domestic currency, are usually approximated by the

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<sup>3</sup> Although they find strong evidence that banking and currency crises are closely linked, Kaminsky and Reinhart (1999) do not control for a banking crisis variable in their model for balance-of-payments problems.

change in official foreign reserves. To identify currency crises, an exchange market pressure index (EMP)<sup>4</sup> that measures the weighted average change of the exchange rate and the foreign reserves is constructed:

$$(1) \quad EMP_{i,t} = -\sigma_{REER_i}^{-1} \times \left[ \log \left( \frac{REER_{i,t}}{REER_{i,t-1}} \right) - \mu_{REER_i} \right] - \sigma_{RES_i}^{-1} \times \left[ \log \left( \frac{RES_{i,t}}{RES_{i,t-1}} \right) - \mu_{RES_i} \right]$$

The EMP proposed here is calculated for each economy  $i$  separately, and captures the logarithmic monthly rate of change of the real effective exchange rate  $REER_{i,t}$ <sup>5</sup> and the international reserves  $RES_{i,t}$  at the point in time  $t$ . The EMP captures the deviation of observed values from their long-term country-specific average  $\mu$ . Taking into account that changes of exchange rates, foreign reserves and interest rates have different volatilities and those volatilities vary across different countries, these components are weighted by the inverse of their country-specific volatilities  $\sigma_{i,REER}$  and  $\sigma_{i,RES}$ . In comparison to equal weighting of components, the component with the higher volatility does not dominate the EMP (Schnatz 1998). Money market rates are not available for many developing economies or only accessible for limited period. So the EMP is only based on the exchange rate and the reserves.<sup>6</sup>

An event is defined as a currency crisis when the EMP exceeds a critical threshold. In some cases currency depreciation implies a correction of a misaligned exchange rate rather than a currency crisis: a one-off short-term appreciation of a currency may be followed by rapid depreciation; a short-term increase of foreign reserves may be followed by a sharp decline, both resulting in an extraordinarily high EMP. To focus on structural and prolonged currency crises rather than one-time short-term shocks, the analysis considers a smoothed currency crisis indicator. Schnatz (1998) applies a *backward-looking* indicator and considers the last three months with declining weights  $\alpha_n$ . The backward-looking principle is unbalanced and results

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<sup>4</sup> The EMP concept goes back to the monetary approach of Girton and Roper (1977). The original model has been revised and generalized by Weymark (1995). Eichengreen et al. (1994) introduce a volatility-weighted EMP, also used by Kaminsky and Reinhart (1999) and Bussiere and Fratzscher (2006).

<sup>5</sup> The real effective exchange rate considers both the basket of most important trading countries as well as the domestic and foreign price levels. It captures a lot of different information and is able to identify currency distortion in a very fast and effective manner. Therefore, this measure is superior to nominal or bilateral exchange rates. Among others, Bussiere and Fratzscher (2006) and Kaminsky and Reinhart (1999) consider the real effective exchange rate for the EMP calculation.

<sup>6</sup> Kaminsky and Reinhart (1999) examine 20 countries for the period 1970-mid-1995. They do not use money market rate for the EMP calculation. In contrast, Bussiere and Fratzscher (2006) examine 20 emerging markets for the period 1993-2001 and consider the interest rates.

in a certain time lag: the starting date of some crises can be identified too late. In contrast, this study calculates a *forward-and-backward-looking* smoothed indicator:

$$(2) \quad \overline{EMP}_{i,t} = \sum_{n=-1}^1 \alpha_n EMP_{i,t+n} \quad \text{with} \quad \sum_{n=-1}^1 \alpha_n = 1 \quad \text{and} \quad \alpha_{|n|+1} = \frac{\alpha_{|n|}}{2}$$

A currency crisis signal is defined as an episode when the smoothed EMP exceeds its mean and 1.5 standard deviations. The binary currency crisis signal indicator  $C_{i,t}$  equals 1 if this characteristic is true and 0 otherwise:

$$(3) \quad C_{i,t} = \begin{cases} 1 & \text{if } \overline{EMP}_{i,t} \geq \mu_{EMP_i} + 1.5 \times \sigma_{EMP_i} \\ 0 & \text{otherwise} \end{cases}$$

Estimating the binary  $C_{i,t}$  indicator allows for differentiation between four different states of the economy:

- i) the *pre-crisis* phase in the twelve months preceding a crisis,
- ii) the *crisis* phase beginning when the indicator turns from zero to one and lasting until the post-crisis phase,
- iii) the *post-crisis* phase lasting twelve months and beginning when the indicator changes from one to zero and remains in this state for at least twelve months,
- iv) the *tranquil* phase if the indicator is equal to one neither in any of the preceding twelve months nor in the following twelve months.

This paper examines the deviation of fundamentals from their norm in the run-up to currency crises. As the outbreak of a currency crisis affects the economic environment, there might be an endogeneity problem in the model if all four states of the economy are included. Bussiere and Fratzscher (2006) show that post-crisis recovery phases are often characterized by disordered fundamentals and do not provide meaningful information about the likelihood of a crisis. To address the post-crisis bias, all crisis and post-crisis observations are dropped and a binomial discrete-dependent-variable model is estimated. The model is designed with a twelve months forecast horizon and only differentiates between tranquil and pre-crisis phases, whereas crisis and post-crisis phases are not considered:

$$(4) \quad Y_{i,t} = \begin{cases} 1 & \text{if } \exists k = 1, \dots, 12 \text{ s.t. } C_{i,t+k} = 1 \text{ (pre-crisis)} \\ 0 & \text{if } \exists k = -12, \dots, 12 \text{ s.t. } C_{i,t+k} \neq 1 \text{ (tranquil)} \end{cases}$$

As currency crisis events do not affect the control variables in this setup, there is no reverse causality between dependent and independent variables in the model.<sup>7</sup>

The definition of currency crisis episodes is not arbitrary. In the case that the critical threshold is too low, the EMP sends too many crises signals and in the case of a high threshold it may miss some crises. The smoothed EMP and the critical threshold have been calibrated to currency crises that are referred to in existing literature. The EMP identifies 103 episodes of currency crises in 58 economies, including but not limited to Latin America (1970s and 1980s), European Monetary System (1992/93), Mexico (1994), Southeast Asia (1997/98), Russian Federation (1998) and Argentina (2002). In addition, it also captures the global foreign exchange market turmoil following the Lehman Brothers collapse in September 2008. Twelve economies, including Canada, Germany, Switzerland and the United States as well as the Euro area have not been hit by a currency crisis between 1975 and 2010. A full country list, the estimated country-specific EMPs and crisis periods are summarized and illustrated in the data appendix (see Table 6 and Figure 3).

### **3.2. Macroeconomic characteristics of currency crises**

The identification of exact crisis dates allows analyzing the evolution of fundamentals in their run-up. The variables used in the seminal paper of Kaminsky and Reinhart (1999) “were chosen in light of theoretical considerations and subject to data availability”. This paper builds upon their model and uses a set of economic indicators related to the financial, external, real and fiscal sectors. In particular it controls for the effect of banking crises which represent the financial sector vulnerability particularly highlighted in the third-generation models of currency crises. Banking crisis dates are taken from the database of systemic banking crises of Laeven and Valencia (2008; 2010; 2012).<sup>8</sup> In addition, the analysis also covers a number of

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<sup>7</sup> In contrast, Bussiere and Fratzscher (2006) estimate a multinomial logit model with three outcomes (pre-crisis, crisis/post-crisis and tranquil regimes). They argue that the binomial method (i.e. pre-crisis vs. crisis/post-crisis/tranquil) “ignores data that could provide valuable information, in particular on how fundamentals behave during recoveries and when or whether economic variables return to levels of tranquil or ‘normal’ times”. Their paper does not address the reverse causality issue in a multinomial approach with more than two outcomes.

<sup>8</sup> Most dates are provided on monthly basis. For crises where only the onset year is available, this paper defines the monthly starting date based on public information available or assume that the starting point was at the

balance-of-payments items which have not been taken into account by Kaminsky and Reinhart (1999). The definition of variables is provided in the data appendix.

Some fundamentals can potentially reflect causes of balance-of-payments problems. Other fundamentals, however, cannot explain the causes of balance-of-payments problems but may reflect the symptoms of currency crises (e.g. the abandonment of a pegged exchange rate regime). Both causes and symptoms of currency crises are able to provide an early warning indication of balance-of-payments problems. The goal of the following analysis is identification of reliable leading indicators of currency crises.

The analysis covers 70 economies and the Euro area representing ca. 95 percent of the world output. It is done on a monthly basis for the period between 1975 and 2010 including data for the recent global financial crisis which was not yet available in earlier publications. In contrast to many previous studies, the analysis is not limited to developing and emerging countries but also covers mature economies. Using monthly data allows for a clearer view and for capturing the moment of deterioration in the fundamentals. Low frequency data was interpolated where required.

To choose an appropriate set of leading indicators for the model, the behaviour of fundamentals in the run-up to currency crises is compared relative to tranquil period observations. As fundamentals are subject to seasonal effects, the 12-month percent change is calculated for all variables and compared to their long-term growth rates in tranquil periods. For interest rates, the percentage point difference between tranquil and crisis periods is used. Macroeconomic data is often subject to outliers. To deal with outliers, exponential interest and growth rates are used.

Table 1 provides median statistics for fundamentals by the state of economy (additional summary statistics provided in the data appendix). Figure 1 portrays the behaviour of variables relative to the country-specific tranquil period median during a 73 months window beginning five years prior the currency crisis and ending one year after its onset. It combines elements of

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mid-year. The end of a banking crisis is defined as the year before two conditions hold: “real GDP growth and real credit growth are positive for at least two consecutive years” (Laeven and Valencia 2010; 2012). As this definition results in long crisis durations in a number of crises, Laeven and Valencia (2010; 2012) truncate the duration at 5 years. Their end dates are calculated on annual basis. This paper uses monthly data and applies the same definitions for the offset of banking crises but does not truncate the duration.

both a common event study analysis and a fan chart technique that is used by the Bank of England in its ‘Inflation Report’.

Usually, the event study analysis illustrates the average deviation of fundamentals and its confidence band equal to plus/minus one standard deviation. In contrast, Figure 1 portrays real observations. It illustrates the median deviation (dark blue line) and the confidence bands (blue bands representing 5 percent to either side of the median). The pre-crisis deviation of fundamentals is benchmarked against their country-specific tranquil period median (horizontal red line). The vertical red line marks the beginning of the crisis period. The combination of an event study analysis with the fan chart technique allows for precise capturing of both the starting points of deterioration and the deviation from the norm. A widening confidence band suggests an increasing volatility in fundamentals. To the author’s knowledge, the technique proposed here is new and has not been utilized in this area before.

Kaminsky and Reinhart (1999) apply an event study analysis and demonstrate the deviation of variables relative to tranquil periods during a three years window centred around the outbreak of crises. They define the tranquil period as the remaining observations outside the three years window. Obviously, this paper uses a longer time window and a more powerful tool for visualising the deviation of fundamentals from their norm. Moreover, it applies a more sophisticated definition for tranquil periods. Although the results are similar to those of Kaminsky and Reinhart (1999), there are important differences which are highlighted and discussed in the following.

### **3.2.1. The financial sector**

The growth in *domestic credit / GDP* increasingly outperforms the norm starting five years before the onset of the crisis and only returns to the norm one year following its onset. The accelerating domestic credit / GDP ratio particularly highlights the increasing leveraging of households and private businesses which exceeds the output growth. In contrast, the growth rate of *bank deposits* remains close to normal levels in the pre-crisis phase but declines following the onset of the crisis as customers withdraw their deposits from the financial institutions. These observations imply that bank lending is not fully financed with bank deposits (in other words, the credit-boom is not covered by bank deposits) particularly highlighting the vulnerability of the financial sector.

Systemic *banking crises* representing the vulnerability of the financial sector take a key role in the theoretical considerations and empirical studies on currency crises but have not been adequately addressed in earlier publications. The event study analysis implies that balance-of-payments problems follow systemic banking crises. Almost every third currency crisis is preceded by a banking crisis, whose severity reaches its peak just at the moment when currency crises become evident, and remains at this high level for the following periods.

