Macroeconomic determinants of currency turbulences in emerging markets

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Summary

In recent years, the currencies of some emerging markets came repeatedly under severe speculative pressure, rendering harsh currency crises. Since such attacks are generally not only associated with tremendous strain for the directly affected countries, but also with potential hazards for the international monetary system, the entailed risks call for a clarification of the responsibilities, particularly since in the affected countries, frequently, fickle speculators, who supposedly deal without referring to the fundamentals, are blamed for these disturbances. This study shows in a comprehensive empirical analysis, that occasionally such statements are risen quite hasty.

Following a short overview over the present theoretical literature on speculative attacks, currency turbulences are defined and empirically identified in sample which covers 26 emerging markets and a period of more than 25 years. Thereafter, the pattern of selected macroeconomic variables prior to currency distress compared to tranquil times is examined by applying univariate and multivariate methods. On the whole, this study underpins the hypothesis, that often distorted macroeconomic conditions loomed already prior to currency turbulences. Thus, in the past the distress in the foreign exchange markets in many emerging markets should be rather attributable to macroeconomic flaws than random products of unpredictable speculators.

TABLE OF CONTENTS

LIST OF TABLES AND CHARTS

Macroeconomic determinants of speculative attacks in emerging markets*

1. Introduction

Following the currency turbulences in the Exchange Rate Mechanism (ERM), in the last few years the currencies of some emerging markets have been at the centre of violent speculative attacks. Just a brief glance at their history points to consequences which regularly seem to follow turbulences in the foreign exchange markets. Experience has shown that the countries affected are denied access to international financial markets (at least temporarily), which is, however, of crucial importance in accelerating the process of economic development. Additionally, problems of the domestic banking system, which are often exacerbated by speculative attacks, hamper effective financial intermediation. Combined with the fall in the domestic currency's purchasing power and plunging securities prices, these factors are squeezing domestic demand. Moreover, the rising import prices and the loss of credibility suffered by economic policy frequently undermine the hard-won successes in fighting inflation. For instance, in the year after the "peso crisis", the Mexican economy shrank by more than 6%, and the rate of inflation went back up from single digits to some 35%. Even the Asian economies, so used to economic success, having had average growth rates of over 7 % over the nineties prior to the outbreak of the currency crises in 1997, are predicted to have at best a growth rate of zero for 1998, with inflation simultaneously on the rise (IMF 1998). Furthermore, turbulences have rarely been restricted to a single country but instead have spread to other countries with similar economic structures, and have at times dragged those countries' currencies into the downward spiral of devaluation. In worst-case scenarios, such contagion effects may even jeopardise the stability of the international monetary system.

* I received many valuable comments on my work in lively discussions held at workshops at the Deutsche Bundesbank and the Austrian National Bank, with the staff of the Council of Economic Experts (*Sachverständigenrat*), at the 73rd Annual Conference of the Western Economic Association in Lake Tahoe, Nevada, U.S. and at the "Summer School on International Macroeconomics" at the Centre for European Integration Research (*Zentrum für Europäische Integrationsforschung, ZEI*), University of Bonn, Germany. I should like to thank Jörg Clostermann, Michael Dueker, Barry Eichengreen, Bernhard Fischer, Ilan Goldfajn, Graciela Kaminsky, Inci Ötker-Robe, Carmen M. Reinhart, Pu Shen and Elke Speidel-Walz for the many intriguing suggestions they offered. I am furthermore obliged to the following colleagues in the Economics Department of the Deutsche Bundesbank for their constructive comments on an earlier version of this paper: Willy Friedmann, Dieter Gerdesmeier, Hermann Hansen, Bettina Landau, Rasmus Rüffer, Michael Scharnagl, Elmar Stöß, Andreas Worms and particularly Heinz Herrmann. Of course, any remaining errors are my own.

These problems ushered in a renaissance of academic studies on the determinants of speculative attacks and currency crises starting after the turbulences in the ERM.[1] Some recent papers attempt to go beyond a pure analysis of balance of payments crises and seek to develop early-warning systems to forecast approaching currency turbulences empirically. Such an approach is very ambitious — maybe even too ambitious — for two reasons. One is that the requisite data are only available following a pronounced time lag. Moreover, experience shows that the willingness to provide data in a timely manner declines even further once tensions in the foreign exchange markets begin to threaten the stability of a currency.[2] Another reason is that a more general problem arises: if market participants are given an instrument to forecast currency crisis, they may well change their previous behaviour and instead attack currencies sooner. In that case, the structural links ascertained empirically from the past would not carry over into the future.

The following approach is limited to a historical perspective and provides an ex-post analysis of the determinants of currency turbulences in emerging markets. This is intended as a contribution to the heated debate on whether the culprits in the past were just fickle speculators who attacked currencies virtually at random or whether the international financial market participants were only playing their assigned monitoring role by mercilessly punishing political deficiencies. A systematic analysis of the behaviour of macroeconomic variables prior to currency turbulences may provide a clue or two. Taking recourse to only a selection of possible fundamentals, though, forces us to limit the potential spectrum of our findings: even a rejection of the hypothesis that the macroeconomic variables being examined here are linked to currency turbulences would not schematically permit the conclusion that fickle speculators should bear responsibility. Rather, this may owe to factors that could not be captured sufficiently through empirical methods.

In light of the economic policy relevance of the question, it comes as a surprise that there is still a lack of comprehensive studies on the determinants of currency turbulences in emerging markets. Often only individual episodes are analysed; at best, parallels are drawn to preceding turbulences.[3] The following analysis, though, was stimulated by some broadly based empirical

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1 See here particularly Kaminsky et al. (1998), as well as the literature comprehensively quoted therein and especially the studies listed in this section in the following. Some banks, though, are trying to establish early warning systems, too. Two representative examples are Deutsche Morgan Grenfell (1997) and J. P. Morgan (1998).

2 This analysis, too, leaves out the time structure with which new data, and thus new information for the market participants, is published. This seems admissible, though, since this paper only claims to make an ex-post study.

3 See, for example, Corbo and Fischer (1994) as well as Eyzaguirre (1993), who explain the Chilean experience; Edwards et al. (1996), Fischer and Schnatz (1996) as well as Langhammer and Schweikert (1995) on the Mexican currency crisis, Diehl and Schweikert (1998) as well as Reisen (1998) on the Asian currency crisis, and Dornbusch et al. (1995), who compare different periods of speculation in the foreign exchange markets.

studies on this topic. However, none of those studies explains the interplay of macroeconomic variables and currency turbulences in a *relatively homogeneous group of countries* composed entirely of *emerging markets*. In a seminal paper, Eichengreen et al. (1995) compare the behaviour of macroeconomic and political variables immediately prior to and after currency turbulences with their behaviour in periods of tranquillity using a non-structural approach. Their study is based on quarterly data of OECD countries over a period of more than 30 years. Both univariate and multivariate testing procedures are applied. The samples taken by Ötker and Pazarbasioglu (1994), Funke (1996) and Weber (1998) make up a broad spectrum (mostly) of industrial countries analysed using monthly or quarterly data taken between the 1970s and 1990s. Whereas the first two studies analyse the relationships between macroeconomic fundamentals and currency crises using probit models, Weber (1998) prefers a structural VAR model.

The first comprehensive analysis of developing countries is provided in Frankel and Rose (1996) on the basis of annual data. Using univariate and multivariate methods, the authors study the behaviour of some macroeconomic variables and of indicators of the structure of international debt prior to extraordinary exchange rate devaluations over a (very broad) sample of over 100 developing countries. Moreno (1996) conducts nonparametric tests covering a sample of Asian countries. In a very comprehensive and univariate study, Kaminsky and Reinhart (1996) as well as Kaminsky et al. (1998) develop an approach which shows in great detail which macroeconomic variables are best suited to signalling critical macroeconomic conditions prior to individual currency turbulences. The authors additionally highlight the interplay between banking and balance of payments crises. In addition to numerous emerging markets, their sample includes some European countries as well, which are analysed based on monthly data going back to 1970.

This study seeks to combine the advantages of each of those papers. Since the likelihood is slim that the comparability of the reaction patterns can be preserved given a very heterogeneous selection of countries, this study focuses on a rather homogeneous sample consisting of 26 emerging markets with a sufficiently well-developed domestic financial sector.[4] The analysis spans a period of over 25 years. There is, however, a certain dilemma

[4] Along the lines of Sachs et al. (1996), the underlying sample of countries encompasses those economies whose capital markets foreign investors have relatively open access to (Argentina, Brazil, Chile, Colombia, India, Indonesia, Jordan, Korea, Malaysia, Mexico, Pakistan, Peru, the Philippines, Sri Lanka, South Africa, Taiwan, Thailand, Turkey, Venezuela and Zimbabwe). Small-sized financial centres and city-states (Hong Kong and Singapore) have been left out. Due to a lack of available data, Taiwan was left out of this sample, in contrast to Sachs et al. (1996), and instead some east European countries (the Czech Republic, Hungary, Poland, the Slovak Republic and Slovenia) were included following their transition to market economies, as well as Israel and Uruguay. It is obvious that considerable differences do exist between these countries in terms of their degree of financial openness, which has also changed over time. For some countries (especially those in eastern Europe), data is not always available over the entire estimation period.

surrounding the selection of the data frequency. On the one hand, the frequency should be as high as possible, since especially financial markets tend to react quickly to fundamental imbalances; on the other, the number of variables for which a consistent data base exists declines as the frequency of the data rises. This study is based on monthly data, recognising that this can only be a middle course. On the one hand, even this frequency might be too long, since, in particular, speculative attacks which are successfully warded off in a matter of days might not show up in an analysis using monthly averages. On the other hand, this time frequency already demands that some variables be left out (such as, for instance, those on the maturity and structure of foreign debt), although they are generally believed to have played an important role in the crises in Mexico and Asia. However, they are gathered systematically and throughout a broad spectrum of countries almost exclusively on an annual basis.

The study is divided into five sections. After the introduction, Section 2 initially presents a method of empirically identifying currency turbulences. Those criteria are then used to assemble a catalogue of episodes in which the foreign exchange markets in emerging economies were exposed to particular strains. To reduce the risk of a biased selection of currency turbulences, the term "currency turbulence" includes both currency crises (i.e. extraordinary devaluations) and successfully averted speculative attacks. In Section 3, a selection of macroeconomic variables is presented which - eclectically following the core ideas of various theoretical approaches - may show a different pattern prior to currency turbulences compared to periods of tranquillity. All together, the behaviour of 24 macroeconomic variables available on short notice is analysed. The interrelationships between banking and currency crises, contagion effects and political conditions are excluded, since it is very difficult to capture such qualitative elements empirically without allowing further elements of arbitrariness.[5] This does not mean that such factors are irrelevant to explaining speculative attacks *per se*. On the contrary: such moments should always be added (*ad hoc*) to the determinants which prove to be relevant in the following study in order to obtain an overall picture of a country's vulnerability to speculative attacks. On the whole, therefore, only one single aspect of currency turbulences is extracted and analysed: the question of whether, prior to speculative attacks, the macroeconomic environment - also seen in isolation - points to peculiar behaviour.

The focus of this study is on the empirical analysis in Section 4, in which the statistical features of macroeconomic variables are illustrated using different testing procedures taken for the most part from the empirical work mentioned at the beginning. Analogously to those analyses, a non-structural method has been chosen: instead of subjecting a certain theory for

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[5] On contagion effects of currency turbulences, see e.g. Gerlach and Smets (1994), Glick and Rose (1998) and Eichengreen et al. (1996).

explaining speculative attacks to an empirical examination using a structural model, rather, a comprehensive statistical picture of the typical behaviour of macroeconomic variables prior to currency turbulences is to be drawn.[6] At this stage, different empirical approaches are applied: firstly, parametric and nonparametric tests are used to find out whether certain macroeconomic variables, on average, point to different behaviour prior to typical currency turbulences than during periods of tranquillity (Section 4.1).[7] This analysis is already refined thereafter through a graphical "event study" which illustrates the characteristic patterns of these variables prior to currency turbulences (Section 4.2).[8] The following "signal approach" promises additional understanding by loosening the metaphor of the "typical crisis" and analysing the signalling behaviour of *every* macroeconomic variable prior to *every* period of turbulence in the foreign exchange markets. Simple weighting of the signalling behaviour which is observed over the course of time, moreover, allows the construction of a composite indicator which illustrates the vulnerability of individual countries to speculative attacks (Section 4.3).[9] In order to document the stability of these results and also taking into consideration the underlying correlation structures between the explanatory variables, these univariate findings are ultimately carried over into a multivariate framework using a logit analysis (Section 4.4). Section 5 summarises the most important findings and presents an agenda for further research.

2. Identification of turbulences in foreign exchange markets

2.1. The construction of a foreign exchange market indicator

Before subjecting the behaviour of macroeconomic variables prior to currency turbulences to a systematic empirical examination, turbulences in the foreign exchange markets themselves should initially be defined according to uniform criteria and then empirically identified. There are basically two conceivable approaches: either to generate a list of turbulent periods in the foreign exchange markets extracted from the existing literature, or to assemble an indicator which shows tension on the foreign exchange markets.

In particular, some analyses on the ERM underlie the first approach, mainly by classifying the discretionary changes in existing exchange arrangements, such as the adjustment of the central rates or transition to a regime with flexible rates as deviations from the norm, and then attempting to explain these events with suitable early-warning variables. The disadvantages of

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6 For empirical analyses with structural models see, e.g., Blanco and Garber (1986), Cumby and van Wijnbergen (1989) and Goldberg (1994).

7 See, for instance, Eichengreen et al. (1994) and Moreno (1995).

8 See, for instance, Eichengreen et al. (1995), Frankel and Rose (1996) and Kaminsky and Reinhart (1996).

9 On the "signal" approach see Kaminsky and Reinhart (1996) and Kaminsky et al. (1998).

such an approach are plain to see; however, they probably affect emerging markets much more severely than industrialised countries. In particular, it can be assumed that this method mainly identifies currency crises with considerable devaluations, whereas episodes in which the parity is successfully defended are generally not given the same attention and thus would probably not be sufficiently captured. It likewise does not appear appropriate to solve this problem by restricting the analysis to abrupt devaluations. Bearing in mind the fact that macroeconomic variables provide an important contribution to explaining tensions in the foreign exchange markets, their behaviour prior to currency turbulences should be different from that in periods of tranquillity regardless of whether the government finally decides to defend or to surrender a certain parity in the event of a speculative attack. Furthermore, even if the foreign exchange market reports are examined carefully, this method still grants a considerable discretionary scope as to which events are to be included in the catalogue to be established. In any case, it is difficult to identify currency turbulences according to this principle *using uniform criteria.*

Basically following the lines of Eichengreen et al. (1995), Kaminsky et al. (1998) and Sachs et al. (1996), therefore, the second method will be applied here. Essentially, with the help of a foreign exchange market indicator, currency turbulences are identified using uniform criteria. This method not only has a decisive advantage over the first approach in that currency crises, i.e. unusual devaluations, can be captured more easily. In addition, this method makes it possible, for one thing, to perform a more systematic diagnosis of episodes in which the exchange rate peg was successfully defended, and, for another, it enables currency turbulences to be graded according to their intensity. A starting point for the construction of such an *indicator to capture tension in the foreign exchange markets* would appear to draw on the well-known symptoms of currency turbulences:

1. a sudden and extraordinarily sharp devaluation of a currency,
2. a plunge in foreign exchange reserves, and
3. a leap in short-term interest rates.