Controlling for the money multiplier as the transmission channel for bank lending Kaminsky and Reinhart (1999) observe large increases in the M2 multiplier. They interpret the increasing M2 multiplier as a possible result of financial liberalization and reduced reserve requirements. In this sample, the *money multiplier* remains close to normal levels both in the run-up and following the crisis. The summary statistics even imply a declining M2 multiplier change. Possibly, the variation of the multiplier follows structural macroeconomic changes rather than fundamental imbalances. In their recent paper, Carpenter and Demiralp (2012) examine monetary data for the United States and find evidence against the role of money multiplier as a transmission mechanism. In the light of a relatively stable money multiplier, the increasing growth in *M2/reserves* ratio is a result of reduced minimum reserves. In contrast to Kaminsky and Reinhart (1999), it was not possible to find evidence for *excess M1 balances*: the ratio remains close to its normal level. The summary statistics and the marginally downwards-skewed fan chart even imply that the ratio declines below its norm during the pre-crisis period.

In their seminal paper, Kaminsky and Reinhart (1999) find evidence for an increasing lending-deposit rate ratio reflecting the deterioration in credit risk. In contrast, in the setup of this study the *lending-deposit rate ratio* declines below the normal level five years before the crisis. The significant and prolonged decline in the ratio continues after the onset of the crisis. Subtracting the money market rate from both deposit and lending rate allows controlling for the impact of the interest rate level on the lending-deposit rate ratio. For some countries, the credit spread significantly increases around the date of a currency crisis. But the median credit spread does not deviate significantly from its norm remaining close to tranquil levels. It does not fluctuate much either in the run-up or in the aftermath of the crisis. These observations indicate that the declining lending-deposit rate ratio reflects the increasing interest rate level rather than the deterioration in credit risk.

Inflation rates are particularly high in the run-up to balance-of-payments problems and increase after the crises. The money market rate does not deviate from its norm during tranquil periods up to about four years before a currency crisis but then gradually rises significantly outperforming at the onset of the crisis and during the following periods. The rising nominal money market rates are partly driven but not fully offset by increasing inflation rates and the *real interest rate* outperforms its norm during tranquil periods in the fifteen months prior to the crisis and declines in the aftermath of the currency turmoil.

### **3.2.2. The external sector**

Kaminsky and Reinhart (1999) analyse the deviation of the real effective exchange rate from trend and find evidence of significant overvaluation prior to currency crises. In contrast, this study compares the change in the exchange rate relative to its long-term tranquil fluctuation and does not consider the trend<sup>9</sup>. Though slightly outperforming the benchmark, the steady development does not indicate an overvaluation. The *real effective exchange rate* only starts to underperform three months prior to the onset of a currency crisis but first tendencies towards devaluation of the domestic currency become particularly apparent long before. The steadily increasing money market rate prior to the crisis and a gradual loss of foreign *reserves* beginning one year before the onset of balance-of-payments problems reflect the intervention of policy makers defending the exchange rate. The intensified pressure on the exchange market forces those policy makers who maintain a pegged exchange rate system to float the currency. The author controls for the *abandonment of a pegged exchange rate regime* and finds it a valuable early warning indicator sending signals shortly before the outbreak of currency crises. This signal provides clearer results than pure dummy variables classifying the status quo exchange rate system as pegged or free floating (both exchange rate regimes not reported in Table 1 and Figure 1 to save space).

Despite increasing money market and real interest rates, the *real interest rate differential* against the G20 economies remains close to the norm and does not significantly outperform the tranquil benchmark. It deteriorates and underperforms following the crisis. This regularity also applies to the real interest rate against the most traded and therefore most important currencies, in particular the U.S. dollar, the Euro, the British pound sterling, the Swiss franc, the

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<sup>9</sup> Kaminsky and Reinhart (1999) specify the trend as log, linear, and exponential. They select the best fit among these alternatives on a country-by-country basis. As the best-fit choice is discretionary and may be arbitrary in some cases, this study does not consider it.



Japanese yen and the former Deutsche Mark (not reported to save space). The results suggest that most currency crises occur in times when global real interest rates are particularly high.

Both *exports* and *imports* underperform relative to tranquil periods starting two years prior the crises. But their underperformance is less dramatic as illustrated by Kaminsky and Reinhart (1999) and remains close to normal levels. As a consequence of national currency devaluation, exports recover and outperform tranquil period growth rates in the aftermath of a crisis, whereas imports underperform more considerable. In contrast to Kaminsky and Reinhart (1999) who find evidence for deterioration in the country's terms of trade, in this setup the *terms of trade* factor remains close to normal levels in the pre-crisis phase but underperforms with the onset of the crisis. For those developing countries where import unit values were not available, Kaminsky and Reinhart (1999) use the index of prices of manufactured exports from developing countries. As they use the same data for several countries – and some of these countries have probably experienced the crisis roughly at the same time – the effect observed by Kaminsky and Reinhart (1999) may be data-driven, and therefore differs from the results presented here.

A thorough external sector analysis requires a balance of payments evaluation. The balance of payments results are more accurate than sole export and import analysis and provide additional insight. The variables related to the balance of payments oscillate around the zero point. The relative growth rate is not an appropriate measure to determine the direction of change when these variables turn from positive to negative or vice versa. Therefore, the trailing 12-month magnitude of balance of payments accounts items measured in percent of GDP is more appropriate. It measures the 12-month change of the international investment position.

The *current account* increasingly deteriorates starting ca. 54 months before the crisis. The deteriorating current account corresponds to observations by Bussiere and Fratzscher (2006). The current account performance is largely attributed to the balance on goods. Continuously underperforming exports and outperforming imports result in a deteriorating *trade balance* prior to the currency crises. The results illustrate the volume of exports and imports relative to the GDP and are not contradictory to those mentioned above where the relative growth of exports and imports is measured. The balance on services also contributes to the current account deterioration. But its influence is significantly less important than the trade balance impact. The capital account does not deviate from its norm in the five years around the currency crisis and is not reported here to save space.

Obviously, high real interest rate attracts foreign capital. The *financial account* is characterized by high foreign capital inflow in the run-up to balance-of-payments problems. The decline in foreign capital inflow starts with the onset of a crisis and continues in the following periods. The fan chart and the statistics provide significant evidence for a sudden slowdown or even a reversal in foreign capital in the aftermath of currency crises. Direct investments and portfolio investments do not fluctuate much around the currency crisis date (both not reported to save space). The deterioration of the financial account is largely attributed to other investment assets and liabilities, in particular to *bank investment liabilities*. The results are consistent with observations during the Southeast Asian meltdown where bank capital has been withdrawn but direct investments and portfolio investments remained relatively stable.

The *overall balance* – the sum of current account, capital account, financial account and net errors and omissions – deteriorates in the run-up to currency crises. First, the outperforming financial account compensates the underperforming current account. But starting eighteen months before the currency crisis, the overall balance significantly underperforms its tranquil norm and only recovers almost one year after the currency turmoil.

### **3.2.3. The real sector**

The real sector analysis confirms that currency crises follow recessionary effects. The underperforming output (both *production* and *real GDP* growth rates) and an increasing *unemployment rate* worsen and continuously deteriorate starting eighteen months before the onset of currency crises.

Stock markets reflect the slowdown in economic activity in the run-up to balance-of-payments problems. As equity prices are volatile by nature, their return constantly fluctuates around the tranquil benchmark in the five years before the onset of a crisis. Focusing on equity prices denominated in the national currency allows to eliminate the exchange rate effect. The pre-crisis phase is characterised by plunging *stock prices* significantly underperforming by ca. 12 percent (ca. 17 percent in real terms). The underperformance increases with the outbreak of a currency crisis to ca. 20 percent (ca. 26 percent in real terms) and continues until one year following the onset of a crisis.<sup>10</sup>

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<sup>10</sup> Note: The panel in Figure 1 illustrates extreme underperforming stock prices around the period of the currency onset, exceeding 100%. These results make sense as we use exponential growth rates to deal with outliers (especially with extremely large values) and are comparable with ca. 63 percent linear growth rates.

The historical *stock price volatility*<sup>11</sup> is below the norm in the five years before the crisis, possibly reflecting steadily rising equity prices. But it significantly increases and mirrors the growing uncertainty and nervousness of investors in the last year prior to balance-of-payments problems. A sudden shock drives the volatility up and results in panic on equity markets following the onset of a currency crisis. The observations illustrate significant loss in investors' confidence and provide strong empirical evidence for second-generation theories of currency crises.

Kaminsky and Reinhart (1999) use stock prices measured in U.S. dollars. The regularity described above also applies to equity prices converted to U.S. dollars but the magnitude of underperformance significantly increases in the light of the currency depreciation following the onset of balance-of-payments problems.

### 3.2.4. The fiscal sector

The pre-crisis phase is characterized by increasing fiscal deficits particularly highlighted in first-generation theories on currency crises. The increasing *government expenditures-revenues ratio* reflects the widening gap between government expenditures and revenues in the two-and-a-half years before the onset of the balance-of-payments problems and indicates deterioration of government finances. The *real government revenue* growth rate remains stable in the run-up to a crisis and slightly underperforms its norm during tranquil phases starting twelve months before the crisis outbreak, possibly reflecting lower income tax revenues as a consequence of unfavourable economic development. Yet, the relative deviation from norm is less dramatic than for output, probably mirroring the government's countermeasures partly offsetting the loss in revenues by increasing tax rates and cutting public subsidies. The *real government expenditures* start to rise at above the regular rate eighteen months prior to currency crises, possibly reflecting the government's rescue operations. Their growth rate reaches the peak around the onset of the crisis potentially intensified by the currency devaluation and reflecting the increasing interest expenses for foreign debt. The real government expenditures underperform after the crisis onset as a consequence of severe austerity measures.

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<sup>11</sup> Implied volatilities could provide additional information concerning the investors' expectations. Unfortunately, implied volatility data is rare and usually limited to industrialized economies, and therefore not available for most developing and emerging markets.

Table 1: Summary statistics by state of the economy

The table provides median statistics for fundamentals by the state of economy (additional summary statistics provided in the appendix). For binary dummy variables the table provides the means. The variables related to the balance of payments oscillate around the zero point. The relative growth rate is not an appropriate measure to determine the direction of change when these variables turn from positive to negative or vice versa. Therefore, the trailing 12-month magnitude of balance of payments accounts flows measured in percent of GDP is more appropriate. It measures the 12-month change of the international investment position.

	no crisis	pre crisis	crisis	post crisis	total
<i>Financial sector</i>					
Domestic credit / GDP: 12-month change	1.740	4.515	5.949	2.588	1.947
Bank deposits: 12-month change	6.175	5.403	3.373	1.466	5.963
Banking crisis (dummy)	0.063	0.157	0.308	0.306	0.084
M2 multiplier: 12-month change	2.019	1.621	0.603	1.443	1.974
M2/reserves: 12-month change	-0.283	6.023	13.036	-5.756	-0.101
Excess M1 balances	0.215	0.034	-0.293	0.434	0.204
Lending-deposit rate ratio	54.401	29.364	32.005	29.765	50.859
Real interest rate	1.245	1.893	0.507	-0.137	1.218
<i>External sector</i>					
Real effective exchange rate: 12-month change	1.066	1.879	-11.367	-12.395	0.740
Reserves: 12-month change	10.761	3.355	-22.564	-6.656	9.564
Abandonment of pegged exchange rate regime (dummy)	0.030	0.112	0.147	0.062	0.037
Real interest rate differential	-0.091	0.310	-0.309	-1.315	-0.125
Exports: 12-month change	10.550	6.113	-1.329	4.231	9.984
Imports: 12-month change	10.886	5.427	-1.753	-6.670	9.979
Terms of trade: 12-month change	0.071	-0.716	-2.010	-1.842	-0.042
Goods exports / GDP	24.324	18.848	18.823	19.483	23.581
Goods imports / GDP	-22.377	-19.174	-18.987	-19.513	-22.098
Trade balance / GDP	-0.015	-1.662	-0.440	-0.024	-0.099
Current account GDP	-1.140	-3.322	-2.974	-1.986	-1.347
Bank investment assets / GDP	-0.397	-0.170	-0.213	-0.215	-0.366
Bank investment liabilities / GDP	0.557	0.567	0.175	-0.001	0.516
Bank investment assets & liabilities/ GDP	0.082	0.335	0.043	-0.268	0.076
Financial account / GDP	1.645	2.247	1.548	0.537	1.631
Overall balance / GDP	0.565	-0.275	-1.781	-1.241	0.428
<i>Real sector</i>					
Production: 12-month change	3.057	2.271	0.327	-0.093	2.881
GDP volume: 12-month change	3.676	3.013	1.397	0.749	3.521
Unemployment rate: 12-month change	-1.036	7.925	13.353	17.127	0.000
Stock prices in LCU: 12-month change	12.248	0.640	-7.575	4.884	11.373
Real stock prices in LCU: 12-month change	7.556	-9.397	-18.451	-8.878	6.150
Stock price volatility in LCU: 12-month change	-0.479	2.505	8.256	4.794	-0.145
Stock prices in USD: 12-month change	12.270	-1.268	-26.875	-14.962	10.578
Real stock prices in USD: 12-month change	8.752	-5.917	-29.949	-18.242	6.970
Stock price volatility in USD: 12-month change	-0.586	3.815	12.938	9.012	-0.246
<i>Fiscal sector</i>					
Real government revenues: 12-month change	4.417	2.840	2.195	0.407	4.097
Real government expenditures: 12-month change	3.933	5.514	4.642	1.183	3.911
Gvt. expenditures-revenues ratio: 12-month change	-0.406	1.947	1.893	1.162	-0.228
N	20,423	1,120	312	1,234	23,089

Figure 1: Empirical regularities in the run-up to currency crises compared to tranquil phases

Each panel portrays the behaviour of a variable relative to its tranquil period median during a 73 months window around the outbreak of currency crises. The dark blue line illustrates the median difference between the average deviation of a variable during each month of the 73 months window compared to country-specific tranquil period observations. The chart shows the deviation distribution. The central band, coloured deep blue, represents 10 percent of observations (5 percent to either side of the median) at any month. The next deepest shade, on both sides of the central band, takes the distribution out to 10 percent; and so on, in steps of 10 percentage points.

For binary dummy variables the confidence bands are based on the standard deviation (e.g. the central band represents observations within 0.126 standard deviations to either side of the mean, which accounts for 10 percent of the population).

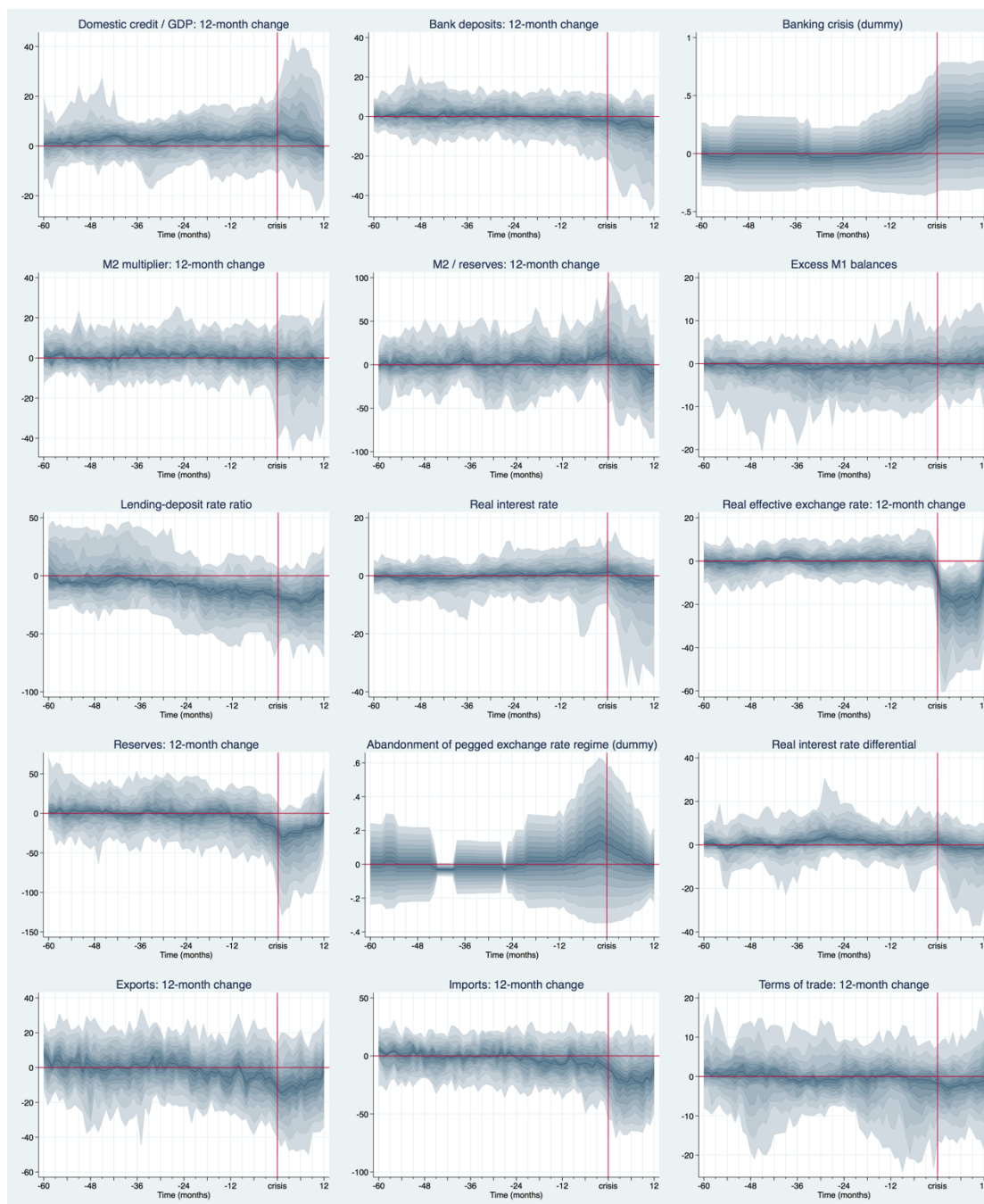
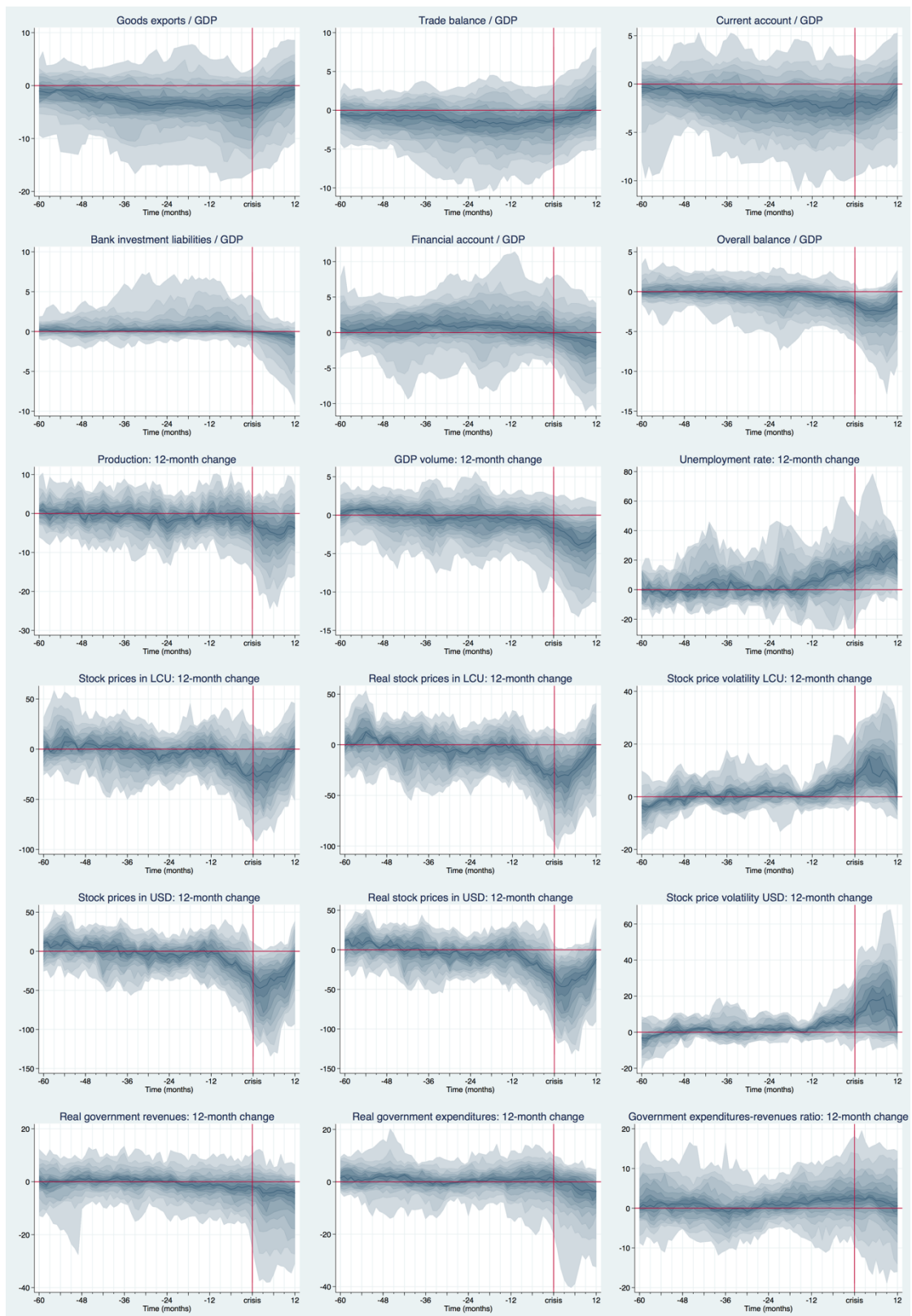


Figure 1: Empirical regularities in the run-up to currency crises compared to tranquil phases (continued)



#### 4. Results and discussion

Most existing early warning systems for financial crises can be classified as either a signal or a discrete-dependent-variable approach.<sup>12</sup> Kaminsky and Reinhart (1999) design a signal approach transforming all variables to quasi-dummy variables: an indicator sends a crisis signal if it exceeds a critical threshold which is chosen to minimize the noise-to-signal ratio. The signal approach is a simple and transparent method for sole indicator-by-indicator vulnerability analysis summarizing the indicators exceeding the critical thresholds. But the transformation process results in certain loss of information. Defining fixed cross-country thresholds, the signal approach assumes constant partial effects and does not allow for interaction between different indicators. Moreover, the partial effects are assumed to be equal for all countries.

In contrast, in case of a discrete-dependent-variable approach, the partial effect of a variable on the likelihood of a crisis is not constant but depends on the variable's intensity and the specifications of other variables. The binary discrete-dependent-variable approach has been applied in numerous studies, including but not limited to Kaminsky et al. (1998) and Borensztein et al. (2000). Bussiere and Fratzscher (2006) extend the binomial logit approach to a multinomial logit model with three outcomes (pre-crisis, crisis/post-crisis and tranquil regimes) and show that addressing the post-crisis bias can significantly improve the predictive power of the model.

In this paper, the discrete-dependent-variable approach has been chosen to replicate the signal approach model of Kaminsky and Reinhart (1999). To address the post-crisis bias, all crisis and post-crisis observations have been dropped (see section 3.1) and a binomial logit model has been estimated. In contrast to earlier models, a panel design is used to control for country-specific characteristics which have been widely neglected in the past. The author summarizes the regression results and reports the average marginal effects in Tables 2-4. A robustness

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<sup>12</sup> Over the years, the variety of models has been extended and recent models have been adapted to more complex alternative techniques. Sarlin and Peltonen (2011), for example, argue that financial crises are complex events. They adopt a Self-Organizing-Maps (SOM) approach – a non-parametric neural-network-based visualization tool – and show that alternative non-linear methods are more appropriate for analysis of extreme events given their changing nature. Sarlin and Marghescu (2011) use the Self-Organizing-Maps to replicate the probit model of Berg and Pattillo (1999), compare it with the classical probit model and find that both models provide similar results. Manasse et al. (2003), and Manasse and Roubini (2009) apply a statistical technique called Classification and Regression Tree (CART) analysis to identify possible (nonlinear) interactions between the potential variables. They use a binary recursive tree analysis to predict the probability sovereign debt crises and compare the result to a logit model, showing that the tree model has a higher hit but also a higher false alarm rate.

check proposed by Sala-I-Martin (1997) and out-of-sample predictions which are summarized in Table 5 and Figure 2 conclude this section.