Whereas there are sufficient data for the first two characteristics, substantiated data on changes in the interest rates for the countries being studied here are not available over the entire period under investigation.[10] After all, it is precisely in numerous developing countries where the financial markets have in the past been characterised by a large degree of government intervention, preventing a market-based determination interest rates.

[10] See Kaminsky et al. (1998), whose study covers a similar period and likewise leaves out interest rate data when constructing this indicator owing to a lack of available data.

The construction of the foreign exchange market indicator, therefore, is restricted to the percentage change in the foreign exchange reserves $\%\Delta fxr_{i,t}$, (in US$) and the percentage change in the real exchange rate $\%\Delta rer_{i,t,}$ (each taken as a logarithm vis-à-vis the preceding month).[11] The *real* exchange rate is given preference over the *nominal* exchange rate in order to avoid (arbitrary) corrections which would otherwise be necessary for periods with exceptionally high rates of inflation. In such periods, considerable (nominal) depreciations are not necessarily a reflection of speculative attacks but instead normal in order to offset the inflation differential between the home country and abroad.[12] In concrete terms the indicator is calculated as follows:

$$X_{i,t} = \gamma_{i,1} \%\Delta fxr_{i,t} - \gamma_{i,2} \%\Delta rer_{i,t}$$

The large difference in the variabilities of the foreign exchange reserves and the real exchange rate is corrected by weighting the indicator. As usual, the conditional volatilities of the two variables are taken to this end. The weighting is done separately for each country with the country-specific value calculated in each case. This approach has an advantage over equally weighting both components in that the movement of the indicator is not dominated by that component which generally fluctuates the most violently; for currency turbulences are characterised precisely by unusual fluctuations, which means the weighting scheme chosen here captures the actual deviation from the norm for each component. Both falling foreign exchange reserves and a rising real exchange rate (depreciation) are entered into the calculation of the indicator with a negative sign. The tensions on the foreign exchange market are accordingly all the more intensive, the more sharply this foreign exchange market indicator dips into the negative.

Moreover, then, the indicator is smoothed in such a manner that the values of the two preceding months - with declining weights - are also included in the indicator of the current month. This is intended to prevent the "normalisation" of a preceding short-lived appreciation or an excessive increase in foreign exchange reserves from being typified as turbulence. Formally speaking, the following correction is undertaken:

$$I_{i,t} = \alpha_1 X_{i,t} + \alpha_2 X_{i,t-1} + \alpha_3 X_{i,t-2}$$

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[11] The real exchange rate is defined as the nominal exchange rate of a currency to the US $, adjusted for movements in consumer prices in the United States and in the emerging market. A rising real exchange rate corresponds to a real depreciation of the currency.

[12] Most other studies, though, use the nominal exchange rate and then make adjustments for phases with high rates of inflation; see Kaminsky and Reinhart (1996), Frankel and Rose (1996). However, see also Goldfajn and Valdés (1997), who, among other things, also apply the change in the real exchange rate to determine turbulences.

where: $\sum_{i=1}^{3} \alpha_i = 1$; $\alpha_{i+1} = \alpha_i / 2$

This method allows an examination for every country and every month, according to the presented uniform criteria, of whether extraordinary tensions in the foreign exchange markets ("currency turbulences") existed, expressing themselves in the form of extreme swings in the indicators. Moreover, it permits a classification of currency turbulences by type and intensity. As far as intensity is concerned, the events are classified in three categories depending on how sharply the indicator surpasses the standard deviation of the indicator calculated over all countries (σ):[13] if the indicator exceeds 1.5 times this value, then the turbulence is termed "ordinary". In order to diagnose "strong" or "severe" turbulence, the standard deviation calculated over all countries would have to be exceeded by a factor of two or three, respectively.[14] The tensions are, moreover, split up according to the contribution the variables make to explaining the foreign exchange market indicator. Turbulences are classified as a (successful) speculative attack - i.e. *currency crisis* - if the explanatory value of the real exchange rate in the foreign exchange market indicator amounts to at least 60 %. Otherwise they are termed an (unsuccessful) *speculative attack*. The various categories can then be summarised as shown by the following matrix (Table 1):

Table 1
Classification of turbulences

	Contribution of the real exchange rate to the value of the indicator	
Deviation	greater than 60 %	less than 60 %
greater than 3σ	severe crisis (1)	severe attack (4)
between 2σ and 3σ	strong crisis (2)	strong attack (5)
between 1.5σ and 2σ	ordinary crisis (3)	ordinary attack (6)
less than 1.5σ	Period of tranquillity	

[13] In this point the analysis differs, say, from the study by Kaminsky and Reinhart (1996), which calculates overshoots of the standard deviation in a country-specific manner. Whereas in this study, therefore, turbulences are defined uniformly through the entire sample, their study defines turbulences as behaviour which deviates from the country-specific norm. However, it also follows that in countries where the index runs smoothly, even rather small fluctuations in the index are identified as turbulences. Since, according to the method used here, countries were identified in which during the period under review no turbulences occured, a sample-selection bias which adversely affect some papers is avoided.

[14] Admittedly, it would be better to measure the intensity of currency turbulence in terms of their actual real economic impacts. However, such a strategy would involve empirical difficulties that could hardly be overcome.

Moreover, the indicator often shows extreme values at rather short intervals. For instance, deep-seated currency crises are often preceded by (unsuccessful) speculative attacks, or currency crises are exacerbated if, for instance, the already fragile banking system in the emerging market continues to destabilise as the crisis continues. This in turn often has repercussions on the value of the currency, which means that turbulences often drag on for several months, or sometimes even over several quarters (Kaminsky and Reinhart 1996). In Indonesia, this indicator, for instance, already identifies the first exceptional currency devaluation in August of 1997 as a currency crisis. After a period of relief in autumn, this crisis worsened once again in early 1998. However, in the interim period there should hardly have developed new macroeconomic adjustment pressure in the same degree which was not visible already prior to the break-out of turbulences in August. As a result, such turbulences must be understood as a unity. In order to prevent a double counting of the same turbulences, the length of the event - "*the episode*" - is defined.

The beginning of an episode is defined as that month in which the indicator, after a period of tranquillity, exceeds the critical threshold of 1.5 standard deviations for the first time. From that point a window of three quarters is drawn. If a new event occurs in this area, then the time in-between is defined as an episode. Otherwise the last point in time of an event is fixed as the end of the episode. Episodes are given their highest rank as a classification, with a characterisation as a crisis always taking precedence over a classification as an attack. An example shall serve to illustrate this outline: applying this method, a severe currency crisis is identified in the Philippines in October 1983. However, this crisis was already preceded by a strong attack in September of 1983. In June and July of 1984, i. e. less than three quarters later, the indicator once again shows turbulences. Following the systematic outline described, the beginning of the episode is thus defined as September 1983, and its length limited to July 1984, and the episode is classified at its highest rank as a "severe crisis".

The selection of currency turbulences in emerging markets presented below, too, must be seen against the background of some basic deficiencies in the design of the indicator, however:[15] firstly, any calculation of such an indicator requires some more or less arbitrary definitions. For example, there is neither any compelling reason for smoothing the indicator over three periods, nor for the threshold values used in classifying the individual episodes. Secondly, countries sometimes decisively curtail international capital movements in order to ward off speculative attacks. If such measures were able to reduce pressure on the foreign exchange markets in isolation, attacks remain undiscovered by the chosen indicator. Experience shows,

[15] Some limitations of such indexes are also pointed out by Eichengreen et al. (1994, 1995) and Flood and Marion (1998).

however, that such defence strategies are not very effective, since investors generally come up quickly with ways of circumventing these administrative hurdles.[16] Thirdly, the change in foreign exchange reserves, precisely in emerging markets, provides only a limited amount of information on the scale of intervention in the foreign exchange market, since neither credit lines in foreign currency to which recourse can be taken in the event of a speculative attack nor interventions in the futures markets are recorded in the published balance sheets.

2.2. A catalogue of currency turbulences in emerging markets

According to the method presented in Section 2.1., the following is a catalogue of a total of 103 episodes of turbulence compiled for 26 emerging markets between 1970 and mid-1997, which can be divided into 76 currency crises and 27 speculative attacks (Table 2).

Table 2
A sample of turbulences

Type / Intensity	Currency crises	Speculative attacks	Total
severe	36	5	41
strong	16	11	27
ordinary	24	11	35
Total	76	27	103

Two aspects immediately pop up: one is that according to the identification method used here, most tensions exceed the threshold value of three standard deviations and must accordingly be classified as severe turbulences. The other is that in each category there are fewer speculative attacks than currency crises.[17] Provided the flaws in the design of the indicator are not all too important, this finding may indicate that if a currency is attacked, the attack is usually successful, i.e. evolves into a currency crisis. In the first category of severe turbulences, the ratio of currency crises to speculative attacks is particularly high. The (far-reaching) agreement of these severe turbulences with the episodes listed by Kaminsky and Reinhart (1996), for one thing, proves the reliability of the indicator in identifying currency

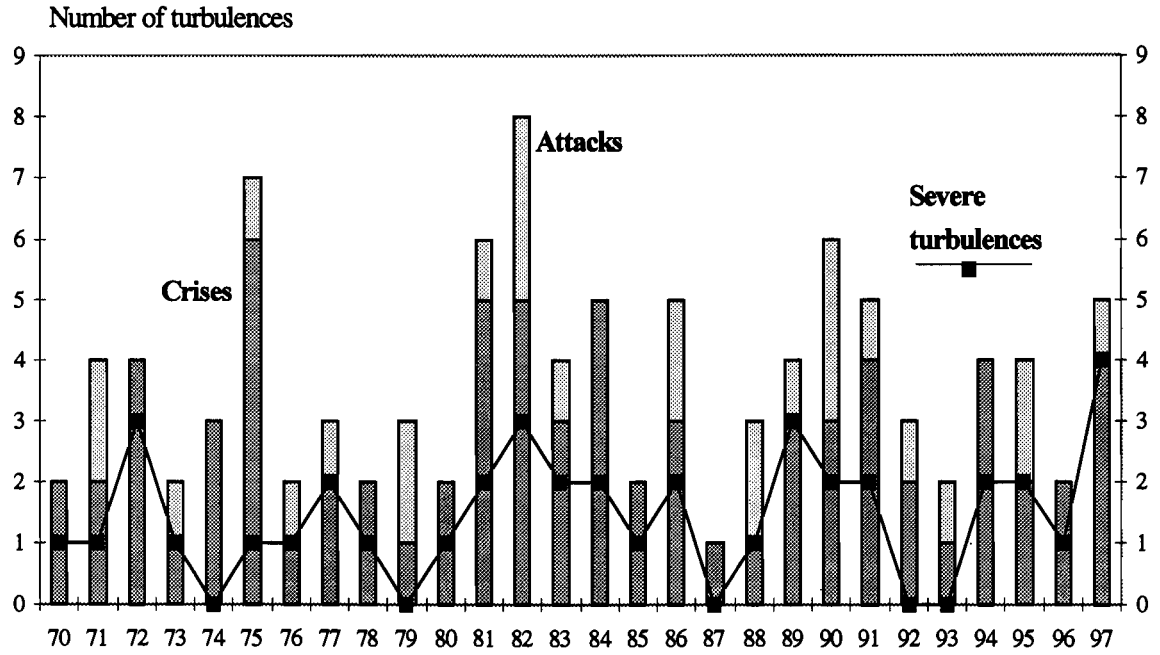
[16] See, for instance, Mathieson and Rojas-Suarez (1992).

[17] This basic finding does not change even if the explanatory potential of the real exchange rate is reduced to 50 % or 40 %.

turbulences.[18] Since, to capture tension in the foreign exchange markets, the indicator needs to exceed the standard deviation calculated across all countries, the definition selected here allows for the possibility of no currency turbulence being identified for some economies in the period of the study. This includes a number of east European countries (e.g. Hungary, Slovenia) and Colombia.

It is often asserted that currency turbulences periodically cluster since they are amplified by contagion effects or external factors. The temporal distribution of the currency turbulences, upon first glance, cannot back up this assertion as unambiguously as one might perhaps imagine. The derivation of such conclusions from such simple diagrams may generally be affected by the underlying country sample, though. It is true that a certain accumulation can be first seen in the mid-seventies (Chart 1).

Chart 1
Currency turbulences in emerging markets, 1970-1997



However, they were for the most part "only" ordinary turbulences, which, besides, did not cluster on a regional basis. A second concentration of currency turbulences becomes visible in the early eighties. That is due to the outbreak of the international debt crisis which particularly affected Latin American countries in the years 1981-82. In that period the foreign exchange

[18] In order to underscore the integrity of their selection, the authors draw a brief sketch of the international financial environment for those episodes they localised turbulences and come to the conclusion that they often occur simultaneously with a transition to another exchange rate regime, a revaluation of the currency or drastic intervention in the foreign exchange markets.

market indicator displays the highest values for Argentina, Mexico and Uruguay. In the two following years extremely strong fluctuations of the foreign exchange market indicator are identified for Indonesia, the Philippines and Venezuela. The next clustering of turbulences can be identified in the late eighties and early nineties. Once again it was mostly Latin American countries that were the focal point of speculative attacks. However, Poland became the first east European country to suffer a severe currency crisis. When, during 1992-93 - the time of the ERM crisis - some European industrial countries were at the centre of speculative attacks, the foreign exchange markets of the emerging markets did not show any signs of severe tension. As of late, severe currency turbulences in the emerging markets have picked up again, culminating in 1997 with the currency crises in Asia.

3. Variables with early-warning potential

3.1. Theoretical background

An empirical analysis of the determinants of currency turbulences requires a catalogue of variables which give reason to assume that in the run-up to speculative attacks they behave differently than in times of tension-free exchange rate conditions. A glance at the theoretical literature on speculative attacks, which will be summarised briefly in the following, may give the reader an idea of what variables are to be included in this catalogue.[19] The convention has prevailed in the meantime of making a distinction between what are known as "standard models" of speculative attacks and newer approaches, which particularly include models with multiple equilibria.[20] All the same, there does not exist a dichotomy between these two classes of models. In particular, one widespread preconceived notion must be avoided here: even if self-fulfilling prophecies are very important in the newer models, the authorities - who, as experience has shown, are fond of shifting the blame for currency turbulences to unpredictable speculators - are not let off the hook. Namely, these approaches do *not* show that attacks can occur everywhere and at all times, i.e. completely independently of the fundamentals. Obstfeld (1996) justifiably mentions that the macroeconomic fundamentals in some countries can be so stable that their currencies are never attacked, whereas in other countries a speculative attack seems inevitable owing to pronounced fundamental weaknesses. However, a "grey zone" could materialise between these two extremes, in which, in the words of Eichengreen et al.

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[19] In light of the multitude of fruitful summaries of this branch of the literature and the empirical leanings of this study, only a short overview shall be provided here. See Agenor et al. (1992), Blackburn and Sola (1993), Garber and Svensson (1995), Eichengreen et al. (1995), Krugman (1996) and Obstfeld and Rogoff (1995) for more comprehensive studies.

[20] On standard models see, in particular, Krugman (1979) and Flood and Garber (1984). An overview of the literature is contained in Agenor et al. (1992) and in Obstfeld and Rogoff (1995). On the class of models with multiple equilibria see Obstfeld (1994), Obstfeld and Rogoff (1995) and Bensaid and Jeanne (1997). On the more recent debate see also Krugman (1996).

(1995, p. 253) "... some of the 'innocent' are slaughtered, while not all the 'guilty' suffer...". Whether one model or the other is better suited to depicting the reality depends thus on the extent of this grey area, which can hardly be ascertained using empirical methods.