#### **4.1. Replication of the Kaminsky and Reinhart (1999) model**

Table 2 starts with the set of variables used by Kaminsky and Reinhart (1999). Columns (1)-(4) present OLS and logit regression results for cross-section and country fixed effects models. The results are essentially consistent with the event study analysis illustrated in section 3.2. The coefficients of *domestic credit / GDP*, *lending-deposit rate ratio*, *M2/reserves*, *production* and *government expenditures-revenues ratio* are all significant at the 1 percent level and have the expected signs. *Imports* and *the real effective exchange rate* have negative coefficients and are significant in the fixed effects setup. *Bank deposits* are not significant in the fixed effects setup: as illustrated in section 3.2, they only decline following the crisis. The coefficient of *M2 multiplier* is significant but not consistent with theory. *Reserves* are only significant in the fixed effects setup but their coefficient is positive and contradictory to theory and the results illustrated in section 3.2. Equity prices are volatile by nature and the effect of *stock prices in USD* is also not as high as expected and illustrated in the event study analysis. It is close to zero and only significant in the fixed effects setup. *Real interest rate*, *terms of trade*, *exports* and *real interest rate differential* are not significant either.

In columns (5)-(7), the variables related to the financial sector (*M2 multiplier*, *real interest rate*, *excess M1 balances*, *bank deposits* and *real interest rate differential*), trade (*exports*, *imports* and *terms of trade*) and other external sector variables (*real effective exchange rate* and *reserves*), which have been found neither significant nor robust nor consistent with theory, are simultaneously removed from the original model. In column (8), all of them are removed. The variables that have been found significant and have the expected signs in columns (1)-(4) remain so in columns (5)-(8).

The results confirm that increasing domestic leverage, rising interest rates, declining output growth, deteriorating government finances and an increasing M2/reserves ratio are statistically significant indicators of balance-of-payments problems.



Table 2: Regression of early warning indicators for currency crises excluding banking crisis dummy, dependent variable: pre-currency-crisis period

Unbalanced panel. The table presents the average marginal effect. For OLS t-statistic and for logit z-statistics in parentheses (robust standard errors). An intercept term is included in each regression but not reported to save space.

	Kaminsky and Reinhart (1999) model				reduced Kaminsky and Reinhart (1999) model			
	(1) OLS	(2) Logit	(3) OLS	(4) Logit	(5) Logit	(6) Logit	(7) Logit	(8) Logit
DOMCRED	0.001*** (4.539)	0.002*** (5.842)	0.002*** (7.958)	0.007*** (4.713)	0.003*** (3.563)	0.004*** (3.769)	0.007*** (5.252)	0.003*** (3.920)
BANKDEP	0.001*** (2.951)	0.001*** (3.199)	-0.000 (-0.962)	0.002 (0.837)		0.001 (0.739)	0.004** (2.046)	
M2MULT	-0.001*** (-4.159)	-0.001*** (-5.253)	-0.001** (-2.454)	-0.003** (-2.528)		-0.003*** (-3.590)	-0.003** (-2.003)	
M2RES	0.000 (1.551)	0.001** (2.218)	0.002*** (5.391)	0.004*** (3.580)	0.002*** (2.740)	0.003*** (3.317)	0.001*** (2.881)	0.001*** (2.812)
EXM1B	0.000 (0.319)	0.000* (1.746)	0.000 (1.186)	0.002*** (2.719)		0.002*** (3.226)	0.002*** (2.892)	
LENDEP	-0.001*** (-9.471)	-0.001*** (-9.217)	-0.000*** (-2.740)	-0.004*** (-7.179)	-0.004*** (-11.455)	-0.005*** (-23.202)	-0.004*** (-7.322)	-0.004*** (-27.986)
RINTR	-0.000 (-0.452)	0.000 (0.087)	0.001 (0.813)	0.003 (0.825)		0.006** (2.020)	0.000 (0.044)	
REER	-0.000 (-0.343)	-0.000 (-0.741)	-0.002*** (-3.113)	-0.004** (-2.246)	-0.001 (-0.758)	-0.002* (-1.868)		
RES	0.000 (0.862)	0.000 (1.158)	0.002*** (4.579)	0.003*** (2.825)	0.002** (2.024)	0.002** (2.065)		
EXPORT	-0.000 (-0.121)	-0.000 (-0.117)	0.000 (0.546)	-0.000 (-0.027)	-0.001 (-0.995)		-0.000 (-0.525)	
IMPORT	-0.000 (-1.334)	-0.000 (-1.222)	-0.001*** (-3.323)	-0.001 (-1.629)	-0.001 (-1.616)		-0.001 (-1.619)	
TOTRADE	0.000 (0.396)	0.000 (0.599)	-0.000 (-0.457)	0.001 (0.661)	0.003** (1.982)		0.001 (0.446)	
RINTDIF	-0.001 (-1.307)	-0.001** (-1.962)	-0.000 (-0.481)	-0.002 (-0.944)		-0.004** (-2.385)	0.000 (0.068)	
PROD	-0.001 (-1.411)	-0.001** (-2.440)	-0.002*** (-3.334)	-0.011*** (-4.650)	-0.008*** (-4.299)	-0.008*** (-5.400)	-0.009*** (-4.091)	-0.006*** (-5.299)
SPUSD	-0.000 (-1.428)	-0.000 (-1.575)	-0.000** (-2.329)	-0.000* (-1.891)	-0.000* (-1.845)	-0.000** (-2.364)	-0.000 (-1.464)	-0.000* (-1.955)
GOVDEF	0.003*** (4.701)	0.002*** (5.404)	0.002*** (4.310)	0.005*** (3.447)	0.008*** (5.604)	0.004*** (3.954)	0.004*** (2.671)	0.006*** (5.409)
Country FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	4,579	4,579	4,579	2,192	2,805	2,710	2,232	3,364
Number of countries	38	38	38	16	18	19	16	21
(Pseudo-)R-Squared	0.035	0.122	0.034	0.132	0.106	0.161	0.127	0.123
Log-Likelihood	540.081	-806.207	788.318	-578.455	-763.126	-669.046	-601.447	-883.271

\*\*\* Significant at 1 percent level. \*\* Significant at 5 percent level. \* Significant at 10 percent level.

#### **4.2. Introduction of a banking crisis indicator and balance-of-payments items to the model**

In Table 3, columns (1)-(8) are replicated including a dummy variable for systemic banking crises into the regressions. The banking crisis dummy enters the regression with a positive coefficient. The estimated average marginal effect would suggest that a banking crisis would increase the probability of a currency crisis by up to 16.1 percent. All other variables remain robust.

The coefficient of banking crises is not significant when external sector variables related to trade are not included into the model. External sector plays a key role in currency crisis theories. But Table 3 and Table 4 indicate that variables related to the external sector which have been used by Kaminsky and Reinhart (1999) are neither robust nor significant. In their seminal paper, the authors do not consider the balance-of-payments ratios. Table 4 summarizes several replications of column (16) including balance-of-payments items related to foreign trade and private capital flows which clearly deviate from norm prior to currency crises as illustrated in section 3.2.

The currency crisis vulnerability decreases for higher *export / GDP* ratios and increases for higher *import / GDP* ratios. These ratios seem to be superior to relative export and import growth rates used above. In particular the share of exports in percent of GDP is a useful indicator which measures the competitiveness of an economy. Imports, in contrast, include necessary raw materials and have lower price elasticity. Therefore, exports react faster on fundamental imbalances and structural changes than imports. The results imply that high *trade balance* and *current account* deficits can significantly increase the likelihood of currency turmoil and balance-of-payments problems.

Third-generation theories of currency crises highlight the financial sector vulnerability resulting from dependence on foreign funding. Prior to currency crises, *bank investment liabilities / GDP* increase significantly. A five percent increase in bank investment liabilities / GDP inflow has an average partial effect of 7.0 percent on the likelihood of a currency crisis. In contrast, *bank investment assets / GDP* are not significant. The *financial account* enters the regression with a positive coefficient. Beyond bank investment assets and liabilities, it also includes direct investments and portfolio investments, as well as general government and monetary authorities

assets and liabilities, which remain relatively stable around the currency crisis outbreak.<sup>13</sup> Therefore, the financial account does not reflect the slowdown in foreign capital inflow as well as bank investment liabilities prior to currency turmoil and has a lower average partial effect. Overall, related balance-of-payments positions (e.g. exports and imports the sum of which is the trade balance) are potentially correlated. Including related items into the regression does not provide better results but could lead to multicollinearity. As both positions are correlated, they partly compensate each other and their balance is less significant (not reported to save space). In total, exports and bank investment liabilities have been found to be better indicators than imports, bank investment assets, trade balance, current account and financial account.

As described earlier, alongside with dependence on foreign financing, third-generation theories also focus on government guarantees, including a currency peg. In column (23), a dummy variable for the *abandonment of a pegged exchange rate* is introduced. The coefficient is positive and highly significant. The average marginal effect suggests that the probability of a currency crisis increases by 23.3 percent when policy makers give up their exchange rate regime and float their currency.

Overall, the results go hand-in-hand with existing currency crisis theories and are consistent with the earlier event study analysis in section 3.2. Again, the coefficient of stock prices enters the regression with a negative sign but its effect is not always significant. The balance-of-payments coefficients are highly significant and substantially improve the quality of the model.

The banking crisis coefficient remains positive in all regressions in Table 3 and Table 4. Its coefficient is highly significant. Its average partial effect is higher when financial account variables are included. Obviously, banking crises are highly dependent upon foreign bank credit and the economies' reliance upon foreign indebtedness. Banking crises are sudden shocks reflecting abrupt macroeconomic changes. A strongly growing government expenditures-revenues ratio can result in a high sovereign debt burden and indicates deteriorating government finances. It is a proxy for a sovereign debt crisis. Including both variables into the model allows for a more clear view on the overall economic environment and extends the existing empirical work on balance-of-payments crises to twin and triple crises. The author has also examined different interaction terms. They have not provided additional information, and are therefore not reported here.

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<sup>13</sup>Note: Reserve assets, Fund credit and loans, and exceptional financing are not included into the financial account.

Table 3: Regression of early warning indicators for currency crises including banking crisis dummy, dependent variable: pre-currency-crisis period

Unbalanced panel. The table presents the average marginal effect; for OLS t-statistic and for logit z-statistics in parentheses (robust standard errors). An intercept term is included in each regression but not reported to save space.

	Kaminsky and Reinhart (1999) model				reduced Kaminsky and Reinhart (1999) model			
	(9) OLS	(10) Logit	(11) OLS	(12) Logit	(13) Logit	(14) Logit	(15) Logit	(16) Logit
DOMCRED	0.002*** (5.381)	0.002*** (6.435)	0.003*** (8.666)	0.007*** (4.960)	0.004*** (4.167)	0.004*** (3.915)	0.007*** (5.509)	0.003*** (4.307)
BANKDEP	0.001*** (3.647)	0.001*** (3.594)	-0.000 (-0.819)	0.002 (1.033)		0.001 (0.767)	0.005** (2.260)	
M2MULT	-0.001*** (-4.558)	-0.001*** (-5.580)	-0.001*** (-2.697)	-0.004*** (-2.852)		-0.003*** (-3.685)	-0.003** (-2.326)	
M2RES	0.001* (1.742)	0.001** (2.332)	0.002*** (5.408)	0.004*** (3.591)	0.003*** (2.716)	0.003*** (3.322)	0.002*** (3.000)	0.001*** (2.916)
EXM1B	0.000 (0.473)	0.000* (1.918)	0.000 (1.220)	0.002*** (2.724)		0.002*** (3.219)	0.002*** (2.928)	
LENDEP	-0.001*** (-9.194)	-0.001*** (-9.177)	-0.000*** (-2.664)	-0.004*** (-7.232)	-0.004*** (-11.520)	-0.005*** (-22.175)	-0.004*** (-7.235)	-0.005*** (-26.383)
RINTR	-0.000 (-0.137)	0.000 (0.010)	0.001 (1.022)	0.004 (0.899)		0.006** (2.109)	0.000 (0.067)	
REER	-0.000 (-0.373)	-0.000 (-0.616)	-0.001*** (-2.999)	-0.003** (-1.988)	-0.001 (-0.578)	-0.002* (-1.694)		
RES	0.000 (1.026)	0.000 (1.164)	0.002*** (4.544)	0.003*** (2.771)	0.002** (1.971)	0.002** (2.018)		
EXPORT	-0.000 (-0.180)	-0.000 (-0.126)	0.000 (0.481)	-0.000 (-0.146)	-0.001 (-1.075)		-0.000 (-0.596)	
IMPORT	-0.000 (-1.568)	-0.000 (-1.428)	-0.001*** (-3.256)	-0.001* (-1.716)	-0.001* (-1.706)		-0.001* (-1.672)	
TOTRADE	0.000 (0.543)	0.000 (0.796)	-0.000 (-0.164)	0.001 (0.667)	0.003** (2.058)		0.001 (0.380)	
RINTDIF	-0.001 (-0.995)	-0.001 (-1.514)	-0.000 (-0.357)	-0.002 (-0.788)		-0.004** (-2.310)	0.000 (0.186)	
PROD	-0.001* (-1.649)	-0.001** (-2.527)	-0.002*** (-3.641)	-0.010*** (-4.546)	-0.008*** (-4.170)	-0.008*** (-5.327)	-0.009*** (-4.017)	-0.006*** (-5.196)
SPUSD	-0.000 (-1.407)	-0.000 (-1.212)	-0.000** (-2.195)	-0.000* (-1.683)	-0.000* (-1.672)	-0.000** (-2.266)	-0.000 (-1.285)	-0.000* (-1.851)
GOVDEF	0.002*** (4.346)	0.002*** (4.890)	0.002*** (3.929)	0.005*** (3.133)	0.007*** (5.166)	0.004*** (3.827)	0.004** (2.282)	0.005*** (5.082)
BANKCR	0.080*** (4.297)	0.054*** (4.996)	0.062*** (4.069)	0.139*** (2.605)	0.161*** (3.895)	0.059 (1.556)	0.136*** (2.664)	0.091*** (2.852)
Country FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	4,579	4,579	4,579	2,192	2,805	2,710	2,232	3,364
Number of countries	38	38	38	16	18	19	16	21
(Pseudo-)R-Squared	0.042	0.133	0.037	0.137	0.114	0.163	0.132	0.128
Log-Likelihood	556.039	-796.102	796.682	-575.090	-755.550	-667.803	-597.886	-879.069

\*\*\* Significant at 1 percent level. \*\* Significant at 5 percent level. \* Significant at 10 percent level.

Table 4: Regression of early warning indicators for currency crises including banking crisis dummy and balance-of-payments items, dependent variable: pre-currency-crisis period

Unbalanced panel. The table presents the average marginal effect; for OLS t-statistic and for logit z-statistics in parentheses (robust standard errors). An intercept term is included in each regression but not reported to save space.

	(17) Logit	(18) Logit	(19) Logit	(20) Logit	(21) Logit	(22) Logit	(23) Logit	(24) Logit
DOMCRED	0.001*** (3.708)	0.001*** (4.103)	0.003*** (3.846)	0.002* (1.889)	0.003*** (3.842)	0.003*** (3.571)	0.003*** (4.512)	0.002*** (3.463)
M2RES	0.000*** (3.285)	0.000*** (3.107)	0.001*** (2.722)	0.001*** (3.585)	0.001*** (2.953)	0.001*** (3.425)	0.001** (2.336)	0.001*** (3.039)
LENDEP	-0.002*** (-6.985)	-0.002*** (-6.383)	-0.004*** (-21.804)	-0.004*** (-19.981)	-0.005*** (-21.562)	-0.005*** (-21.392)	-0.005*** (-24.752)	-0.002*** (-7.026)
PROD	-0.003*** (-4.223)	-0.002*** (-3.900)	-0.008*** (-5.576)	-0.008*** (-5.911)	-0.008*** (-5.729)	-0.008*** (-5.511)	-0.006*** (-4.694)	-0.004*** (-4.079)
SPUSD	-0.000 (-1.475)	-0.000* (-1.729)	-0.000 (-1.636)	-0.001*** (-3.844)	-0.000 (-1.633)	-0.000* (-1.767)	-0.000 (-1.423)	-0.000 (-1.053)
GOVDEF	0.002*** (3.677)	0.001*** (3.006)	0.006*** (5.477)	0.005*** (4.982)	0.007*** (5.782)	0.006*** (5.512)	0.004*** (4.017)	0.002*** (3.124)
BANKCR	0.050*** (3.303)	0.029** (2.420)	0.117*** (3.427)	0.133*** (3.993)	0.151*** (4.123)	0.119*** (3.445)	0.070** (2.211)	0.071*** (3.220)
EXPGDP	-0.004*** (-11.114)							-0.004*** (-9.737)
IMPGDP		0.004*** (12.120)						
CURAC			-0.006** (-2.058)					
BASGDP				0.003 (0.668)				
BLIGDP					0.014*** (3.228)			0.008*** (2.914)
FINACCT						0.007*** (2.635)		
APEGREG							0.233*** (7.021)	0.117*** (4.544)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	3,276	3,276	3,276	3,022	3,181	3,276	3,364	3,181
Number of countries	21	21	21	20	21	21	21	21
Pseudo-R-Squared	0.164	0.166	0.138	0.150	0.141	0.140	0.155	0.185
Log-Likelihood	-836.802	-834.394	-862.033	-779.508	-849.322	-860.401	-851.296	-806.022

\*\*\* Significant at 1 percent level. \*\* Significant at 5 percent level. \* Significant at 10 percent level.

### **4.3. Sala-I-Martin robustness analysis**

Kaminsky and Reinhart (1999) use 16 different indicators. Tables 2-4 summarize theoretically justified and significant indicators of currency crises. They show that banking sector distress and balance-of-payments items can significantly improve the quality of a model, all other indicators remaining significant.

A number of additional theoretically and empirically justified potential control variables have been introduced in section 3.2. Given their large number and especially the variety of balance-of-payments items, there are a high number of potential combinations. Not all of them are reported here. To control for the robustness of results, the robustness check proposed by Sala-I-Martin (1997) is applied. The basic idea of this method is to use many possible combinations of explanatory variables. For each variable, the log-likelihood weighted coefficient and standard error are calculated. Finally, assuming that coefficients are normally distributed, the cumulative distribution function (CDF) is calculated for each variable. The higher the weighted CDF, the more significant the indicators. In addition, the weighted average marginal effect as well as the share of significant regressions at the 1, 5 and 10 percent level are reported for each variable. The share of significant models is only reported as a secondary quality measure for the sake of completeness. In contrast to CDF which is based on weighted coefficients and accounts for the quality of different regressions, the share of significant variables provides the arithmetic share and does not account for the quality of the overall model. Therefore, the CDF is a superior quality measure.

The baseline model contains four variables which have been found highly significant and robust earlier: *domestic credit / GDP*, *lending-deposit rate ratio* and a *banking crisis* dummy variable. These variables are also well explained by the theoretical framework. The baseline model is included into each regression. For other indicators, 14,089 different combinations of up to six variables are used.

Although *production* has been found significant in the analysis, it is not included into the baseline model. In countries which are highly dependent upon commodity production, production growth rates are better measures for output growth than *GDP volume* which depends upon the market prices for commodities. Unfortunately, production indices are not available for some economies. Production is potentially correlated with GDP volume and the *unem-*

*ployment rate*. To control for the robustness of all three variables, they are all used in the extended model but their combinations are not allowed. Based upon these considerations, the *government expenditures-revenues ratio* has also not been included into the baseline model but has been considered in the extended model alongside with *real government expenditures* and *real government revenues*. Any combination of *government expenditures-revenues ratio* with *real government expenditures* or *real government revenues* is not allowed.

*Stock price* returns and *stock price volatility* in U.S. Dollars have been found better indicators than those in local currency units. Obviously, the foreign investors' perspective is more important than local stockholders' view in the run-up to currency crises. Therefore, the latter have not been used for the Sala-I-Martin robustness analysis. Real stock prices have not been considered either because they only provide limited additional information and are potentially correlated with nominal stock prices.

The results are summarized in Table 5. Except for *domestic credit / GDP*, the baseline model is highly significant. *Domestic credit / GDP* is highly significant throughout all regressions in Tables 2-4 but its CDF only equals 71.7 percent. *Imports / GDP* and *balance of trade / GDP* do not have the expected coefficients and have both low CDF values and share of significant regressions. The *bank investment assets / GDP* ratio also does not have the expected coefficient. *Exports / GDP* and *government expenditures* also have low CDF values but the signs are expected. All other variables have the signs consistent with theoretical considerations and empirical evidence presented in earlier sections. Except for the *financial account / GDP*, they are highly significant at the 1 percent level.

The robustness analysis confirms that the main results which are reported in Tables 2-4 remain robust when additional or alternative variables are introduced to the model. The *systemic banking crises* and the *abandonment of a pegged exchange rate regime* result in significantly higher likelihood of balance-of-payments problems (average partial effects on average equals 9.6 percent for banking crises and 16.1 percent for the abandonment of a pegged exchange rate regime). The results remain robust if production and government expenditures-revenues ratios are included into the baseline model and GDP volume, unemployment rate, real government expenditures and real government revenues are not considered.

Table 5: Sala-I-Martin robustness analysis, dependent variable: pre-currency-crisis period

The results are derived from 14,089 logistic regressions (country FE, unbalanced panel) conditional on the currency crisis dummy variable. Each regression includes the baseline model variables and different extended models that contain the combinations of up to six further variables. To avoid potential multicollinearity problems, combinations of potentially correlated variables were not included into the extended models. In particular, combinations of related balance-of-payments items have been excluded (e.g. exports / GDP and trade balance / GDP not included into the same model).

The share of significant models summarizes the percentage of regressions in which the respective coefficient is statistically significant at the 1 percent, 5 percent and 10 percent level.

	Average APE	Average $\beta$	Average standard error	CDF(0)	Share significant (%)		
					1% level	5% level	10% level
<i>Baseline model</i>							
DOMCRED	0.000	0.003	0.006	71.7%	69.6%	64.4%	56.8%
M2RES	0.001	0.008	0.002	100.0%	77.4%	73.4%	65.7%
LENDEP	-0.003	-0.029	0.003	100.0%	97.8%	97.3%	94.6%
BANKCR	0.096	0.961	0.270	100.0%	75.2%	68.0%	55.2%
<i>Extended model</i>							
APEGREG	0.161	1.539	0.209	100.0%	97.5%	97.1%	96.2%
EXPGDP	-0.031	-0.575	1.940	61.7%	83.6%	81.7%	78.0%
IMPGDP	-0.025	-0.450	1.937	59.2%	76.5%	73.1%	67.4%
TRGDP	0.016	0.343	1.555	58.7%	63.8%	59.1%	50.8%
CACGDP	-0.017	-0.132	0.030	100.0%	87.9%	84.9%	77.1%
BASGDP	0.004	0.043	0.032	91.2%	65.1%	54.2%	36.3%
BLIGDP	0.013	0.133	0.027	100.0%	86.5%	84.7%	80.8%
BASLIGDP	0.016	0.177	0.032	100.0%	94.0%	92.6%	89.0%
FACGDP	0.003	0.026	0.021	89.5%	61.5%	54.8%	44.4%
OABGDP	-0.007	-0.084	0.026	99.9%	74.2%	70.3%	60.8%
PROD	-0.004	-0.036	0.008	100.0%	98.4%	97.3%	92.3%
GDPVOL	-0.008	-0.092	0.017	100.0%	98.4%	96.9%	92.8%
UNEMPL	0.006	0.054	0.008	100.0%	100.0%	100.0%	100.0%
SPUSD	-0.001	-0.008	0.002	100.0%	85.5%	79.2%	67.6%
SPVUSD	0.004	0.046	0.011	100.0%	99.4%	97.1%	89.1%
GOVDEF	0.003	0.026	0.007	100.0%	80.9%	72.1%	59.7%
GOVEXP	0.000	0.002	0.007	60.1%	37.8%	30.1%	18.9%
GOVREV	-0.003	-0.031	0.007	100.0%	84.2%	76.0%	65.7%



#### **4.4. Forecasting and out-of-sample prediction of currency crises**

The author performs out-of-sample testing to evaluate the predictive power of the model studied in this paper. To test the performance of the model, the author uses a receiver operating characteristic (ROC) statistic, a technique which is often used for validating the discriminatory power of rating systems.