The standard models emphasise the role played by fundamental imbalances prior to speculative attacks and present some distinct features of currency crises. The time of the attack is also precisely fixed in these models. The starting point is generally an excessively expansionary monetary and fiscal policy in a system of fixed exchange rates.[21] To ensure that the underlying monetary conditions correspond to the currency parity, that policy must result in portfolio shifts by investors which are then reflected in continually diminishing foreign exchange reserves. Such a policy, however, undoubtedly cannot be maintained *ad infinitum*. When the foreign exchange reserves run dry at the latest (and recourse is not taken to additional tranches provided by external lenders), then either a marked policy shift is demanded, or the exchange rate peg will have to be forsaken. However, usually such a "natural collapse" of the exchange rate regime does not happen. In an expansion of Krugman's model, Flood and Garber (1984) substantiate the exact point in time of a speculative attack by adding to his theories the idea of the *flexible shadow exchange rate* - a hypothetical exchange rate determined by the economic fundamentals and which would set in under the given conditions in a system of flexible exchange rates without interventions. As soon as this "shadow exchange rate" exceeds the fixed exchange rate, the market players will attack the currency, i.e. even before the foreign exchange reserves are actually used up. This attack then immediately depletes the still-existing foreign exchange reserves and forces the exchange rate parity to be dropped.[22]

These basic models have been expanded in numerous directions and thus brought closer to reality. By introducing uncertainty about the ("critical") volume of foreign exchange reserves which, if necessary, can be used to ward off an attack, Krugman (1979, p. 323) already showed that the timing of a speculative attack itself can become a stochastic variable and that the attack does not inevitably lead to a surrender of the exchange rate parity. It can also be successfully warded off and can empirically be reflected in alternating attack-confidence cycles. After all, it is only for a very short time that speculators need to hold foreign exchange until they recognise whether the critical reserve level of the central bank (which speculators do not know) has been exceeded and the parity will be floated. Otherwise, they can (in a

[21] In his seminal paper, Krugman (1979), for instance, applies a model of an economy with a regime of fixed exchange rates in which an increase in the budget deficit is completely accommodated by creating money (going beyond the demand for money).

[22] Otherwise lucrative arbitrage possibilities would emerge, which are incompatible with basic model assumptions.

system of fixed rates) shift their portfolios back to the starting situation at the original exchange rate.

Moreover, it was shown that an excessive real appreciation of the currency prior to foreign exchange market turbulences, which in turn *(ceteris paribus)* is reflected in falling exports, rising imports and increasing deficits in the balance of trade and the current account, can be derived from plausible theoretical assumptions. Such real appreciations prior to speculative attacks are theoretically substantiated by models which explicitly permit expectations regarding future price movements in the process of wage negotiations. If labour judges the unconditional defence of a certain exchange rate parity as not completely credible, and therefore does not rule out the possibility of a sharp devaluation of the domestic currency sometime during the length of the contract, then it will attempt to push through higher wage demands than justified by inflation expectations in the event the exchange rate regime is actually upheld. In fact, the anticipated price increases (weighted with the probability of devaluation) are entered into the wage negotiation process discounted in order to take account of the risk of lower real wages in the event of a currency crisis. This then gives impetus to a real appreciation of the currency which is not backed by the fundamentals.[23] To sum up, according to this branch of the literature, the following signs should be expected prior to a speculative attack: an excessively expansionary monetary and fiscal policy, low and continually falling foreign exchange reserves, an overvalued currency, a disproportionately low volume of exports and a disproportionately high volume of imports, and relatively high deficits in the balance of trade and in the current account.

In more recent models, political action is determined no longer exogenously, but rather endogenously, through the (strategic) behaviour of the market players. Thus, the expectations of the economic agents regarding the behaviour of the government can themselves ultimately have important repercussions on the actual measures taken by the government. Two items are key to this class of models. First, a given parity can be defended against speculative attacks at any time, at least as long as the exchange rate target is not subordinated to any other economic policy objective. Secondly, the market players do not unfailingly believe in the superiority of the exchange rate objective as postulated by economic policy makers. Rather, they reason from past experience that measures to ward off speculative attacks (such as hiking interest rates) can also have welfare-reducing side effects, as they generally curb economic growth, exacerbate recessions, put a strain on the government budget, and jeopardise the stability of the domestic banking system. Therefore, market players also take account of the possibility that in the event of a speculative attack the authorities, in accordance with their welfare

[23] This argument carries particular weight in stabilisation programmes in which the exchange rate is used as a nominal anchor; see e.g. Edwards (1993), Edwards et al. (1996) and Agenor et al. (1992, p. 372).

function, always weigh the benefits in terms of credibility gains (or averted credibility losses) from decisively defending the parity against the potential real economic costs. What ultimately matters is whether the market players believe that the government has the political will to resist a speculative attack. On the whole, market players will have less confidence in the maintenance of a given parity the greater the political pressure already is on a government owing e.g. to a fragile banking system, a weak macroeconomic situation or high unemployment; any further exacerbation of the problem would entail a progressive deterioration of the cost-benefit ratio for the government.

This can lead to a vicious circle: once economies start to show certain weaknesses, causing market players to have expectations of devaluations, the authorities are forced to defend the parity by raising interest rates. At the same time, the government's cost-benefit ratio in terms of holding on to the parity worsens. Investors once again take this into consideration and in turn consider it more likely that the parity is abandoned. That would once again lead to increasing expectations of devaluations, with even higher interest rates, and the whole process would start again at the very beginning, with the parity's credibility steadily going downhill. In this paradigm it is only through the emerging expectations of devaluations which makes it optimal for the government to actually devalue the currency; the economy is propelled into a new equilibrium by a speculative attack only by the anticipation of a devaluation. On the other hand, if the market players expect the announced parity to be maintained, then the economy remains in the original equilibrium, and the currency is not attacked, either. In those models, the market assessment, and thus the timing of a speculative attack, can depend on apparently negligible news (so-called "sunspots"), which can unleash such a circular process and thus trigger the attack. That also has implications for the empirical analysis. If self-fulfilling prophecies and sunspots prevail in the explanation of speculative attacks, the identification of variables with early warning characteristics may prove difficult, since a peculiar behavioural pattern of these variables prior to currency turbulences is merely a necessary condition, but not a sufficient condition, for a speculative attack. It is only the relevant market expectations which suffice, yet they can hardly be observed, however.

3.2. A list of macroeconomic variables

These models are used as a starting point from which, in the following, the behaviour of a total of 24 macroeconomic variables (which in earlier empirical studies already proved to have some explanatory power) will be examined.[24] As already mentioned at the beginning, some

[24] On earlier studies see the extensive overview in Kaminsky et al. (1998). Moreover, in this study we will not address the fact that the explanatory variables may also be affected by other factors. For instance, the surge of foreign capital flows into the emerging markets are often held responsible for the real appreciations and thus

variables which might possibly have been a significant factor in the crises in Mexico and Asia are not considered in this study. For example, the available data on the maturity and the structure of the foreign debt for the selected countries is insufficient. An analysis of annual data (e.g. World Bank data) does not seem appropriate here, since the maturity structure and the composition of the foreign debt often change within a rather short period of time. Moreover, the interplay between banking crises and balance of payment crises, contagion effects of speculative attacks, the institutional structure of exchange rate regimes and the underlying political conditions are very difficult to capture without allowing further elements of arbitrariness to enter into the empirical analysis.

Along the lines of Kaminsky and Reinhart (1996), the macroeconomic variables are divided into three categories:

1. Variables from the financial sector,
2. variables from the external sector, and
3. variables from the real sector.

On the basis of ***variables of the financial sector,*** this paper will analyse whether an excessively expansionary monetary and fiscal policy was systematically conducted in emerging economies prior to currency turbulences. These include the growth of a narrowly defined and of a broadly defined monetary aggregate, each in terms of nominal GDP.[25] However, according to the theoretical considerations, the sign of these variables is not unambiguously determined. On the one hand, one might expect that in the run-up to turbulences in the foreign exchange markets an excessively expansionary monetary policy might be reflected in these variables growing at a higher-than-average rate. From a demand perspective, though, the incentives to hold domestic media of payment will decrease considerably if the risk of a currency crisis becomes visible, which tends to lead one to expect the value to decline prior to foreign exchange market turbulences. In order to be better able to capture the monetary policy stance of a country, simple money demand functions are estimated for each country.[26] The deviation of the estimated value from the actual value in percent is entered as an indicator of the supply and demand functions in the money market. If the actual real cash balances are higher than the values forecast by this function, the verdict is

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also for the growth of the balance of trade deficit and the expansionary monetary policy; see, for instance, Corbo and Hernández (1993, 1994), Calvo et al. (1993, 1996) and Schnatz (1998).

[25] In each case growth rates have been calculated on a year-on-year basis. Data on GDP and the balance on current account have been interpolated as appropriate. The data used here are based on the CD-ROM (November 1997) version of the International Financial Statistics of the IMF; the stock market data were provided by Bloomberg, which obtains data from the International Finance Corporation (IFC).

[26] Following the lines of Kaminsky and Reinhart (1996), the demand for real cash balances (deflated by consumer prices) was estimated depending on the output index (seasonally adjusted), the inflation rate based on consumer prices, and a linear time trend.

that monetary policy is "too expansionary". Furthermore, the inflation differential between each emerging market and the United States is included in the catalogue as an indication of a non-stability-oriented economic policy. Growth in domestic lending in terms of GDP continues to be taken into account as a sign of an excessively expansionary economic policy. Admittedly, this might also be an expression of banks' increased leeway to grant loans provided by lasting deregulation measures in the domestic financial system and of the increased transmission of foreign capital inflows through the banking sector. In order to take account of the substantial inflow of (short-term) foreign capital which has been channelled into many emerging markets through the banking sector, the change in lending to the private sector as a percentage of GDP is also examined.

In addition, the ratio of foreign exchange reserves to a broad and to a narrow monetary aggregate is also taken into consideration. Here, the analysis assumes that a country is all the less susceptible to speculative attacks the higher this ratio is and the more sharply it increases. By including the ratio of foreign exchange reserves to a broad monetary aggregate, the argument put forward by Calvo and Mendoza (1996) is to be taken into account. According to them, especially in emerging markets, market players tend to convert their financial assets to an international key currency as monetary policy loses credibility. Among other things, this is to capture the central bank's ability to meet the demand (for conversion of funds) in an emergency. Given a fragile banking system, in particular, the central bank may feel obligated not only to cover the monetary base with its available foreign exchange reserves, but also, as the "lender of last resort", to back other bank deposits. Owing to a lack of available data, fiscal policy cannot be illustrated using operating variables on the budget deficit. Therefore, the behaviour of the public sector is captured approximately by the growth in central bank lending to the public sector.

As regards the indicators from the ***external sector,*** the analysis includes both the real exchange rate and individual components of the current account. The real exchange rate, which is bilaterally calculated against the US dollar and on the basis of consumer prices, enters as a rate of change, for one thing.[27] The more sharply the currency has appreciated in real terms over the previous year, in a sense, the higher the probability that the external sector has lost a significant degree of competitiveness and that the exchange rate needs adjustment. For another thing, an indicator of the adequacy of the real exchange rate is taken into account. Following the lines of Kaminsky and Reinhart (1996), however, not a complicated equilibrium concept is estimated; instead, the deviation of the real exchange rate from its (linear) trend is measured. For an insignificant trend variable, on the one hand purchasing

[27] A positive value stands for a real devaluation of the currency, whereas a negative value signals a real appreciation of the currency.

power parity is implicitly assumed as an "equilibrium concept". On the other hand, however, the trend variable leaves enough leeway, especially for emerging markets, to catch up with the industrialised world, which can be reflected in an equilibrium real appreciation according to the theorem postulated by Balassa and Samuelson.[28]

Furthermore, real appreciations generally have implications for trade flows. Therefore, changes in exports and in imports are taken into consideration. Real appreciations reduce the prices of imports and increase the prices of exports. It thus follows that a decline in export growth should be expected, as well as an increase in import growth. On balance, these relationships are also reflected in the higher deficits in the balance of trade and in the current account, both of which are computed as a percentage of GDP.[29] Since deficits in the current account are equivalent to an increase in foreign debt, *ceteris paribus*, the ability to repay the debt - and thus creditworthiness - decreases. On the whole, it is assumed that the likelihood of a speculative attack will increase in line with a rise in the current account deficit.[30] Furthermore, the ratio of foreign exchange reserves to (monthly) imports is also used as an indicator of sufficient holdings of foreign exchange reserves. In this trade-oriented perspective of an adequate level of foreign exchange reserves, the time span in which imports can be paid for from foreign exchange reserve holdings alone is expressed.[31] In turn, the lower this value is, the less able the country will be to pay for its imports in a timely manner, everything else being equal.

Finally, this category captures the US money market rate, which serves as the representative foreign interest rate, in order to also give external factors weight as determinants of foreign capital flows into emerging markets.[32] This variable is based on the hypothesis that as interest rates rise in industrialised countries, their investments become increasingly attractive, which may result either in portfolio withdrawals from emerging markets to industrialised countries

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[28] The lower the actual value of the real exchange rate is compared with the estimated value of this simple function, the more overvalued the emerging market's currency will be considered. An overvaluation approximated in this manner thus has a negative sign, and vice versa. A certain problem with this variable could well emanate from the extreme appreciation of the dollar in the mid-eighties.

[29] The balance of trade position was also analysed as a ratio between exports and imports.

[30] Statements on the sustainability of current account deficits, however, must be analysed more comprehensively, covering both the country's long-term growth prospects and investors' portfolio decisions (see e.g. Edwards et al. 1996 and Reisen 1997), which means that the indicator used here is merely coarse.

[31] An analysis of the correlation structures shows that the dynamics of the foreign exchange reserves, in relation to imports and to the monetary aggregates, is correlated at a relatively high level, which means that their value is to be seen as substitutive rather than complementary. In the univariate analysis, it is to be studied, however, whether one of the variables has superior signalling characteristics.

[32] Eichengreen and Rose (1998) find a close correlation between banking crises and higher industrialised countries' interest rates. As a consequence, by taking the US money market rate into consideration, account could be taken of the banking system's impact on the vulnerability of countries to currency crises, and thus also of the interplay between banking crises and currency crises could be captured, at least in a rudimentary fashion, via this detour.

or, at least, in declining capital flows to emerging markets. Given a certain level of the real exchange rate, this impedes the maintenance of a given current account deficit, on the one hand. On the other hand, if emerging economies were to follow the example of the industrialised world and pursued a more restrictive monetary policy by increasing the interest rate, that might have undesirable repercussions on the domestic economy and the domestic banking system. Admittedly, there is a further feature in which this variable is different from the variables presented heretofore. Whereas the indicators listed in the preceding text would call for economic policy adjustments in the respective countries, a systematically higher foreign interest rate prior to currency turbulences would indicate that factors which are outside the control of the economic policy decision makers in the respective emerging market, too, could increase the vulnerability of a country to speculative attacks.[33]

In addition, real growth in output and the change in the stock market index enter into the analysis as ***real economic indicators***.[34] Provided the expectations of the market players are correct and are accordingly reflected in the stock markets, the fragile overall economic situation or also the mere anticipation of turbulences could be reflected in a below-average trend of stock prices. The overall effect of output growth on vulnerability to speculative attacks is not unambiguous, however. On the one hand, the lower real growth is, the less willing governments will be to put up with a further weakening of the real economy by adhering to a tight-money policy given tensions in the foreign exchange markets. On the other hand, depending on the underlying elasticities, sluggish economic growth may lower the demand for imports, thus improving the balance of trade and simultaneously reducing tensions from that end (Ötker and Pazarbasioglu 1995, p. 13).

4. Empirical analysis

4.1. Parametric and nonparametric tests

In order to obtain initial evidence of whether the prevailing macroeconomic environment may have played a role in the assessment by the market players, in the following the variables presented in Section 3 will be linked to the episodes in the foreign exchange markets identified in section 2. The first step in this process will be to group all observations for each macroeconomic variable into one of three alternative phases:

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[33] However, conspicuous behaviour on the part of this variable does not by any means let the economic policy makers off the hook, since it is generally not one single determinant, but rather a combination of factors, which are responsible for currency turbulences.

[34] The stock market data were based on the IFC Global Price Index of the respective country, denominated in US $.

- The ***first group*** is made up of those observations which occur in the actual *"turbulent episode"*. It is thus that span of time in which erratic fluctuations in the exchange rate or the foreign exchange reserves occur (repeatedly) at short intervals.
- The ***second group*** comprises those values that occur in a certain span of time (usually twelve months) prior to an episode (for short: *"early-warning period"*).
- The ***third group*** contains the remaining observations, which are classified as a tension-free period in the foreign exchange markets (for short: *"tranquil period"*).

The second step is an analysis of the distribution of the last two samples using univariate testing methods. The observations of the variables during the turbulences themselves are excluded, since they may exert an undesirable influence on the distribution of the results, and ultimately their significance, in light of the violent fluctuations in some variables over this period of time. After excluding the values for turbulent episodes, for each variable nearly 6,000 observations are left over, of which, assuming an early-warning phase of twelve months, nearly 20 % are located in the early-warning window.[35] Following the lines of the analyses performed by Eichengreen et al. (1994) and Moreno (1995), two univariate tests are applied which simply compare some standard descriptive statistics of the observations in the two samples: the t-test for equal mean values (parametric test) and the Mann-Whitney test, a rank sum test (nonparametric test) which examines the median values of the two distributions.[36] Both tests assume the null hypothesis that the statistical features of the variables prior to currency turbulences do not differ from those during periods of tranquillity. A rejection of this hypothesis accordingly allows the conclusion that the mean and median values of the variables, respectively, are different prior to turbulences than in tension-free periods, and that this variable may thus contribute to identifying speculative attacks. The results ascertained in this manner are summarised in Table 3.

The first column contains the macroeconomic variables described in Section 2.2. The second column provides the expected sign. A positive sign means the variable should systematically show a higher value prior to turbulent episodes than in periods of tranquillity, when it comes into consideration as a determinant of speculative attacks according to the theoretical ideas. Thus, according to theoretical considerations, for example one would hypothesise that both

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35 An exception is the change in the stock exchange index, for which nearly 1,000 observations exist.

36 In light of the rather high number of observations, a t-test of identical mean values should be able to provide sufficiently accurate results. The Mann-Whitney test is additionally run in order to underscore the robustness of the results. In the t-test a different variance is permitted for the two samples and the number of degrees of freedom is determined according to a formula devised by Welch. The Kruskal-Wallis test used in other studies to some extent is a more general form of the Mann-Whitney test and leads to the same results. However, a caveat is necessary here: these tests actually presuppose the use of independent random variables, a characteristic which exists in this study only to a limited extent.

the level of foreign exchange reserves as a percentage of imports and its rate of change prior to currency turbulences is lower prior to currency turbulences than in periods of tranquillity.

Table 3
Tests for differences in the behaviour of macroeconomic variables in tranquil periods and prior to turbulences

Variables	Expected sign	t-test	Mann-Whitney
Financial sector variables			
Δ Domestic credit/GDP	+	2.999 **	5.007 **
Δ Domestic credit (private sector)/GDP	+	-2.686	-1.015
Δ Claims of mon. auth. on centr. gov./GDP	+	1.329	7.066 **
Δ Narrow money/GDP	+/-	-2.749 **	-1.427
Δ Broad money/GDP	+/-	-1.937 *	-1.225
Money market indicator (narrow money)	+	1.034	2.588 *
Money market indicator (broad money)	+	1.504	0.591
Foreign exchange reserves/narrow money	-	-7.902 **	-13.170 **
Δ Foreign exchange reserves/narrow money	-	-4.505 **	-3.044 **
Foreign exchange reserves/broad money	-	-11.820 **	-11.229 **
Δ Foreign exchange reserves/broad money	-	-3.334 **	-5.250 **
Inflation differential	+	7.867 **	11.970 **
External sector variables			
Real exchange rate (deviation from trend)	-	-13.809 **	-14.338 **
Δ Real exchange rate	-	-5.688 **	-4.013 **
Current account/GDP	-	-5.835 **	-6.820 **
Trade balance/GDP	-	2.601	1.423
Exports/imports	-	1.128	1.188
Δ Exports	-	-6.654 **	-8.024 **
Δ Imports	+	-1.028	-0.993
Foreign exchange reserves/imports	-	-8.854 **	-10.822 **
Δ Foreign exchange reserves/imports	-	-3.585 **	-4.285 **
US money market rate	+	8,845 **	8,094 **
Real sector variables			
Δ Output index	-	-2.004 *	-3.343 **
Δ Stock exchange index	-	-3.452 **	-3.627 **

Δ = Percentage change from the previous year, t-test for identical mean values of two samples (different variance of the samples permitted, definition of degrees of freedom according to Welch); MW = Mann-Whitney rank sum test, */** significant at a level of 5 %/1 % and the correct sign.

The statistical results show that a series of macroeconomic variables behaves conspicuously differently, on average, prior to currency turbulences than in periods of tranquillity. As regards the ***financial sector variables***, the levels of foreign exchange reserves as a percentage of the monetary aggregate and their rates of change each show the expected sign and a significant test result. Moreover, the change in domestic lending (as a share of GDP) and the inflation differential, both of which show above-average values prior to speculative attacks, speak in favour of an excessively expansionary monetary policy. The change in the claims of the monetary authority on the central government (as a share of GDP) as an approximation of the

fiscal policy stance, too, indicates significant differences in the two samples, at least according to the Mann-Whitney test statistics. A significant test result prior to currency turbulences can be generated for the growth rates of the monetary aggregates only with the help of the t-test, whereas the nonparametric test is unable to refute the null hypothesis. This aggregate, however, shows a disproportionately weak behaviour prior to foreign exchange market turbulences. That could indicate a falling demand for money prior to currency turbulences, which may possibly mirror the increasing currency substitution in those countries suffering from chronically unstable foreign exchange markets. By contrast, neither the change in domestic lending to the private sector nor the money demand indicators prior to turbulent episodes calculated from the estimates give clues to peculiar behaviour.[37] This may possibly be due to the fact that the demand for money in many of those countries is not stable during the estimation period and the underlying estimates were performed using auxiliary variables.[38]

An analysis of the ***external sector variables*** underscores the significance of the change in foreign exchange reserves (seen here as a percentage of imports) prior to the onset of speculative attacks. Furthermore, the statistics show a highly significant result in the deviation of the real exchange rate from the estimated trend, which indicates that prior to typical foreign exchange market turbulences the foreign exchange relations had distanced themselves quite a lot from the fundamentals. The overvaluation of the real exchange rate is also reflected in a below-average export growth. By contrast, imports do not seem to follow a peculiar pattern prior to speculative attacks. That, however, could be a reflection of the fact that as early as in the run-up to currency turbulences, a weakening of the real economy is usually discernible, which means that the price effects expected via the exchange-rate channel might be eclipsed by income effects. This assumption is basically supported by the results of the ***real sector variables***, where both the growth in the output index and increases in the stock exchange index are more subdued than in periods of tranquillity.

The effect arising from the import trend seems to be strong enough so that no conspicuously large deficits appear prior to turbulences in the balance of trade, either, as an average of all episodes. What we know as J-curve effects may contribute to explaining the implausible sign of this variable; according to them, the balance of trade reacts normally to exchange rate changes over the *long term*, but abnormally over the *short* and *medium term*, however, owing to delays in adjustments by enterprises in the pricing of their goods. By contrast, the deficits in the current account balance (as a share of GDP) are, on average, higher prior to speculative

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[37] A possible explanation why the sign is different for the change in lending to the private sector may lie in the fact that currency turbulences often precede banking crises, which are then reflected in a disproportionately weak growth of credit aggregates.

[38] See the indications in Kaminsky and Reinhart (1996, p. 12f) and the empirical evidence of the instability of the demand for money for some Asian countries in Dekle and Pradhan (1997).

attacks than in periods of tranquillity. This may reflect the fact that not only the decreased competitiveness, but moreover also the debt service which is linked to the level of the current external debt position booked in the current account balance, has a bearing on the overall economic situation of a country. Additionally, this is indicated by the US money market rate, too, which is significantly higher on average prior to turbulences in emerging markets. Higher interest rates in the industrialised countries contain not only incentives to invest less capital in emerging markets and even to withdraw it but at the same time increase the debt burden of the country vis-à-vis foreign countries, especially if the loans are taken up in foreign currency as is frequently the case.

The results of three alternative specifications largely underline the robustness of the results presented here (Table 4).

Table 4
Univariate stability tests

Variables		18 months		Asia		post 1985	
Financial sector variables	Sign	t-test	MW	t-test	MW	t-test	MW
Δ Domestic credit/GDP	+	1.8 *	4.3 **	1.1	1.1	0.7	3.5 **
Δ Domestic credit (private sector)/GDP	+	-2.2	-1.2	-0.8	-0.7	-3.3	-1.5
Δ Claims of mon. auth. on centr. gov./GDP	+	-1.5	7.1 **	4.2 **	5.5 **	-0.7	4.1 **
Δ Narrow money/GDP	+/-	2.6 **	1.5	-2.8 **	-2.5 **	2.6 **	0.3
Δ Broad money/GDP	+/-	2.6 **	1.8	-2.7 **	-3.4 **	4.0 **	2.4 *
Money market indicator (narrow money)	+	1.1	3.2 **	0.2	-1.4	-2.3	-0.1
Money market indicator (broad money)	+	-2.3	-0.5	-0.2	-0.7	-4.4	-3.3
Foreign exchange reserves/narrow money	-	-9.0 **	-14.5 **	-11.4 **	-11.4 **	-11.0 **	-9.1 **
Δ Foreign exchange reserves/narrow money	-	-2.3 *	-3.6 **	-3.3 **	-4.6 **	0.6	-0.1
Foreign exchange reserves/broad money	-	-11.7 **	-11.8 **	-10.0 **	-9.6 **	-5.6 **	-4.0 **
Δ Foreign exchange reserves/broad money	-	-2.4 **	-4.4 **	-3.3 **	-4.4 **	1.1	-0.4
Inflation differential	+	9.2 **	13.5 **	2.7 **	2.8 **	6.8 **	9.0 **
External sector variables							
Real exchange rate (deviation from trend)	-	-15.2 **	-15.9 **	-11.1 **	-9.6 **	-5.3 **	-5.8 **
Δ Real exchange rate	-	-5.5 **	-4.9 **	-3.4 **	-1.4	-5.0 **	-3.8 **
Current account/GDP	-	-4.9 **	-6.3 **	-5.9 **	-6.4 **	-1.6	-2.4 *
Trade balance/GDP	-	4.5	2.9	-1.0	-1.3	4.6	3.1
Exports/imports	-	3.1	0.0	0.6	-1.1	4.0	1.5
Δ Exports	-	-4.8 **	-6.4 **	-1.8 *	-3.9 **	-4.4 **	-4.7 **
Δ Imports	+	-1.2	-1.0	0.1	-0.9	-2.2	-1.6
Foreign exchange reserves/imports	-	-9.4 **	-11.9 **	-10.5 **	-9.9 **	-2.0 *	-2.6 **
Δ Foreign exchange reserves/imports	-	-2.4 **	-3.4 **	-2.8 **	-3.5 **	0.6	0.5
US money market rate	+	11.0 **	11.2 **	-0.0	-1.7	5.2 **	5.7 **
Real sector variables							
Δ Output index	-	-1.9 *	-3.5 **	-1.1	-1.0	-1.6	-2.5 *
Δ Stock exchange index	-	-4.1 **	-3.8 **	-8.0 **	-6.4 **	-3.5 **	-3.6 **

Δ = Percentage change from the previous year, t-test for identical mean values of two samples (different variance of the samples, definition of degrees of freedom according to Welch); MW = Mann-Whitney rank sum test, */** significant at a level of 5 %/1 % and the correct sign.

Firstly, the tests are repeated with an early-warning period of 18 months to preclude the results reacting sensitively to the early-warning period chosen here (*ad hoc*) of 12 months. In a second alternative experiment, the same testing method is used to examine only the Asian economies, with around 2,500 observations available per variable. Thirdly, the sample is then limited to the period following 1985, reducing the original sample range to some 3,000 observations.

For numerous variables the results are robust compared with all alternative specifications; the levels of foreign exchange reserves are lower prior to foreign exchange market turbulence in all test statistics than in periods of tranquillity, regardless of whether they are measured in terms of monetary aggregates or imports. The deviation of the real exchange rate from the trend, the change in the stock exchange index, the inflation differential and the growth in exports, too, have the right sign in all specifications and are highly significant. Apart from the Mann-Whitney-Test covering the Asian sample, the statistics additionally point to a sharper appreciation of the real exchange rate prior to turbulences. By contrast, some other variables, independently of the underlying sample, are always either insignificant or have a sign that is at least not immediately congruous with intuition. This category includes increases in domestic lending to the private sector (in terms of GDP), import growth and the balance-of-trade variables. Apart from one single significant result, the null hypothesis that the behaviour of money market indicators prior to turbulences does not differ from that prior to periods of tranquillity cannot be rejected.

4.2. Event studies

These simple test statistics are refined by means of a graphic illustration of the average behaviour shown by macroeconomic variables in a window of twelve months prior to currency turbulences by carrying out event studies. As opposed to the studies by Eichengreen et al. (1995) or Frankel and Rose (1996), who also use event studies to examine currency turbulences, the following is not a study of the entire time span *surrounding* a specific event but instead only of the behaviour of the variable *prior* to the event. Although the analysis remains univariate, this graphic approach can provide at least an intuitive insight into the characteristic patterns of selected macroeconomic variables prior to currency turbulences.

Charts 2a and 2b are made up of 12 illustrations each. Each of these illustrations shows the average course taken by a specific macroeconomic variable in the twelve months prior to the onset of currency turbulences. Chart 2a illustrates the typical pattern of the financial sector variables in this period; Chart 2b summarises trends in the external sector variables and the

real sector variables. In order to get an idea of whether a variable varies from "the norm" on average prior to currency turbulences, in each of these charts, in periods of tranquillity the mean of these variables is normalised to the zero line. Periods of between 1 and 12 are marked off on the horizontal axis, with 1 being the first month of the 12-month early-warning period, and 12 being the last month prior to the onset of turbulences.