The models' predicted pre-crisis period probabilities are sorted from highest to lowest. The cumulative fraction of all proportion and the cumulative proportion of pre-crisis observations within the predictions are calculated. The ROC curve plots the cumulative proportion of pre-crisis observations (true positive rate) against the cumulative proportion of all observations (false positive rate). In a random model all observations have the same probability of being in the pre-crisis period, and the curve is strictly monotonically increasing proportionally to the cumulative observations. In other words, in a random model the 10 percent of all observations with the highest probability will include 10 percent of all pre-crisis observations. In a perfect model all pre-crisis observations have higher probabilities than tranquil observations, and the curve is strictly monotonically increasing until reaching 100 percent. In other words, in a sample including 10 percent pre-crisis period observations, the curve will linearly increase between 0 and 10 percent of the cumulative fraction of all predictions and remain at 100 percent afterwards. Usually, the ROC curve is somewhere between the perfect model and random model curve. The closer it is to the random model, the worse it is. The area below the curve can lie in a range between 0 and 100 percent and is called the ROC statistic.

The in-sample predictions of column (24) yield a ROC equal to 0.762. Usually, the out-of-sample predictions are worse and yield a lower ROC than in-sample data which is used for the model estimation. Therefore, an out-of-sample analysis of forecast results is necessary to evaluate the model's predictive power and robustness. In contrast to earlier studies this paper examines a large number of countries that are not limited to a specific geographic region or level of development. However, some fundamentals are not available for all countries. Moreover country-fixed logit design requires a dependent variable which takes on both true and false values. The economies, that have not experienced a currency crisis, are not included in the model. Overall, the model in column (24) is based on 3,181 observations from 21 different economies.

Often, earlier observations are used as in-sample data for estimating the parameters and most recent data for out-of-sample predictions. Most countries have only experienced one currency crises and the country fixed effects model would omit all countries which had not experienced a currency crisis during the in-sample period. This approach would substantially reduce the sample resulting in significant loss of information. Therefore, this paper provides an alternative approach. To evaluate the predictive power of the model, the sample of column (24) has been randomly divided into two parts using a univariate distribution with each observation having an equal chance of being drawn (draw without replacement). One part has been used to re-estimate column (24). The estimated model has been used to make predictions for the remaining out-of-sample observations. To control for the robustness of the predictive power, the model has been estimated and applied to 1,000 different randomly divided samples. The analysis applies different out-of-sample proportions: it begins with 90 percent in-sample and 10 percent out-of-sample observations and increases the ratio of out-of-sample observations to 90 percent in 10 percent increments.

Figure 2 illustrates the ROC curves. The red curve represents the in-sample ROC. The dark blue line illustrates the out-of-sample median ROC curves. The blue area illustrates the 90 percent confidence band of all out-of-sample ROC curves. The author utilises the fan chart technique and applies it in a field where, to author's knowledge, it has not been used before. The diagonal line represents a random prediction model.

The out-of-sample ROC remains close to the in-sample ROC. Moreover, the 90 percent confidence band is relatively narrow. It becomes wider for both very small and very high out-of-sample ratios. For the 10 percent out-of-sample ratio, the confidence band is relatively wide reflecting the high marginal partial effect of each hit rate (note: there are only a few out-of-sample pre-crisis observations). The results are similar in the range between 20 and 80 percent out-of-sample ratio. For 90 percent out-of-sample data, the out-of-sample results underperform the in-sample benchmark but significantly outperform random forecast. Overall, the results reflect the strong predictive power and robustness of the model. Its predictive power is similar for both in-sample and out-of-sample observations. Even relatively small sets of in-sample observations allow for estimating a model which can predict potential balance-of-payments problems and provides significantly better results than a random prediction model.

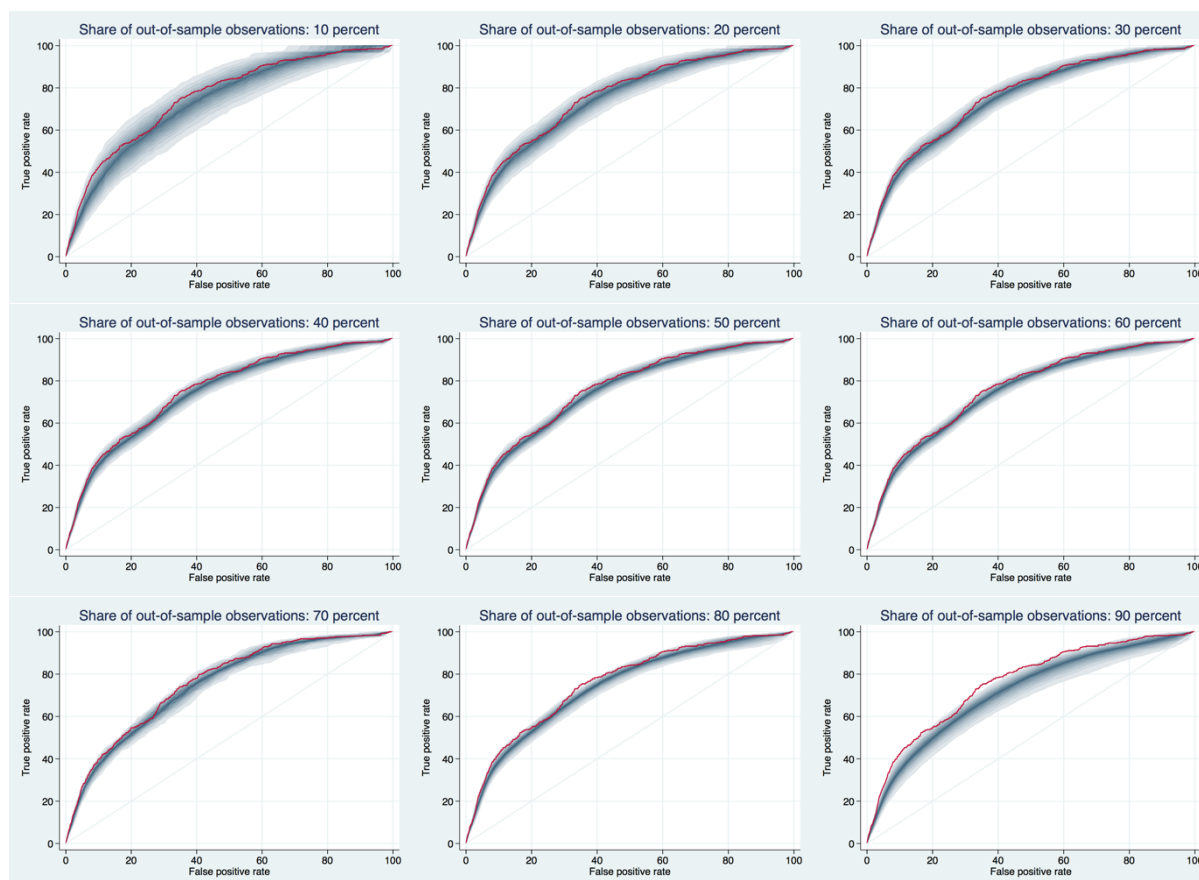
However, the future forecast results should be treated with caution. As soon as an early warning system becomes public, it is available to both policy makers and the private sector. If the model provides an early warning signal, policy makers adopt preventive measures and thereby possibly prevent a potential currency crisis. Although the model would provide a correct signal, the prediction would be wrong because the crisis has been prevented.

The following section summarizes the main results, comments on possible limitations and discusses potential further research building upon these results.

*Figure 2: Receiver operating characteristic*

Each panel shows the out-of-sample receiver operating characteristic (ROC) curve for column (24). The analysis applies different out-of-sample proportions: it begins with 90 percent in-sample and 10 percent out-of-sample observations and increases the ratio of out-of-sample observations to 90 percent in 10 percent increments. For each of them, the sample has been randomly divided 1,000 times to in-sample and out-of-sample observations.

The red curve represents the in-sample ROC from column (24). The dark blue line illustrates the out-of-sample median ROC. The blue area illustrates the 90 percent confidence band of all out-of-sample results. The chart shows the out-of-sample ROC distribution. The central band, coloured deep blue, represents 10 percent of observations (5 percent to either side of the median). The next deepest shade, on both sides of the central band, takes the distribution out to 10 percent; and so on, in steps of 10 percentage points. The diagonal curve represents a random prediction model.



## **5. Summary and concluding remarks**

The paper examines the evolution of fundamentals in the run-up to typical balance-of-payments crises and identifies additional leading indicators of balance-of-payments problems. A new visualising tool which combines the advantages of an event study analysis and a fan chart technique illustrates the macroeconomic imbalances around the prototype currency crisis. The average partial effect analysis quantifies the adverse effect of individual indicators on currency turmoil likelihood. The results are used to build a new early warning system for currency crises.

The analysis builds upon the seminal paper of Kaminsky and Reinhart (1999) and extends their work to triple-crises. It accounts for both banking and private capital flows which were not considered by Kaminsky and Reinhart (1999). Increasing financial sector vulnerability, recessionary effects and deteriorating government finances characterize the pre-crisis period. Foreign bank credit inflow is extraordinary high before the crisis. The increasing domestic leverage particularly highlights the rising risk exposure of the financial sector. Almost every third currency crisis follows a systemic banking crisis. A banking crisis increases the likelihood of a currency crisis by ca. 9.6 percent on average. The underperforming output and an increasing unemployment continuously deteriorate further. Stock markets reflect the slowdown in economic activity and underperform considerably. Their historical volatility significantly increases and mirrors the growing uncertainty and nervousness of investors. The increasing fiscal deficit reflects the widening gap between rising government expenditures and slightly underperforming revenues, both indicating deterioration of government finances. Shortly before the crisis, the economy experiences a sudden slowdown or even a reversal in foreign capital inflow. The overall balance of payments deteriorates in the run-up to currency crises. First, the outperforming financial account compensates the underperforming current account. But starting eighteen months before the currency crisis, the overall balance significantly underperforms its tranquil norm and only recovers almost one year after the currency turmoil. The results suggest that foreign investors withdraw their capital shortly before the currency crisis occurs and highlight the vulnerability of foreign capital funding.

First tendencies towards devaluation of the domestic currency become particularly apparent long before the currency turmoil. Policy makers adopt preventive measures and try to defend the exchange rate. The steady increasing money market rate and a gradual loss of foreign re-

serves beginning one year before the onset of balance-of-payments problems reflect their intervention. Their attempts are not successful. The intensified pressure on the exchange market forces those policy makers who maintain a pegged exchange rate regime to float the currency. On average, the likelihood of balance-of-payments problems increases by ca. 16.1 percent following the abandonment of a pegged exchange rate system.

The results are similar to those of Kaminsky and Reinhart (1999) but there are important differences. In this setup bank deposits, money multiplier, excess supply of real M1 balances, real interest rate differential and terms of trade remain close to normal levels in the run-up to currency crises. The underperformance of exports and imports is less dramatic as illustrated by Kaminsky and Reinhart (1999). The real effective exchange rate does not indicate an overvaluation. Moreover, the lending-deposit rate ratio declines below the normal level five years before the crisis. It indicates the increasing interest rate level rather than the deterioration in credit risk.

The overall results reflect elements of all three generations of currency crisis theories. The robustness check proposed by Sala-I-Martin (1997) suggests that the main results are robust and highly significant. Taking these factors and particularly private capital flows and the occurrence of banking crises into account can improve the predictive power of existing early warning systems and allow policy makers to adopt timely preventive measures in the run-up to potential currency crises. These factors have been used to build a new early warning system. Its forecast results are very promising and are significant both for in-sample and out-of-sample predictions.

Crisis and post-crisis observations have been excluded. As the currency crisis events do not affect the control variables in the setup, there is no reverse causality between dependent and independent variables in our model. However, reverse causality cannot be fully eliminated for stock prices and stock price volatility which reflect the market's expectations and anticipate the future development. Therefore, potential limitations of main results in prediction of balance-of-payments problems cannot be fully excluded.

The scope of this paper includes domestic fundamentals but not contagion effects. Further research projects may introduce contagion, validate the model's forecast outcomes and compare

them to the predictions of the early warning system presented here. Notably, most fundamentals deteriorate long before the onset of currency crises. Banking crises, in contrast, are near term leading indicators. Currency crises follow shortly after banking crises. In case of a banking crisis, quick and resolute interventions are necessary to prevent a currency crisis. These results suggest that a combination of both long-term and short-term indicators might be effective. It might also be worthwhile to consider their timing rationale. Further research projects could also build upon the methodology and data provided here and replicate the model for banking crises proposed by Kaminsky and Reinhart (1999). Using data for the latest systemic banking crises and including both mature and emerging markets could provide new insight and empirical evidence for banking crisis research and validate existing banking crisis theories.