The following example is designed to illustrate this basic concept in general terms. The illustration in the lower left-hand part of Chart 2a shows the typical movement of foreign exchange reserves in terms of broad money in the 12 months preceding currency turbulences. In periods of tranquillity this quotient is 25.8 % as an average of all countries, i.e. an average of one-quarter of broad money is covered by foreign exchange reserves in tension-free periods. In the 96 episodes for which data on this variable is available, as early as the beginning of the early-warning period — i.e. 12 months prior to the onset of turbulences — this variable shows an average value of only 21.4 %, which continues to fall thereafter and reaches a low of 16.6 % immediately prior to the beginning of the episode. Since the mean of the observations in periods of tranquillity serves to norm the vertical axis, the chart shows values between - 4.4 and - 9.2, each of which is calculated from the difference between the mean value of the variable of that particular month (calculated for all episodes) and the mean value of all observations in periods of tranquillity. As an average of all episodes, the coverage of the broad monetary aggregate by foreign exchange reserves was therefore 4.4 percentage points at the beginning, or 9.2 percentage points in the end, lower than in periods of tranquillity. To provide an idea of the reliability of the movement of the variables prior to currency turbulences, two-sided confidence intervals are also included.[39]

[39] They are calculated from the sum of the standard error of the observations gathered for a specific month prior to the turbulences and of the standard error of the mean of the variables in periods of tranquillity. This value was then doubled in order to obtain a 95 % confidence interval. In some cases variables do not show significant behaviour even though they were significant in the t-test on the equality of means; this is because many more observations went into the univariate test method, as the mean values of the sample of *all* months prior to turbulences are taken into account, whereas in this case *every* month is observed separately. Owing to the larger number of observations, in the univariate tests the mean values — statistically speaking — can be determined much more precisely. Frankel and Rose (1996) also point out that such a construction of confidence margins is not without pitfalls, as currency turbulences might well not be independent of one another. Since the standard error which underlies the confidence margins has to be re-calculated every month and the number of observations is not the same for each month, the fluctuation width in the individual pictures also varies slightly.

Chart 2a

Pattern of financial sector variables
in the 12 months prior to turbulent episodes

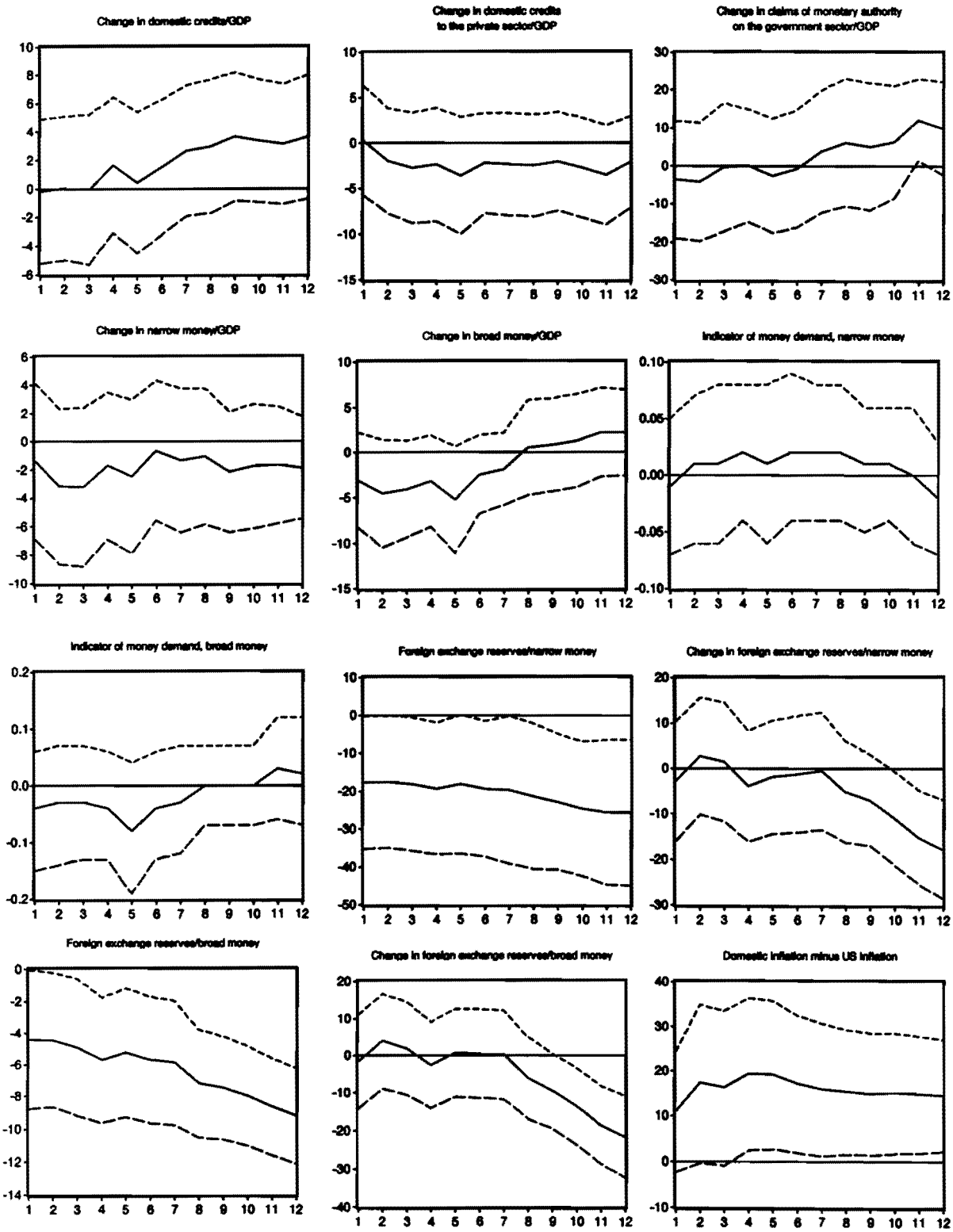
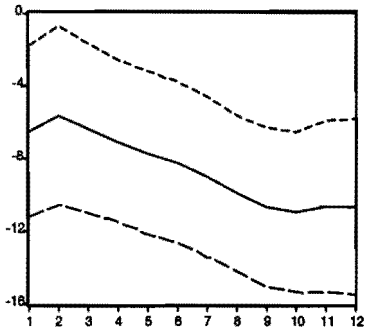


Chart 2b

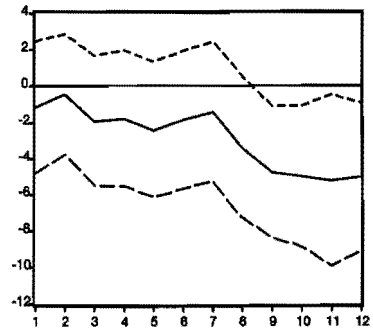
Pattern of external sector and real sector variables

in the 12 months prior to turbulent episodes

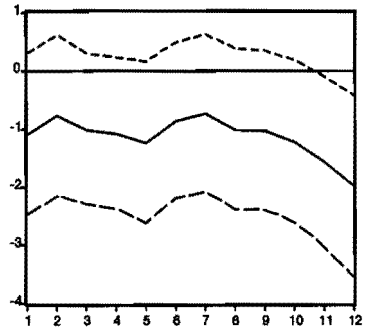
Deviation of the real exchange rate from an estimate with a linear trend



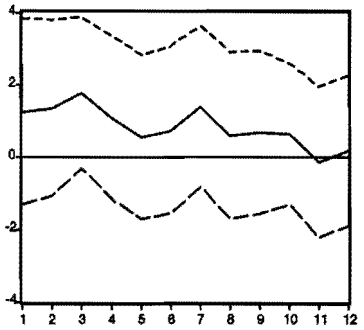
Change in the real exchange rate (+ depreciation)



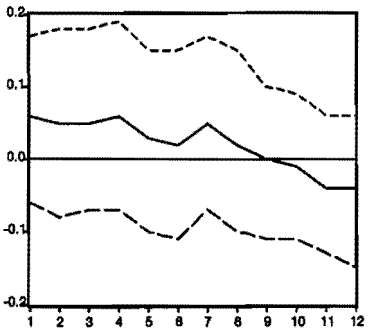
Current account as a share of GDP



Balance of trade as a share of GDP

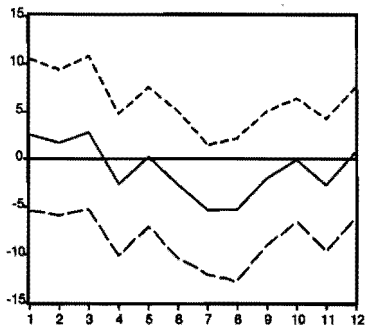


Exports as a share of imports

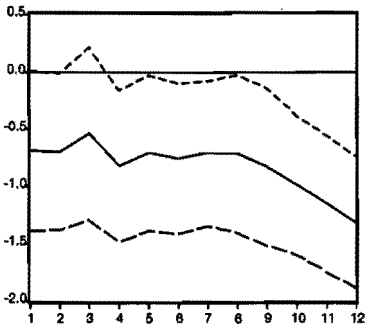


Change in exports, in US $

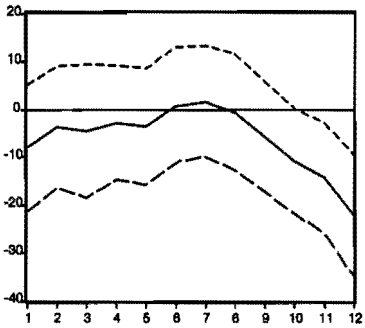
Change in imports, in US $



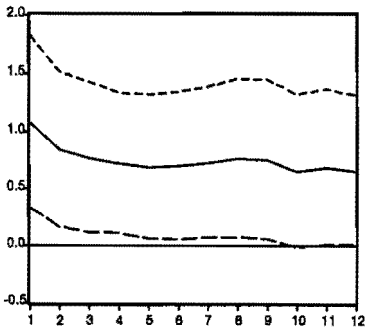
Foreign exchange reserves as a share of imports



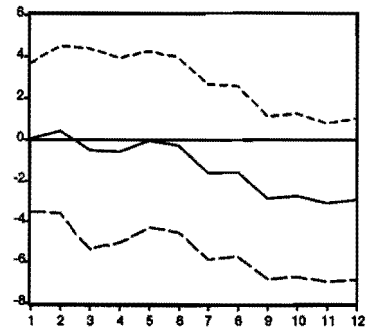
Change in foreign exchange reserves as a share of imports



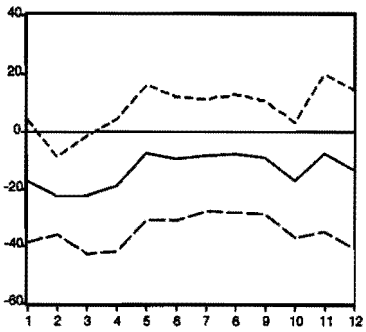
US money market rate



Real growth



Change in the stock exchange index



This procedure is repeated for the 24 macroeconomic variables already studied in the univariate analysis, with data on almost all variables available for more than 80 episodes. The results of the univariate test method are largely confirmed. In the ***financial sector variables***, the foreign exchange reserves (in terms of the monetary aggregates) and the inflation differential show a statistically significant deviation from the norm over (almost) the entire early-warning period. In the changes in foreign exchange reserves, conspicuous behaviour only shows up around six months prior to the onset of turbulences. In that period, though, foreign exchange reserves diminish rather evenly, in a sense confirming central theoretical considerations of the standard models, according to which the foreign exchange reserves already diminish in the run-up to speculative attacks until they fall below a certain critical threshold value, upon which the currency is immediately attacked.

Growth in domestic credit as a share of GDP is also on average higher prior to currency turbulences than in periods of tranquillity, although this must be qualified by admitting that the confidence margin covers the zero line at the 5 % level, which should lead one to interpret this figure with some caution. In the last few months prior to the onset of turbulences, domestic credit as a share of GDP rises by an average of over 3 percentage points more sharply than in periods of tranquillity. This may be considered as an indication that either diminishing foreign exchange reserves are a result of domestic lending being too expansionary or that the contractionary influence of diminishing foreign exchange reserves on liquidity provision is not to be permitted and should be "sterilised" by pursuing an expansionary domestic liquidity policy. Furthermore, growth in claims of the central bank on the government sector rise at an above-average rate prior to currency turbulences. This trend, too, supports one of the standard models' core propositions, i.e. that speculative attacks are typically preceded by an excessively expansionary economic policy which is at times financed by printing money. The growth rates of the monetary aggregates, the growth of lending to the private sector and the money market indicators, however, do not show a conspicuous pattern; the mean values are often close to the zero line, they also occasionally overlap this norm, and at all events the confidence margins cover the zero line quite clearly, which means that no definite results are to be expected even if the confidence level is lowered.

In the ***external sector variables*** the behaviour of foreign exchange reserves initially confirms the course already described above. Moreover, the behaviour of the real exchange rate compared to behaviour in periods of tranquillity also indicates a visible overvaluation prior to currency turbulences over the entire early-warning period, which according to this simple concept averages around 10 % just before the outbreak of turbulences. Here the real exchange rate seems to receive a considerable impetus once again in the last six months prior to the

onset of tension, which probably ultimately undermines confidence in the government's commitment to defend the parity.

These appreciations are reflected in a disproportionately low rate of export growth, which is an average of between 5 and 10 percentage points lower in the last months preceding the onset of turbulence than in periods of tranquillity. Admittedly, that does not mean exports necessarily have to go down in the run-up to tensions on the foreign exchange markets. Whereas the exports of all countries over the entire period of this study grew at an annual average rate of over 13 %, this growth went down to between 3 % and 6 % on average prior to currency turbulences. In imports, however, no reverse pattern appears as a consequence of the real appreciation. On average, import growth is even lower than average during the early-warning period, which can also be attributed to tendencies toward a slowdown in real economic growth during that time span. At all events, output growth was, on average, around 3 percentage points lower than usual immediately prior to currency turbulences, and the stock exchange index also grew more sluggishly than average. These ***real economic factors***, too, should be interpreted with caution, since the confidence intervals used here eclipse the zero line.

The patterns shown by the balance of trade indicators confirm the results of the univariate tests, since they do not permit the diagnosis of peculiar behaviour in the early-warning period. On the contrary, the indicators are sometimes even above the zero line on average, which would document a relatively better balance of trade position prior to currency turbulences. Looking at the current account balance, by contrast, over the entire early-warning period a relatively higher average deficit appears in the run-up; shortly before the onset of currency turbulences, it is some 2 percentage points higher than in periods of tranquillity. This underscores the line of argument introduced in the beginning, according to which external factors may have contributed to the onset of currency turbulences. Moreover, US interest rates are systematically significantly higher prior to typical currency turbulence. The associated higher repayment burden to satisfy the demands of the external creditors is then reflected in a higher current account deficit. The higher money market rates in the US may probably have also led to portfolio shifts by internationally operating investors away from the emerging markets.

4.3. The signal approach and the "extended" signal approach

4.3.1. Methodology

The "signal approach", first used by Kaminsky et al. (1998) to study banking and balance of payment crises, stands in the tradition of univariate explanatory approaches, too.[40] In this analysis, the methods introduced in the preceding text are refined in such a manner that it is no longer just the average behaviour of a variable prior to *all* episodes which is studied but rather the behaviour of the potential early-warning variables prior to *each individual* episode. This avoids inaccurate estimates, which might be attributable to the fact that for example a variable behaves completely normally in the vast majority of early-warning phases with only relatively few "outliers" having such a strong influence on the statistical results that simple statistical tests (erroneously) identify a significant peculiar behaviour of this variable in the run-up to currency turbulences.

From the guiding idea that a variable with useful lead characteristics should almost always show a conspicuous trend prior to each individual speculative attack, it follows that one must make an empirical distinction between "normal" and "abnormal" behaviour of the macroeconomic variables being examined. To this end, a threshold value must be defined for each variable. In this still rather simple concept the informative spectrum of a variable (at any given time) is thus limited to one of two possible findings: either the value of a variable exceeds a certain threshold (yet to be defined) and consequently signals an abnormal behaviour, or it remains below the threshold value and consequently gives no signal.