The new visualisation approach that combines elements of an event study analysis and a fan chart technique for illustrating the deviation of fundamentals in the run-up to balance-of-payments problems has provided helpful information and could be a helpful addition to future research projects, including but not limited to early warning system literature.

## Appendix

### The indicators

*Sources:* Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER), International Monetary Fund (IMF); Bank for International Settlements (BIS); International Financial Statistics (IFS), International Monetary Fund (IMF); JP Morgan; Organisation for Economic Co-operation and Development (OECD); World Development Indicators (WBI), World Bank (WB). When data was missing from these sources, national sources and other country-specific sources were used as supplements. Unless otherwise noted, 12-month percent changes (interest rates in levels) are used. The continuous variables have been sourced from Bloomberg and used on monthly basis. Where no frequent observations were available, monthly data has been interpolated from quarterly and/or annual data.

*APEGREG Abandonment of a pegged exchange rate regime (dummy):* Change from a pegged to more flexible exchange rate regimes (AREAER, note: definitions of the report have been revised several times).

*BANKCR Banking crisis (dummy):* Laeven and Valencia (2008; 2010; 2012).

*BANKDEP Bank deposits:* IFS line 24 plus 25 deflated by consumer prices (IFS line 64).

*BASGDP Bank investment assets / GDP:* IFS line 78bqd divided by IFS line 99b (interpolated). If monthly GDP was not available, it was interpolated from quarterly and annual data.

*BASLIGDP Bank investment assets and liabilities / GDP:* IFS lines 78bqd and 78bud divided by IFS line 99b (interpolated). If monthly GDP was not available, it was interpolated from quarterly and annual data.

*BLIGDP Bank investment liabilities / GDP:* IFS line 78bud divided by IFS line 99b (interpolated). If monthly GDP was not available, it was interpolated from quarterly and annual data.

*CACGDP Current account / GDP:* IFS line 78ald divided by IFS line 99b (interpolated). If monthly GDP was not available, it was interpolated from quarterly and annual data.

*DOMCREDD* Domestic credit / GDP: IFS line 32 divided by IFS line 99b (interpolated) to obtain the domestic credit/GDP ratio. If monthly GDP was not available, it was interpolated from quarterly and annual data.

*EXMIB* Excess M1 balances: M1 (IFS line 34) deflated by consumer prices (IFS lines 64) less an estimated demand for money. The demand for real balances is determined by real GDP (interpolated IFS line 99b.p), domestic consumer price inflation, and a time trend. Domestic inflation was used in lieu of nominal interest rates, as market-determined interest rates were not available during the entire sample for a number of countries; the seasonally adjusted exponential time trend is motivated by its role as a proxy for financial innovation and/or currency substitution. In levels.

*EMP* Exchange market pressure index: Function of real effective exchange rate (BIS, JP Morgan, IFS line rec) and total reserves (IFS line IFS line 11.s). If IFS line 11.s was not available, IFS line 11.d (total reserves minus gold measured in U.S. dollars) was converted into SDR (using IFS lines AE and AA or AF and RB). For details see p. (2009).

*FACGDP* Financial account / GDP: IFS line 78bjd divided by IFS line 99b (interpolated). If monthly GDP was not available, it was interpolated from quarterly and annual data.

*FREEREG* Free floating exchange rate regime (dummy): Exchange rates not maintained within relatively narrow margins, independently floating, free float (AREAER, note: definitions in the report have been revised several times).

*EXPORT* Exports: IFS line 70.

*EXPGDP* Goods exports / GDP: IFS line 78aad divided by IFS line 99b (interpolated). If monthly GDP was not available, it was interpolated from quarterly and annual data.

*GDPVOL* GDP volume: IFS line 99bvp and 99bvr. For some countries IFS line 99b.p and 99b.r was used if IFS line 99bvp and 99bvr were not available.

*GOVDEF* Government expenditures-revenues ratio: Consolidated public-sector expenditures (IFS line 82) divided by consolidated public-sector revenues (IFS lines 81). IFS line 81y was used if IFS line 81 was not available. The ratio can take only positive



values and was used in lieu of the consolidated government deficit which oscillates around the zero point.

*GOVEXP* *Government expenditures*: Consolidated public-sector expenditures (IFS line 82) deflated by consumer prices (IFS line 64).

*GOVREV* *Government revenues*: Consolidated public-sector revenues (IFS lines 81) deflated by consumer prices (IFS line 64). IFS line 81y was used if IFS line 81 was not available.

*IMPORT* *Imports*: IFS line 71.

*IMPGDP* *Goods imports / GDP*: IFS line 78abd divided by IFS line 99b (interpolated). If monthly GDP was not available, it was interpolated from quarterly and annual data.

*LENDDEP* *Lending-deposit rate ratio*: IFS line 60p divided by IFS line 60l was used in lieu of differential to ameliorate the distortions caused by the large percentage point spreads observed in high inflation. In levels.

*M2MULT* *M2 multiplier*: The ratio of M2 (IFS lines 34 plus 35) to base money (IFS line 14).

*M2RES* *M2/Reserves*: IFS lines 34 plus 35 converted into U.S. dollars (using IFS line ae) divided by IFS line 11.d.

*MMKTR* *Money market rate*: IFS line 60b.

*OABGDP* *Overall balance / GDP*: IFS line 78cbd divided by IFS line 99b (interpolated). If monthly GDP was not available, it was interpolated from quarterly and annual data.

*PEGREG* *Pegged exchange rate regime (dummy)*: Conventional peg to a single currency or a composite of currencies, pegged exchange rate within horizontal bands, currency board arrangements, crawling peg, crawling band, regimes with limited flexibility with respect to cooperative arrangements or with no separate legal tender (AREAER, note: definitions of the report have been revised several times).

*PROD* *Production*: For most countries, the measure of output used is industrial production (IFS line 66) or manufacturing production (IFS line 6ey). However, for some countries, (the commodity exporters) an index of output of primary commodities is used (IFS lines 66aa) if neither national production nor manufacturing production is available.

- REER* *Real effective exchange rate*: For most countries BIS narrow indices (data available from 1964) and BIS broad indices (data available from 1994). However, for some countries, the indices from JP Morgan and IFS line rec are used if BIS indices were not available or only existing for significantly shorter periods than the alternative indices.
- RINTR* *Real interest rate*: Deposit rate (IFS line 60) deflated using consumer prices (IFS line 64). Monthly rates expressed in percentage points. In levels.
- RINTRDIF* *Real interest rate differential*: Interest rate in the domestic economy are compared with interest rates in the G20 economies. The interest rate differential is constructed as the difference between real rates for the domestic and foreign currencies. Real rates are deposit rate (IFS line 60) deflated using consumer prices (IFS line 64).
- RES* *Reserves*: IFS line 11.s (total reserves minus gold measured in SDR). If IFS line 11.s was not available, IFS line 11.d (total reserves minus gold measured in U.S. dollars) was converted into SDR (using IFS lines AE and AA or AF and RB).
- RSPLCU* *Real stock prices in LCU*: MSCI, STOXX and Standard & Poor's global equity indices measured in local currency units and deflated using consumer prices (IFS line 64) are used; where no indices were available, the quotes from the main boards are used.
- RSPUSD* *Real stock prices in USD*: MSCI, STOXX and Standard & Poor's global equity indices measured in U.S. dollars and deflated using U.S. consumer prices (IFS line 64) are used; where no indices were available, the quotes from the main boards are used.
- SPLCU* *Stock prices in LCU*: MSCI, STOXX and Standard & Poor's global equity indices measured in U.S. dollars are used; where no indices were available, the quotes from the main boards are used.
- SPVLCU* *Stock price volatility in LCU*: 260-day price volatility of MSCI, STOXX and Standard & Poor's global equity indices measured in U.S. dollars is used; where no indices were available, the quotes from the main boards are used.

*SPUSD* *Stock prices in USD*: MSCI, STOXX and Standard & Poor's global equity indices measured in local currency units are used; where no indices were available, the quotes from the main boards are used.

*SPVUSD* *Stock price volatility in USD*: 260-day price volatility of MSCI, STOXX and Standard & Poor's global equity indices measured in local currency units is used; where no indices were available, the quotes from the main boards are used.

*TRGDP* *Balance of trade / GDP*: IFS line 78acd divided by IFS line 99b (interpolated). If monthly GDP was not available, it was interpolated from quarterly and annual data.

*TOTRADE* *Terms of trade*: The unit value of exports (IFS line 74, national sources) over the unit value of imports (IFS line 75, national sources). For those countries or episodes where unit value indices were not available, WDI data was used.

*UNEMPL* *Unemployment rate*: IFS line 67r and OECD.

Table 6: Country list and episodes of currency crises (1975-2010)

The table provides the country list and summarizes the episodes of currency crises between 1975 and 2010 on monthly basis.

Algeria	2008:12-2008:12		1985:10-1985:11	Portugal <sup>(2)</sup>	1976:05-1976:05 1983:06-1983:06
Argentina <sup>(1)</sup>	1975:04-1975:09 1989:03-1989:05 2002:01-2002:02	Hong Kong	1998:09-1998:10	Romania	1997:01-1997:01
Australia <sup>(1)</sup>	1985:03-1985:03 1986:06-1986:07 2008:09-2008:10	Hungary <sup>(1)</sup>	2008:09-2009:02	Russian Federation	1998:08-1998:09
Austria	1979:04-1979:04	Iceland	2006:03-2006:04 2008:10-2008:10	Saudi Arabia	---
Belgium	1982:02-1982:04	India	1990:09-1991:07	Singapore <sup>(1)</sup>	1986:01-1986:04 1997:09-1998:06
Bolivia	1982:11-1982:11 1985:09-1982:10	Indonesia <sup>(1)</sup>	1997:11-1998:01	Slovak Republic <sup>(1)</sup>	1998:09-1998:10
Brazil	1979:12-1979:12 1983:02-1983:02 1990:10-1990:11 1998:09-1999:02	Ireland <sup>(4)</sup>	---	Slovenia <sup>(4)</sup>	---
Bulgaria	1996:04-1996:12	Israel <sup>(2)</sup>	1977:11-1977:11	South Africa <sup>(1)</sup>	1985:08-1985:08 1996:04-1996:04
Cameroon	1993:12-1994:02	Italy <sup>(1)</sup>	1975:12-1976:02 1995:03-1995:03	Spain <sup>(1)</sup>	1977:06-1977:06 1982:11-1982:12 1992:09-1992:10
Canada <sup>(4)</sup>	---	Japan <sup>(1)</sup>	1979:03-1979:11	Sweden <sup>(3)</sup>	1981:10-1982:11 1992:11-1993:01 2008:11-2008:11
Chile	1975:03-1975:03 1982:08-1982:09	Korea <sup>(1)</sup>	1997:11-1998:01 2008:09-2008:10	Switzerland <sup>(4)</sup>	---
China	1992:06-1992:08 1993:12-1994:02	Kuwait <sup>(2)</sup>	1990:08-1990:10	Taiwan	1975:03-1975:04 1977:03-1977:03 1997:10-1997:10
Colombia <sup>(1)</sup>	1985:04-1985:04 1998:09-1998:09	Latvia	2009:04-2009:04	Thailand	1997:06-1997:12
Cote D'Ivoire	1993:12-1994:02	Lithuania <sup>(4)</sup>	---	Tunisia	1986:03-1987:02
Croatia	---	Luxembourg	---	Turkey	1994:03-1994:04 2001:02-2001:03
Czech Republic <sup>(1)</sup>	1997:04-1997:05 1999:02-1999:02	Malaysia <sup>(1)</sup>	1997:07-1997:12	Ukraine	1993:03-1994:04
Denmark <sup>(2)</sup>	1979:12-1980:02	Mexico <sup>(1)</sup>	1976:08-1976:10 1982:02-1982:08 1994:11-1995:01	United Kingdom <sup>(3)</sup>	1976:04-1976:04 1982:12-1982:12 1992:10-1992:10 2008:12-2008:12
Ecuador <sup>(2)</sup>	1984:09-1984:09 1986:07-1986:08 2008:11-2008:12	Morocco <sup>(2)</sup>	1982:02-1983:01	United States <sup>(4)</sup>	---
Egypt	2001:08-2001:08 2003:01-2003:03	Netherlands <sup>(4)</sup>	---	Uruguay	1982:11-1983:01 2002:06-2002:08
Estonia	---	New Zealand <sup>(2)</sup>	1975:08-1975:09 1984:08-1984:08	Venezuela	1984:03-1984:03 1986:11-1987:01 1989:03-1989:03 2010:01-2010:02
Euro area	---	Nigeria <sup>(1)</sup>	1986:09-1986:10 1992:12-1992:12 1994:08-1995:02 2001:09-2001:09		
Finland <sup>(1)</sup>	1992:08-1993:02	Norway <sup>(2)</sup>	1977:10-1977:10 2008:10-2008:10		
France <sup>(1)</sup>	1982:06-1982:07	Pakistan	1996:10-1996:10		
Germany <sup>(4)</sup>	---	Paraguay	1986:12-1987:01 1989:02-1989:02		
Greece <sup>(2)</sup>	1982:12-1983:01	Peru <sup>(2)</sup>	1987:10-1988:10		
		Philippines <sup>(1)</sup>	1995:03-1995:03 1997:08-1997:10		
		Poland <sup>(2)</sup>	2008:09-2009:01		

(1) used both in the cross-section and country-fixed setup

(2) balance-of-payments problems identified but not all fundamentals available for the pre-crisis period, and therefore used only in the cross-section setup

(3) balance-of-payments problems identified but not all fundamentals available for the pre-crisis period, and therefore used only in the country-fixed setup

(4) no balance-of-payments problems identified, and therefore used only in the cross-section setup

Figure 3: Smoothed exchange market pressure index

The figure summarizes the smoothed exchange market pressure indices (EMP) scaled in units of country specific EMP standard deviations less country specific EMP mean. The red line illustrates the critical threshold that equals 1.5 standard deviations of the EMP. The grey shaded area illustrates currency crisis episodes.