As a logical continuation of the univariate analysis, the behaviour of these variables within a window of (*a priori*) 12 months prior to currency turbulences will be examined.[41] Whereas an ideal indicator variable would start continually sending signals at the onset of this early-warning period until the outbreak of turbulences, in reality, however, the pattern is abnormal not just in the immediate run-up to currency turbulences but, at times, also in periods of tranquillity. This is a consequence for one thing of the early-warning window chosen *a priori*,

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[40] Kaminsky et al. (1998) base their approach to a large degree on a previous study by Kaminsky and Reinhart (1996). As regards the methodology, this approach has its roots in empirical studies on forecasting turning points in the business cycle; see e.g. Stock and Watson (1989).

[41] However, this assumption is not quite unproblematic, since the length of this early-warning period will not be the same for every episode and every variable examined. However, the early-warning period is always defined arbitrarily. Kaminsky and Reinhart (1996) as well as Kaminsky et al. (1998) assume an early-warning period of 24 months. However, the change in the early-warning period should not have any major impact on the qualitative conclusions. This was also indicated by the univariate tests, which proved to be robust vis-à-vis differing specifications. In terms of the number of turbulences signalled, this is likely to be a somewhat conservative approach, since random influences here can only be erroneously identified as a signal of turbulences in preceding 12 months.

which does not always coincide with the actual early-warning phase. To avoid possible misjudgements, the statistical results calculated in this manner should therefore always be complemented by a graphic result check. For another thing, besides correct warnings, occasionally some false alarms (signals having no visible correlation to currency crises) are triggered; additionally, some attacks are not at all indicated by the macroeconomic variables. This simple framework thus permits four outcomes (Table 5):[42]

Table 5
Framework for classifying signals

		Within 12 months there are ...	
		... currency turbulences	... no currency turbulences
Realisation	Signal is sent	A	B
	No signal is sent	C	D

A variable always sends a correct signal

- if it exceeds a given threshold value (sends a signal) and is followed within 12 months by currency turbulences (A), or
- if it does not exceed a given threshold value (does not send a signal) and is not followed by currency turbulences within 12 months (D).

By contrast, a signal is classified as false

- if the variable exceeds a given threshold value (sends a signal) and is not followed within twelve months by currency turbulences (B), or
- if it does not exceed a given threshold value (does not send a signal) and is followed within twelve months by currency turbulences (C).

This system can be used to derive a yardstick for the indicator's ability to send accurate signals. Kaminsky et al. (1988) propose the "noise-to-signal" ratio as a measure of indicator quality. This measure is the result of empirical answers to two key questions. Firstly, how many accurate warning signals does a variable send prior to currency turbulences in relation to the maximum possible number of warning signals in this period (A/A+C)? And secondly, how

[42] See once again Kaminsky et al. (1998).

often does the variable trigger a false alarm in periods of tranquillity? An insight into these questions is provided by the ratio of the actual number of false signals in periods of tranquillity to the maximum possible number of false signals in periods of tranquillity (B/B+D). From this ratio the "noise-to-signal" ratio is calculated as the ratio of these two quotients [(B/B+D)/(A/A+C)]. A good indicator variable should, for one thing, trigger as few false alarms as possible, accordingly the numerator of the noise-to-signal quotient should be as small as possible. However, a useful indicator should transmit signals as often as possible in the 12 months prior to currency turbulences, which means that in this ratio the denominator should be as high as possible. That means that the closer the indicator is to 0, the more trustworthy a variable will be in diagnosing a fragile macroeconomic situation in the emerging market. By contrast, if the forecast values are subject to a random process, then the expected value of the indicator approaches 1, and the variable's early-warning capability is accordingly limited. The "odds ratio", which can be interpreted as the chances of a given realisation being correct, can alternatively be used to determine the quality of the indicator. In the odds ratio, the product of the correct signals is divided by the product of the false signals [(A*D)/(B*C)]; in the case of a random variable which transmits roughly the same number of correct and erroneous signals the expected odds ratio encompasses 1. An odds ratio of 2 implies that the probability of the signal being correct is estimated to be twice as high as the probability of it being wrong.

Finally, it is necessary to define empirically the concept of "abnormal behaviour of a variable", which has hitherto been used somewhat casually, i. e. to determine the threshold value. Undoubtedly, such an empirical definition always creates a certain dilemma. For one thing, an abnormal behaviour should be flagged as often as possible prior to currency turbulences. Therefore, setting the threshold value at a somewhat low value harbours the danger of simultaneously triggering frequent false alarms in periods of tranquillity. However, if the threshold value is set rather high, in order to avoid obtaining wrong signals in periods of tranquillity, this provokes the risk of not discovering a conspicuous pattern of the variable prior to most episodes of turbulence.[43] Kaminsky et al. (1998) therefore suggest the following approach: after determining for each indicator, according to theoretical considerations, on which side of the distribution a conspicuous behaviour prior to currency turbulences should become visible, in the following step a country-specific threshold should be defined via the quantile rank of the distribution of the data. Those realisations exceeding the threshold value

[43] It is basically also possible to attach different weights to the two types of error. For instance, it is conceivable to weight the error according to the economic costs resulting from not identifying currency turbulences as opposed to the burdens associated with a false alarm. However, it is difficult to quantify such weights with any measure of reliability.

will be labelled as a "signal".[44] The spectrum of possible quantile ranks in their study is set *a priori* at between 10% and 20%. On balance, therefore, for each country the same rank of the quantile is applied; while the threshold values resulting therefrom may differ from one country to another. Thereafter, the "optimum" rank of the quantile is calculated using an iterative process. The criterion used to define what is "optimum" is the minimum of the noise-to-signal ratio (calculated encompassing all countries) which — as defined above — is the ratio of bad signals to good signals.

However, an important reservation concerning these results should already be noted here: once hazardous disequilibria build up before the currency is attacked, the authorities have the opportunity to react. If the government recognises the "sign of the times" early on and uses the remaining leeway in order to induce a lasting correction of the direction of its economic policy, this procedure will identify suitable warning signals for oncoming currency turbulences over a certain period of time; however, after the corrections in economic policy are accomplished, those signals will prove inaccurate (B) and will thus worsen the quality of the empirical findings. It is not possible to correct this influencing factor in an empirical manner.

4.3.2. Empirical findings

The 24 macroeconomic variables listed at the beginning will be analysed according to the methods of Kaminsky et al. (1988) in the following; the results are summarised in Table 6. The sign in the second column shows which side of the distribution of the variables is of relevance to this study. A positive sign means the observations at the tail of the distribution with the high values should appear prior to turbulent periods. For instance, in the growth of domestic lending, according to the positive sign, extremely high values are supposed to show up systematically prior to speculative attacks. The following columns contain (1) the number of currency turbulences for which data are available; (2) the percentage of currency turbulences prior to which the indicator transmits at least one signal in the early-warning phase; (3) the noise-to-signal ratio; and finally, (4) the odds ratio.

[44] Thus, for instance, in export growth that tail of the distribution should be observed on which the low values — i.e., in particular, low growth rates — are located, whereas in the case of import growth, conversely, the tail of the distribution with the high values would have to be examined.

Table 6
Results of the signal approach

Variables	Sign	Number of turb.	Signals prior to turb.	Noise-to-signal ratio	Odds ratio
Financial sector variables					
Δ Domestic credit/GDP	+	80	0.638	0.682	1.635
Δ Domestic credit (private sector)/GDP	+	83	0.313	0.980	1.024
Δ Claims of mon. auth. on centr. gov./GDP	+	82	0.537	0.807	1.309
Δ Narrow money/GDP	+	84	0.417	0.713	1.478
Δ Broad money/GDP	+	83	0.373	0.810	1.266
Δ Narrow money/GDP	-	84	0.357	0.851	1.196
Δ Broad money/GDP	-	83	0.373	0.925	1.078
Money market indicator (narrow money)	+	86	0.372	0.603	1.771
Money market indicator (broad money)	+	86	0.302	0.642	1.648
Foreign exchange reserves/narrow money	-	101	0.317	0.545	1.965
Δ Foreign exchange reserves/narrow money	-	94	0.372	0.630	1.675
Foreign exchange reserves/broad money	-	101	0.307	0.521	2.070
Δ Foreign exchange reserves/broad money	-	93	0.376	0.663	1.579
Inflation differential	+	97	0.227	0.730	1.425
External sector variables					
Real exchange rate (deviation from the trend)	-	103	0.379	0.279	4.474
Δ Real exchange rate	-	97	0.309	0.593	1.820
Current account/GDP	-	63	0.603	0.454	2.515
Trade balance/GDP	-	89	0.382	0.846	1.205
Exports/imports	-	100	0.450	0.642	1.648
Δ Exports	-	95	0.558	0.535	2.028
Δ Imports	+	96	0.469	0.661	1.601
Foreign exchange reserves/imports	-	101	0.317	0.545	1.965
Δ Foreign exchange reserves/imports	-	95	0.453	0.631	1.668
US money market rate	+	103	0.233	0.597	1.792
Real sector variables					
Δ Output index	-	84	0.357	0.729	1.429
Δ Stock exchange index	-	15	0.563	0.739	1.403

With the exception of the stock exchange index and the current account position, there exist data on each variable for more than 80 episodes. The percentage of currency turbulences announced in advance by signals is only rarely higher than 50 %, and thus visibly lower than in Kaminsky et al. (1998), who (with the exception of one variable) receive at least one early-warning signal in advance in most of the currency turbulences they identified. However, one should not jump to conclusions on the quality of the results. This effect is mostly the result of the fact that the early-warning window in this study, at 12 months, is only half as large as in the aforementioned study. By extending the early-warning period, the signalling probability would rise considerably even for a purely random variable without necessarily improving the explanatory content. Moreover, the number of "scores" depends also to a large degree on the rank of the quantile at which the noise-to-signal quotient reaches its minimum. A higher

quantile rank correlates with a greater number of signals transmitted, which means that, *ceteris paribus*, the likelihood of a signal showing up in the early-warning window rises. In this column, for instance, growth in domestic lending has such a high value only because the variable reaches its lowest noise-to-signal value at a quantile rank of 20 %.

Therefore, an analysis of the goodness of fit measures provides a better insight into the quality of the findings. Here, important features of both the findings reached by Kaminsky et al. (1998) and of the preceding test calculations are confirmed. The best signalling behaviour by far is shown by the real exchange rate variable (deviation from its trend). The probability that a given realisation later proves to be correct is over four times higher for this variable according to the odds ratio than the probability that this is an erroneous signal. Furthermore, export growth, the current account position and the level of foreign exchange reserves indicate a relatively reliable signalling behaviour prior to currency turbulences. Their odds ratio is around 2 in each case. By contrast, some variables also confirm their poor performance in the preceding analyses. In private sector credits, both the noise-to-signal quotient and the odds ratio approach 1, which means that over the estimation period the indicator does not permit any reliable conclusions on a country's vulnerability to speculative attacks; in this case the probability of a signal being correct or incorrect is roughly equal. The monetary aggregates' growth rates, too, do not show any convincingly conspicuous behaviour prior to currency turbulences, either, regardless of which side of the distribution of this variable is studied owing to the indefinite nature of the sign. Ditto, neither the balance of trade deficit as a share of GDP nor the increase in claims by the monetary authority on the central government permit a conclusion to be made regarding useful early-warning characteristics following these test calculations.

However, there is a considerable disadvantage in determining the threshold value according to this method, since the same rank of the quantile is taken for each country and, consequently, the indicator sends roughly the same number of signals for each country. By contrast, one should expect a suitable indicator variable to exceed a certain threshold value all the more often, the more frequently the country was the target of speculative attacks. For example, if currency turbulences systematically followed the overvaluation of a currency, in a country that was the victim of a speculative attack only once one would expect to find signals in only one early-warning window which would indicate this situation. By contrast, if a country had to deal with five instances of currency turbulence, then one would expect a good early-warning variable (the early-warning period being of suitable length) to transmit alarms five times as frequently, too. To give this aspect appropriate attention, the signal approach will be extended by calculating the quantile rank in an alternative examination as the maximum possible number of correct signals prior to currency turbulences (generally 12 per episode) as a

percentage of the total number of observations per country ("extended" signal approach). The findings of these calculations are shown in Table 7.[45]

Table 7
Results of the "extended" signal approach

Variables	Sign	Number of turb.	Signals prior to turb.	Noise-to-signal ratio	Odds ratio
Financial sector variables					
Δ Domestic credit/GDP	+	80	0.625	0.459	2.694
Δ Domestic credit (private sector)/GDP	+	83	0.554	0.677	1.627
Δ Claims of Mon. Auth. on Centr. Gov./GDP	+	82	0.610	0.492	2.449
Δ Narrow money/GDP	+	84	0.560	0.568	2.058
Δ Broad money/GDP	+	83	0.542	0.596	1.926
Δ Narrow money/GDP	-	84	0.619	0.528	2.228
Δ Broad money/GDP	-	83	0.506	0.587	1.943
Money market indicator (narrow money)	+	86	0.547	0.491	2.484
Money market indicator (broad money)	+	86	0.465	0.653	1.704
Foreign exchange reserves/narrow money	-	101	0.535	0.381	3.397
Δ Foreign exchange reserves/narrow money	-	94	0.670	0.472	2.576
Foreign exchange reserves/broad money	-	101	0.554	0.426	2.926
Δ Foreign exchange reserves/broad money	-	93	0.677	0.470	2.584
Inflation differential	+	97	0.412	0.529	2.244
External sector variables					
Real exchange rate (deviation from the trend)	-	103	0.388	0.159	8.084
Δ Real exchange rate	-	97	0.330	0.416	2.735
Current account/GDP	-	63	0.698	0.310	4.580
Trade balance/GDP	-	89	0.652	0.548	2.147
Exports/Imports	-	100	0.650	0.505	2.412
Δ Exports	-	95	0.789	0.452	2.766
Δ Imports	+	96	0.615	0.586	1.998
Foreign exchange reserves/imports	-	101	0.604	0.415	2.991
Δ Foreign exchange reserves/imports	-	95	0.758	0.457	2.673
US money market rate	+	103	0.417	0.468	2.681
Real sector variables					
Δ Output index	-	84	0.643	0.528	2.260
Δ Stock exchange index	-	15	0.625	0.598	1.921

The number of currency turbulences in which an alarm is set off in the early-warning window prior to currency turbulences is thus increased considerably. Despite the relatively small size of the early-warning window, now warning signals are transmitted for almost all variables in the vast majority of cases of currency turbulence. The ranking in terms of the indicator quality,

[45] Furthermore, the test results for two variables were able to be improved considerably by only using part of the number of observations derived from the quantile rank of the distribution for each country. For the deviation of the real exchange rate from the trend, only 40 % of the calculated observations were taken into account, and this figure was only 50 % for the change in the real exchange rate.

by contrast, hardly changes — measured in terms of the fitness. In turn, the best results are provided by the real exchange rate, followed by the current account position and the holdings of foreign exchange reserves. At the same time, for all variables the noise-to-signal and odds ratios, and thus the accuracy of the model, improve. An important caveat is necessary here, however, since following these adjustments (purely) random variables have an expected value of 1 for the individual countries, to be sure, yet no longer throughout the whole sample, which makes the measures of quality calculated here somewhat more difficult to interpret, for one thing.[46] The threshold values derived individually for each variable and each country, which are dependent on the number of the past episodes, are better suited to designing an aggregated indicator in order to identify conspicuous behaviour exhibited simultaneously by several variables.

4.3.3. Illustration of the ability to forecast

These results now provide a good starting point for designing a simple consolidated indicator.[47] We will start with long time series which result for each country (provided data were available) as a by-product of the "extended" signal approach and show only two different realisations: if the value of the variable at a given point in time is at least equal to the "critical threshold value" of this variable in a country, the indicator transmits a signal. Formally speaking, the observation S_t^j is given the value 1. Otherwise the realisation S_t^j is valued at 0. Since the calculations on the signal approach were run for a total of 24 variables, these signals can now be aggregated for several variables. In order to take due account of the different fit of the variables, the number k of suitable variables was weighted according to the odds ratio (α^j) when calculating the overall indicator S_t.[48] This simple aggregation approach can formally be stated as follows:

$$S_t = \sum_{j=1}^{k} \alpha^j S_t^j \qquad \text{where:} \sum_{j=1}^{k} \alpha^j = 1$$

If at a given point in time all variables taken into consideration in the overall indicator S_t transmit signals, the indicator shows a value of 1; if none of the variables transmits a signal, the result is an overall indicator of 0. Although the "weighted signals" calculated in this manner must not be interpreted as *probabilities*, their fluctuations may provide at least an

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[46] Rather, preliminary test calculations indicate that given a random variable, the expected value of the noise-to-signal ratio will be around 0.8.

[47] On this see, in particular, Kaminsky (1997), who applies a similar concept.

[48] Kaminsky (1997) discusses different aggregation methods. The approach used here could accordingly be intensified by additionally taking into account the extent to which the threshold value is overshot and undershot.

impression of whether a country is at a given point in time more or less vulnerable to speculative attacks.

There are weighty reasons, however, that speak against taking all variables into account when putting together the overall indicator. An initial problem results from some variables showing a high degree of correlation. For example, those variables which contain the level of foreign exchange reserves as an argument are rather strongly correlated, irrespective of whether imports, narrow money or broad money is taken in the denominator. The same also goes for the rates of change of the foreign exchange reserves. To avoid counting the same sign of looming currency turbulences several times as a signal, thus distorting the overall indicator, only one variable out of such groups is taken into consideration. Since the quotient of the foreign exchange reserves and narrow money achieved the best results in this group in the "extended" signal approach, the following analysis of these variables shall be given preference to the two alternative definitions. Owing to the insufficient indicator quality of the rates of change of differently defined monetary aggregates and the balance of trade variable, similar considerations for these quantities are rendered superfluous.[49]

Moreover, another reason not to take as many variables as possible into account is that the quality of the aggregated indicator does not necessarily improve by adding variables. For the remaining variables, therefore, an iterative procedure has been selected. In putting together the overall indicator, variables are gradually added, ranked in order of their performance in the "extended" signal approach. The quality of the overall indicator calculated in each case is (just like each individual variable before) in turn evaluated along the lines of how frequently warning signals are transmitted prior to currency turbulences and what their quality is. In fact, the percentage of currency turbulences preceded by at least one alarm signal increases in line with the number of variables taken into account without any considerably deleterious effect on the quality of the findings. From a certain number of variables on, though, the quality of the early-warning characteristics of the overall indicator starts to suffer, again. The best results are achieved when taking into account the following seven ($k = 7$) variables (weights in parentheses):

1. Deviation of the real exchange rate from the trend (0.30)
2. Current account position (0.17)
3. Foreign exchange reserves as a percentage of narrow money (0.13)
4. Change in the real exchange rate (0.10)
5. Change in exports (0.10)

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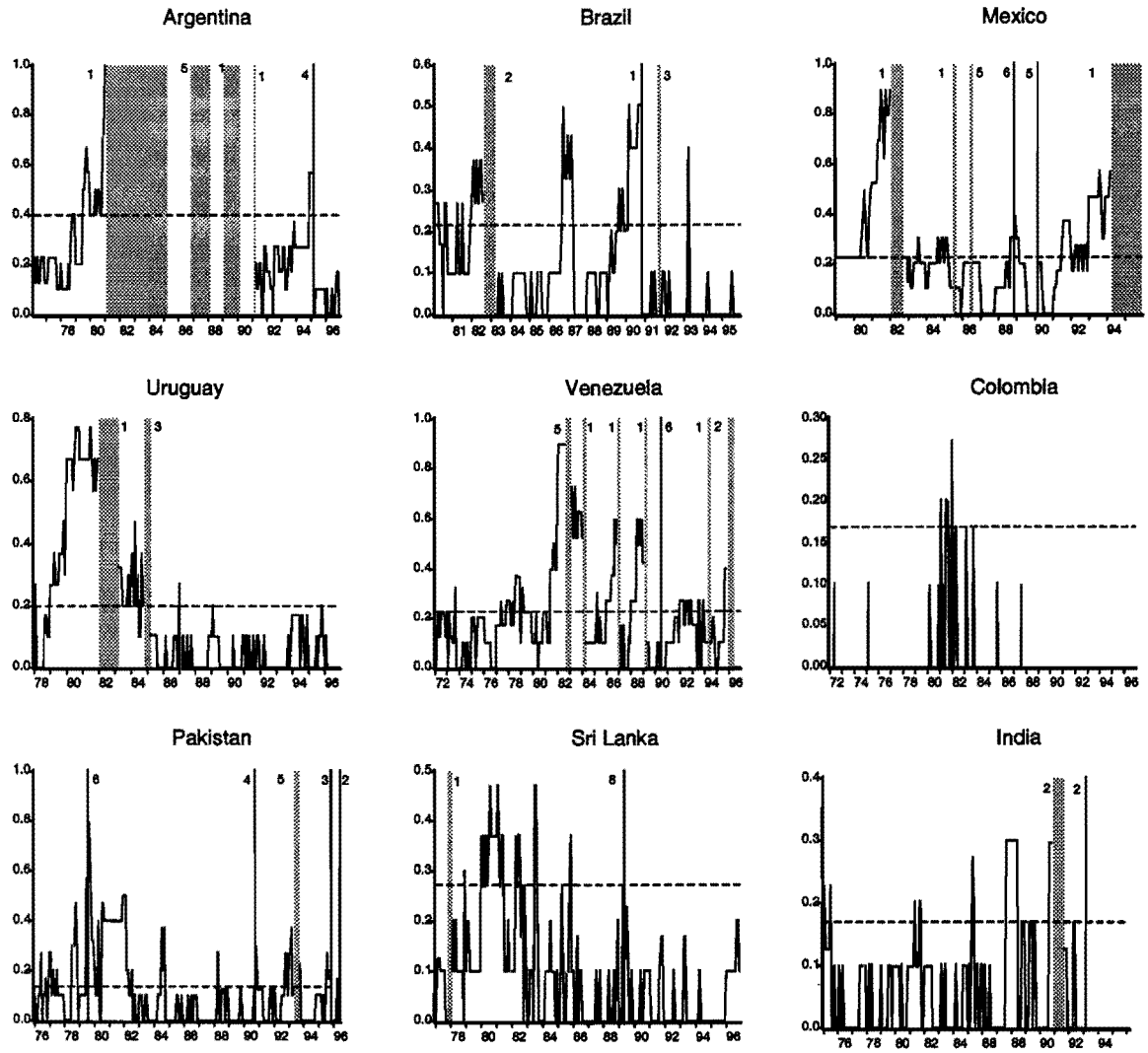
[49] The variables looked at in the following were also examined for being correlated, and are characterised by a rather low level of parallelism.

6. Change in domestic credits as a percentage of GDP (0.10)
7. US money market rate (0.10)

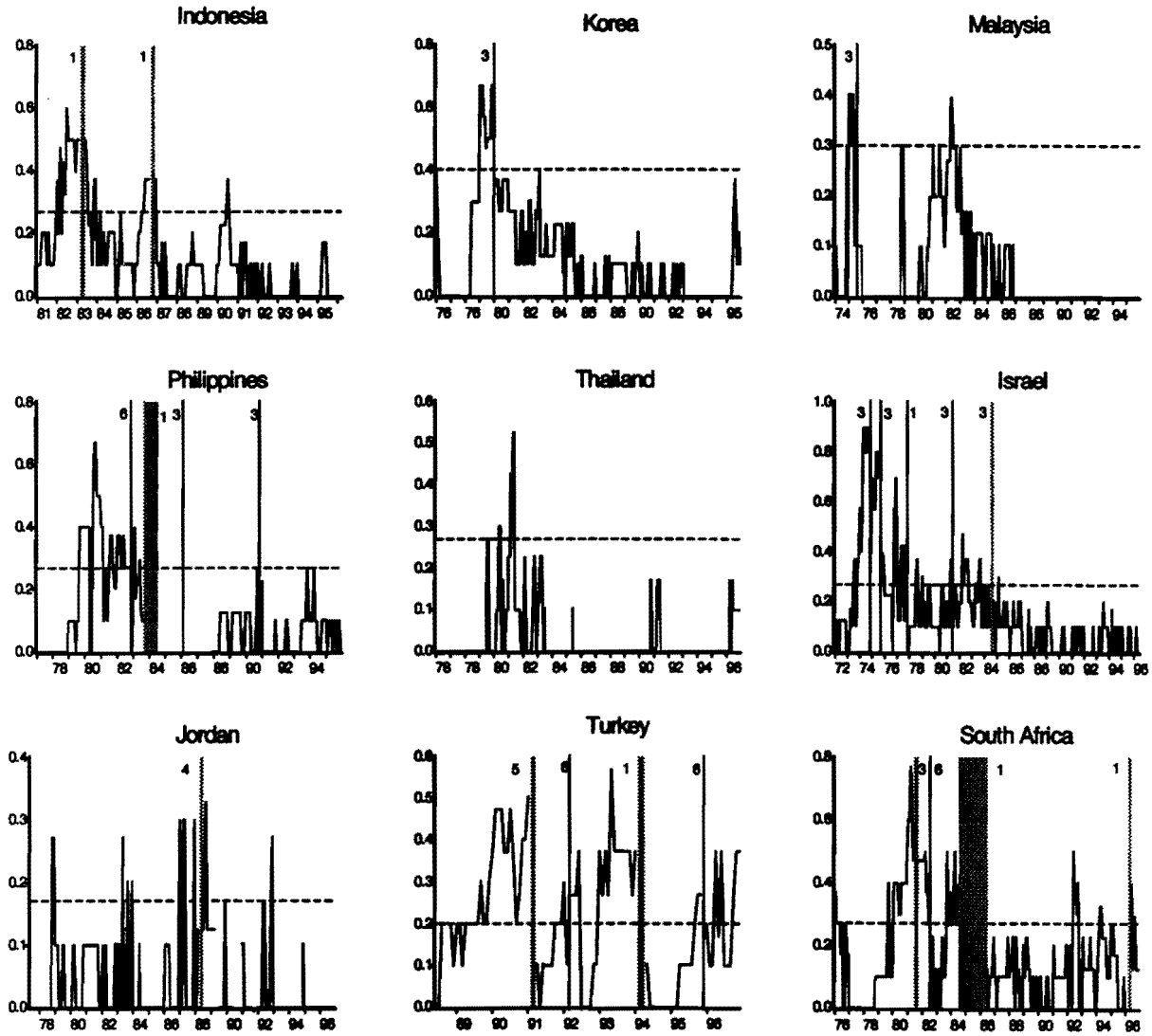
The trends of the weighted signals are then illustrated for each country in individual charts (Charts 3a and 3b).[50]

Chart 3a
Consolidated indicator (signal approach)



[50] Here illustrations were made for only those countries for which currency turbulences were registered in the period under review and for which the data to construct the overall index were also available for considerably long periods of time. Moreover, the consolidated indexes for Thailand and Colombia were illustrated, since rather long time series are available for both countries. The rank of the quantile to calculate the threshold value was calculated here as 6 (half an early-warning phase) divided by the number of observations. By contrast, the signalling behaviour for Peru and Zimbabwe was not illustrated, as these countries' time series show frequent gaps.

Chart 3b
Consolidated indicator (signal approach)



The turbulent episodes in the foreign exchange markets are shown by the vertical lines or — in the case of lengthy turbulences — by the shaded areas. The numbers above characterise the type and intensity of the currency turbulences according to the categories defined in Table 1 (e.g.: severe currency crisis = 1). In addition, threshold values are included on the horizontal axis; in accordance with the "extended" signal approach listed above, they permit statements to be made regarding the quality of the signals for each country. These threshold values are also calculated, analogously to this method, as a quantile of the distribution of the weighted signals per country, with the rank of the quantile in turn being defined while taking into account the number of currency turbulences identified there as a percentage of the overall number of available observations.

Data on the construction of the consolidated indicator exist for a total of 57 crises. Table 8 summarises the signalling behaviour of the consolidated indicator for this sample.

Table 8
Signalling behaviour of the consolidated indicator prior to currency turbulences

	signalled	not signalled	Total	%
Currency crises	36	2	38	95
- severe	18	1	19	95
- strong	5	0	5	100
- ordinary	13	1	14	93
Speculative attacks	14	5	19	74
- severe	3	1	4	75
- strong	3	3	6	50
- ordinary	8	1	9	89
Total	50	7	57	88

No less than 88 % of the time, in the 12 months prior to currency turbulences, at least one warning signal was transmitted. As is shown by the charts, during the early-warning phase, however, considerably more than just one signal was sent, often throughout the entire early-warning period of time and even prior to this period. In the cases of currency crises, the percentage of forecast turbulences, at 95 %, is once again higher. These findings permit the conclusion that currency crises are shown more clearly by the early-warning variables examined here than speculative attacks. Only two of the total number of 38 currency crises were not preceded by a warning signal from the overall indicator in the early-warning window: a *severe* currency crisis in Sri Lanka in the late seventies and an *ordinary* currency crisis in Brazil in autumn 1991. By contrast, the five *strong* currency crises were without exception preceded by at least one signal.

Especially in the early eighties the indicator quite insistently pointed out macroeconomic imbalances in some emerging markets (Chart 3). In Mexico, Uruguay, Venezuela and Indonesia, the overall indicator skyrocketed during that period of time, and reached record levels in all those countries immediately prior to the onset of the crises. In the case of Argentina, in early 1981 — prior to the outbreak of a *severe* currency crisis — every single warning light flashed up simultaneously. But in the early nineties, too, the indicator displayed conspicuously high values, indicating macroeconomic disequilibria quite visibly prior to currency turbulence. In Brazil, prior to the currency crisis which broke out in the autumn of 1990, the indicator was more than twice the threshold value; the indicator transmitted unmistakable warning signals before the currency crisis in Turkey in early 1994; and in the run-up to the Mexican peso crisis, the indicator spent more than a year at a level twice that of the critical threshold value. The signalling behaviour is not quite as pronounced prior to speculative attacks, which did not immediately culminate in currency crises, as it is prior to currency crises. In nearly three-quarters of all cases, however, at least one early-warning signal has been transmitted during the early-warning phase, too.

The quality of the signalling behaviour will now be judged for each country. However, the charts indicate that the early-warning period is often quite different from one crisis to the next. For example, using this framework, initial signs of a fragile economic situation could be identified as early as some 32 months prior to the outbreak of the peso crisis in Mexico in 1994. By contrast, in Indonesia in 1986, the first warning lights only lit up five months prior to the currency crisis. If the early warning phase defined as 12 months *a priori* does not represent the closest thing possible to an optimum early-warning period (on average), the noise-to-signal quotient can be improved by extending or contracting the early-warning window. In Table 9 below, the noise-to-signal quotients and the corresponding odds ratios are listed for those countries for which a sufficient quantity of data exist for at least one early-warning phase (12 months) during the period under review.