Figure 3: Smoothed exchange market pressure index (continued)

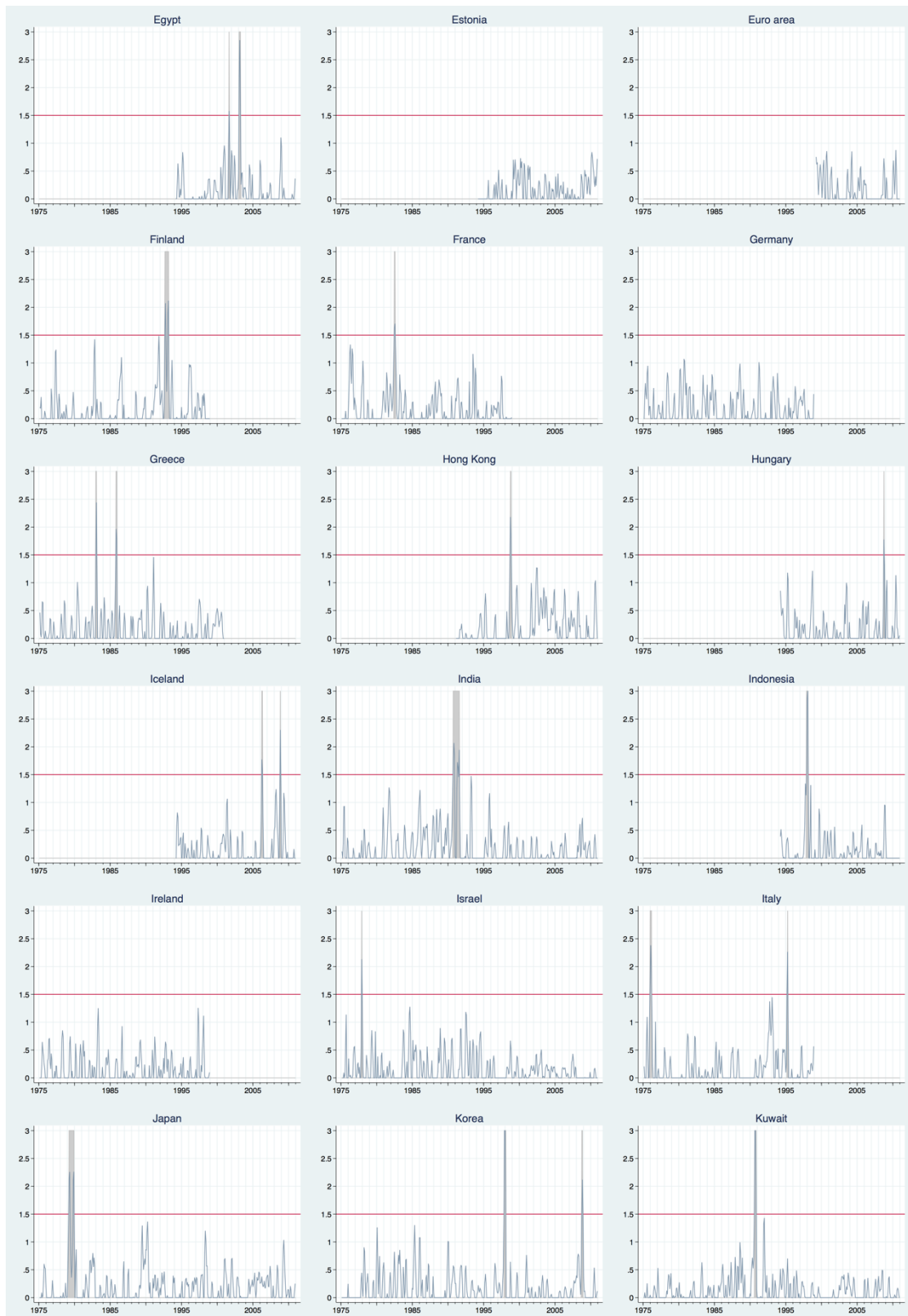


Figure 3: Smoothed exchange market pressure index (continued)



Figure 3: Smoothed exchange market pressure index (continued)





Table 7: Additional summary statistics by state of the economy

The table provides means (standard deviation in parenthesis) for fundamentals by the state of economy. The variables related to the balance of payments oscillate around the zero point. The relative growth rate is not an appropriate measure to determine the direction of change when these variables turn from positive to negative or vice versa. Therefore, the trailing 12-month magnitude of balance of payments accounts flows measured in percent of GDP is more appropriate. It measures the 12-month change of the international investment position.

	no crisis	pre crisis	crisis	post crisis	total
<i>Financial sector</i>					
Domestic credit / GDP: 12-month change	1.814 (19.597)	2.915 (23.403)	4.822 (21.338)	4.049 (25.227)	2.022 (20.154)
Bank deposits: 12-month change	6.820 (14.054)	2.243 (20.848)	-4.701 (31.862)	-2.569 (27.071)	5.961 (15.939)
Banking crisis (dummy)	0.063 (0.242)	0.157 (0.364)	0.308 (0.462)	0.306 (0.461)	0.084 (0.277)
M2 multiplier: 12-month change	2.114 (17.362)	1.026 (19.489)	-4.266 (28.153)	-2.021 (31.155)	1.763 (18.637)
M2/reserves: 12-month change	-2.115 (36.292)	8.871 (42.007)	19.004 (59.651)	-12.276 (65.888)	-1.838 (39.161)
Excess M1 balances	2.963 (30.394)	0.946 (17.729)	0.552 (10.094)	-0.082 (19.751)	2.683 (29.295)
Lending-deposit rate ratio	68.646 (64.031)	34.800 (30.680)	34.008 (27.677)	31.709 (30.805)	64.777 (62.243)
Real interest rate	0.094 (14.827)	-4.113 (53.729)	-17.846 (79.091)	-12.072 (50.197)	-0.990 (23.658)
<i>External sector</i>					
Real effective exchange rate: 12-month change	1.311 (8.603)	2.432 (16.171)	-17.975 (30.041)	-16.821 (28.747)	0.137 (12.477)
Reserves: 12-month change	13.390 (36.442)	-1.146 (39.307)	-37.098 (55.210)	-5.723 (59.925)	10.997 (39.238)
Abandonment of pegged exchange rate regime (dummy)	0.030 (0.170)	0.112 (0.315)	0.147 (0.355)	0.062 (0.241)	0.037 (0.189)
Real interest rate differential	-0.137 (15.494)	-5.090 (52.738)	-18.760 (78.973)	-12.478 (49.299)	-1.274 (23.847)
Exports: 12-month change	9.491 (21.298)	5.881 (23.126)	0.598 (27.943)	4.474 (34.443)	8.931 (22.442)
Imports: 12-month change	10.121 (20.801)	4.221 (28.978)	-1.831 (32.921)	-7.999 (38.703)	8.709 (23.171)
Terms of trade: 12-month change	0.347 (10.014)	-3.131 (15.641)	-5.018 (14.988)	-1.594 (15.922)	0.004 (10.866)
Goods exports / GDP	30.862 (38.923)	23.790 (22.947)	26.998 (31.451)	25.305 (22.847)	30.156 (37.533)
Goods imports / GDP	-29.895 (37.286)	-25.321 (23.024)	-28.030 (30.078)	-25.044 (21.749)	-29.380 (35.962)
Trade balance / GDP	0.966 (12.370)	-1.532 (7.661)	-1.032 (6.435)	0.261 (7.642)	0.775 (11.918)
Current account / GDP	-0.229 (10.940)	-2.611 (7.214)	-2.607 (6.620)	-2.587 (11.237)	-0.508 (10.778)
Bank investment assets / GDP	-1.382 (3.938)	-2.859 (11.081)	-1.523 (7.992)	-0.795 (8.558)	-1.427 (4.987)
Bank investment liabilities / GDP	1.680 (4.561)	3.615 (14.183)	1.445 (7.735)	-0.351 (8.649)	1.666 (5.830)
Bank investment assets and liabilities / GDP	0.338 (2.696)	0.819 (6.976)	-0.045 (3.749)	-1.161 (4.909)	0.277 (3.242)
Financial account / GDP	0.812 (25.695)	2.763 (8.625)	1.471 (7.355)	1.681 (17.577)	0.966 (24.572)
Overall balance / GDP	0.302 (21.921)	-0.427 (3.306)	-2.123 (3.819)	-2.223 (5.126)	0.097 (20.655)

Table 7: Additional summary statistics by state of the economy (continued)

	no crisis	pre crisis	crisis	post crisis	total
<i>Real sector</i>					
Production: 12-month change	3.036 (11.691)	2.076 (8.891)	-3.551 (28.751)	-4.240 (30.696)	2.530 (13.696)
GDP volume: 12-month change	3.589 (4.413)	2.573 (4.989)	0.968 (5.196)	-0.464 (6.044)	3.291 (4.653)
Unemployment rate: 12-month change	0.905 (18.440)	8.303 (27.015)	15.102 (25.471)	21.990 (27.933)	2.331 (20.049)
Stock prices in LCU: 12-month change	12.734 (61.192)	7.768 (64.709)	-6.649 (65.663)	6.866 (96.385)	12.023 (63.574)
Real stock prices in LCU: 12-month change	5.635 (59.280)	-9.089 (49.748)	-23.769 (48.688)	-15.650 (77.190)	3.654 (60.073)
Stock price volatility in LCU: 12-month change	-0.726 (11.651)	3.663 (8.300)	9.889 (9.708)	10.478 (23.226)	0.100 (12.631)
Stock prices in USD: 12-month change	10.720 (60.135)	-2.199 (51.003)	-34.724 (55.487)	-27.382 (80.460)	7.828 (61.590)
Real stock prices in USD: 12-month change	7.327 (60.133)	-6.233 (51.129)	-38.466 (54.568)	-30.157 (79.947)	4.434 (61.543)
Stock price volatility in USD: 12-month change	-1.528 (14.301)	4.796 (9.673)	15.314 (15.711)	17.325 (30.355)	-0.197 (15.943)
<i>Fiscal sector</i>					
Real government revenues: 12-month change	4.884 (18.237)	1.907 (25.100)	-0.862 (27.525)	-6.000 (46.095)	3.957 (21.753)
Real government expenditures: 12-month change	4.730 (17.273)	3.669 (24.784)	-1.046 (22.596)	-4.665 (38.906)	4.011 (19.960)
Gvt. expenditures-revenues ratio: 12-month change	-0.118 (10.956)	1.446 (10.389)	1.608 (12.993)	0.610 (19.062)	0.043 (11.623)
N	20,423	1,120	312	1,234	23,089

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