It follows from the table that according to the odds ratio, given a 12-month early-warning period, the best indicator characteristics can be ascertained for Korea, Uruguay and Indonesia. Quasi-optimum indicator features can be ascertained in this early-warning window for the currency crisis in Korea in the early eighties. Precisely one year prior to the outbreak of the crisis, the overall indicator started transmitting warning signals, and continued this signalling behaviour over the entire early-warning period. At the same time, the overall indicator remained consistently below the threshold value in the remaining (tranquil) period. Given a lack of erroneous signals, this resulted in an odds ratio of infinity, or a noise-to-signal quotient of zero. In the case of Uruguay, one is tempted to assume that the quality of the indicator could potentially be improved by a longer early-warning period. In the run-up to the severe

currency crisis in early 1982, the indicator continually sent alarm signals since January 1979; however, these signals were (erroneously) classified as "false" in the first two years according to the method applied here. After the last currency crisis in 1984-85 the indicator reported a false alarm only sporadically and at irregular intervals. In Indonesia, too, the overall indicator visibly announced the two severe currency crises in the eighties, then falling rapidly back below the threshold value. A short-lived false alarm was triggered here once again in July 1990 and August 1990.

Table 9
Quality of the signalling behaviour of the consolidated indicator

	Noise-to-signal ratio	Odds ratio
Argentina	0.162	13.950
Brazil	0.210	8.766
India	0.586	1.891
Indonesia	0.078	36.250
Israel	0.159	17.767
Jordan	0.173	7.370
Korea	0.000	∞
Malaysia	0.056	34.857
Mexico	1.039	0.932
Pakistan	0.862	1.221
Peru	1.650	0.500
Philippines	0.418	3.257
South Africa	0.234	8.941
Sri Lanka	2.467	0.377
Turkey	0.735	1.995
Uruguay	0.208	46.829
Venezuela	0.270	8.235
Zimbabwe	0.362	8.348
Total sample	0.229	8.048

By contrast, Sri Lanka, Peru and Mexico have the poorest rankings in this table. Sri Lanka's noise-to-signal quotient of 2.5 and its odds ratio of 0.4 give reason to assume that the movement of the macroeconomic variables here in the past hardly permitted an insight into the country's vulnerability to speculative attacks. The severe currency crisis in late 1977 remained completely undiscovered by the overall indicator, and just before the attack in May of 1989 the overall indicator only reached the threshold value once in the entire early-warning window. By contrast, in the period between these events, false alarms were triggered often and sometimes repeatedly, which means the accuracy of the overall indicator for this country is to be assessed as insufficient. By contrast, Mexico is a good example of how the precision of the summary measures can depend on the size of the early-warning window and that therefore an assessment of the characteristics of the consolidated indicator should always be made in two stages: firstly, using the measures of quality, and secondly, using the charts. Whereas the

measures of quality show, precisely in the case of Mexico, that the consolidated indicator's forecast quality was hardly better than that of a purely random variable, if we take a quick look at the course of the overall indicator, we see that at least in the run-up to each currency *crisis*, lasting warning signals were transmitted. When calculating the measures of quality, by contrast, a particularly important factor is that for one thing the consolidated indicator transmitted warning signals very early on prior to the "severe crises", signals which were erroneously categorised as wrong signals by the window of 12 months chosen *a priori*. For another thing, when calculating the measure of quality designed in this manner, no account is taken of the fact that "only" the less burdensome speculative attacks remained undiscovered. In any event, one gains the visible impression that in India and Pakistan the overall indicator's early-warning capability is hardly better than in Mexico, although here the measure of quality points to a different outcome.

4.4. Logit analyses

4.4.1. Methodology

The multivariate analysis introduced as part of the "extended" signal approach (without taking into account the correlation structures of the explanatory variables) is continued in this section in the form of a regression analysis. Since the behaviour of macroeconomic variables is to be analysed in different situations — early-warning phase versus a phase of tranquillity — and thus qualitative factors are used as selection criteria, such an analysis ought to be performed with a binary dependent variable. In concrete terms, a multivariate logit model is estimated in which the observations within the episode itself are left out, the independent variable is set at 1 during the early-warning period, and is set at 0 during the remaining periods of tranquillity.[51] The binary dependent variable is thus specified as follows:

$$Y_{it} = \begin{cases} 1 & \text{in the early - warning period} \\ 0 & \text{in periods of tranquillity} \end{cases}$$

where: $i = 1, ..., N$; $t = 1, ..., T$.

The estimation is run using a panel data approach, i.e. the time series of all countries are entered into the calculations simultaneously. For each country a constant d is inserted in order to capture country-specific fixed effects. In concrete terms this is specified by the following equation:

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[51] An estimation of what is called a linear probability model using ordinary least squares would be problematical, since in this case the residuals are not normally distributed and are heteroscedastic, and the predicted values are not necessarily between 0 and 1 (see e.g. Maddala 1992).

$$Y_{it}^{*} = \beta' X_{it} + d_i + u_{it}$$

Furthermore, we shall assume that there exists a given threshold value $\ddot{Y}_i$ in each country, from which this country is assessed as tending to be vulnerable to currency turbulences:

$$Y_{it} = \begin{cases} 1 & \text{if } Y_{it}^{*} > \ddot{Y}_i \\ 0 & \text{if } Y_{it}^{*} \leq \ddot{Y}_i \end{cases}$$

In this model Y^{*}_{it} represents a latent — i.e. not directly observable — endogenous variable and expresses to a certain extent the vulnerability of country i at time t to currency turbulences. This variable is explained by the coefficient vector ß (to be estimated), together with the exogenous variables X_{it} and the country-specific constants d_i (to be estimated); u_{it} is a logistically distributed error term with an expected value of 0. Formally speaking, the "tendency" of a country to be vulnerable to speculative attacks under certain macroeconomic circumstances is expressed by the expected value in the latent variable, which can be defined more precisely by the following equation:

$$P_{it} = \text{prob}(Y_{it} = 1 | X_{it}, \beta, d_i) = E(Y_{it} | X_{it}, \beta, d_i) = F(\beta' X_{it} + d_i)$$

where E is the expectation operator. F represents the underlying distribution function. In the estimating procedure used here, a (cumulative) logistic probability distribution is assumed; the estimation itself is run, as usual, using the maximum likelihood method.[52] Here the distribution function acts as a probability transformation. From these considerations the result is that the expected value of the latent variables to be estimated can be shown as follows:

$$P_{it} = \frac{1}{1 + e^{-(\beta' X_{it} + d_i)}} \quad .$$

Thus the log likelihood function to be maximised is:

$$\ln L = \sum_{i=1}^{N} \sum_{t=1}^{T} [Y_{it} \ln P_{it} + (1 - Y_{it}) \ln(1 - P_{it})] \, .$$

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[52] Such a logit approach would actually require an estimation using the *conditional* maximum likelihood method (Chamberlain 1980, Maddala 1987). Baltagi (1995, p. 179), however, points out that the estimates of the parameter values are (asymptotically) consistent if, as in this study, very long time series exist for the countries being studied. See also the formal proof in Chamberlain (1980, p. 227). As an alternative, a probit model with random effects could also be estimated. However, this method only generates undistorted estimates if these random effects and the exogenous variables are not correlated. Demirgüc-Kunt and Detragiache (1998), however, claim that this seems unlikely in practice.

4.4.2. Estimation results

The choice of the explanatory variables is initially based on the "extended" signal approach. The regression analysis therefore starts with a group of seven variables which in the preceding approach proved capable of forecasting currency turbulences. Further variables are then gradually added to this abbreviated catalogue of variables, thus reassessing the robustness of the results vis-à-vis alternative specifications. The table below illustrates the findings of the logit estimates conducted in this fashion. To underline anew the fact that the results do not react very sensitively to the length of the early-warning period, the estimates are examined for two different window lengths (12 months and 18 months).

Table 10
Logit estimations I:[a)]
All countries, varying early-warning periods, tried and tested variables

Variables	Expected sign	12 months	18 months
Financial sector variables			
Δ Domestic credit/GDP	+	0.002	0.001
Foreign exchange reserves/narrow money	-	-0.003 **	-0.003 **
External sector variables			
Real exchange rate (deviation from the trend)	-	-0.027 **	-0.024 **
Δ Real exchange rate	-	-0.003	-0.003
Current account/GDP	-	-0.061 **	-0.054 **
Δ Exports	-	-0.016 **	-0.011 **
US money market rate	+	0.090 **	0.115 **
McFadden's R^2		0.188	0.198
Number of observations		3956	3956

a) Estimated by using fixed effects. Chile, Colombia, the Czech Republic, Hungary, Poland, the Slovak Republic and Slovenia are excluded from this estimation method.
Δ = Change from the previous year in percent.
** Significant at a level of 1 %.

The test calculations, in turn, confirm important results of the earlier analyses. Since a nonlinear method is used here, however, it is difficult to interpret the coefficients. Although the respective sign correctly shows the direction of the impact exerted by the independent variable on the dependent variable, the parameter values themselves do not permit a conclusion to be made regarding the strength of the relationship.[53] All variables have the expected sign. According to these estimates, in the run-up to speculative attacks significant

53 The coefficient shows the effect of a 1 % change in the exogenous variables on $\log(P_i/(1-P_i))$. The influence exerted by the exogenous variables thus also depends on the respective slope of the cumulative logistical distribution at the starting point. Since the slope is also very low at the tails of the distribution, an increase in the probability requires a considerably stronger impact than in the middle of the distribution.

correlations can be identified in particular for five variables. In this early-warning period, the levels of foreign exchange reserves are strikingly low, the real exchange rate tends to be overvalued, the current account deficit is excessively high, export growth undergoes a pronounced decline, and short-term foreign interest rates are relatively high. By contrast, this specification can confirm neither a significant influence on the growth of domestic credits (as a percentage of GDP) nor on the change in the real exchange rate. The alternative specifications regarding the early-warning period lead to very similar results.[54]

In the following, some variables shall be added. On the one hand these variables show rather favourable characteristics in the univariate analysis of the "extended" signal approach, yet on the other hand they are not included in the multivariate study of this approach, so as not to diminish the quality of the overall indicator. In the multivariate logit method applied here, however, the results might be different owing to the attention being paid to the correlation structures. Seven additional variables are therefore included in the first alternative estimate. The results of these estimates are presented in column (1) of Table 11.

The significance and the sign of the variables from the preceding specification are confirmed in this estimate, too. Moreover, from the first group of variables, growth in domestic credits is also showing statistically significant behaviour in the run-up to currency turbulences and some newly added variables are also statistically significant. As regards the financial sector variables, both monetary growth and the inflation differential seem to provide an important explanatory contribution. By contrast, these test calculations are unable to detect any discernible influence by the change in foreign exchange reserves, the change in claims by the monetary authorities on the central government or by the estimated money demand indicators. In the external sector variables an implausible result emerges: although a significant effect can be ascertained for the (relative) balance of trade position, it is not pointing in the expected direction. The results of the estimates without these variables listed in the second column, though, confirm that this variable does not have too strong an effect on the robustness of the results. The estimations in the third column, too, show that the stability of the results is not diminished if one leaves out those variables which proved to be insignificant in the preceding computations.

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[54] McFadden's R^2 is defined as 1 minus the quotient of the log likelihood value of the unrestricted model (log L_{UR}) and the log likelihood value of the restricted model (log L_R). Here, L_{UR} is the maximum of a likelihood function which is maximised regarding all parameters, whereas L_R measures the maximum of a likelihood function with a constant only. $L_R \leq L_{UR}$ applies here, and thus also $0 \leq$ McFadden's $R^2 \leq 1$; this R^2, however, is not comparable with the usual measure of goodness of fit from the linear regression model. See Maddala (1992).

Table 11
Logit estimations II:
All countries, additional variables

Variables	exp. sign	(1)[a]	(2)[a]	(3)[a]	(4)
Financial sector variables					
Δ Domestic credit/GDP	+	0.009 **	0.009 **	0.007 *	0.004
Δ Claims of mon. auth. on cent. gov./GDP	+	0.002	0.002		
Δ Narrow money/GDP	+/-	-0.010 **	-0.010 **	-0.010 **	-0.008 **
Money market indicator (narrow money)	+	-0.316	-0.335		
Mon. reserves/narrow money	-	-0.005 **	-0.006 **	-0.005 **	-0.004 **
Δ Mon. reserves/narrow money	-	-0.001	0.000		
Inflation differential	+	0.013 **	0.015 **	0.011 **	0.008 **
External sector variables					
Real exchange rate (Dev. from the trend)	-	-0.040 **	-0.038 **	-0.034 **	-0.025 **
Δ Real exchange rate	-	0.002	0.003		
Exports/imports	-	0.734 **			
Current account/GDP	-	-0.094 **	-0.064 **	-0.066 **	-0.038 **
Δ Exports	-	-0.015 **	-0.014 **	-0.015 **	-0.016 **
US money market rate	+	0.055 **	0.063 **	0.074 **	0.080 **
Real sector variables					
Δ Output index	-	0.007	0.005		
McFadden's R^2		0.218	0.213	0.208	0.088
Number of observations		3844	3844	3956	4502

[a] Estimated by using fixed effects. Chile, Colombia, the Czech Republic, Hungary, Poland, the Slovak Republic and Slovenia are excluded from this estimation method.
Δ = Change from the previous year in percent.
** Significant at a level of 10 %/1 %.

The fourth specification is estimated in Table 11 to examine the robustness of the findings with regard to underlying samples. Demirgüc-Kunt and Detragiache (1998) point out that the use of logit estimations with panel data and fixed effects leads to a certain distortion, as in this procedure all countries in which data do not exist for any early-warning periods are automatically eliminated from the control sample. Therefore, in equation (4) the specification from equation (3) is estimated once again without the country-specific dummies. This raises the number of observations once again by over 10 %. Here, too, though, the statistical results prove to be rather robust. Only in growth in domestic credits (as a share of GDP) is it no longer possible to come up with a statistically significant result at the usual levels.

Starting from equation (3) in Table 11, four additional sensitivity analyses are run in Table 12. In the first two columns, the extent to which regional differences affect the results is analysed.[55] To this end the overall sample is subdivided into different subsamples, with the

[55] See also Kaminsky and Reinhart (1998) about regional differences in the behaviour of macroeconomic variables prior to currency crises and banking crises.

robustness of the relationships being examined in the Asian countries and then in the Latin American countries. Finally, the estimation period is restricted to the period following 1985 to ensure that the far-reaching steps taken to liberalise capital movements in the eighties did not compromise the stability of the structural relationships. The econometric findings should be treated with more caution, though, since both the number of degrees of freedom and the currency turbulences identified therein are visibly reduced by these regional and temporal constraints, respectively.

Table 12
Logit estimations III:
Stability tests

Variables	exp. sign	Asian countries[a)]	Latin American countries[b)c)]	Latin American countries[b)d)]	Period following 1985[c]
Financial sector variables					
Δ Domestic credit/GDP	+	0.021 **	-0.011 **	-0.005	0.013 **
Δ Narrow money/GDP	+/-	0.033 **	-0.015 **	-0.014 **	-0.015 **
Foreign exchange reserves/narrow money	-	-0.049 **	-0.006 **	-0.004 **	-0.009 **
Inflation differential	+	0.043 **	0.006 **	0.006 **	0.025 **
External sector variables					
Real exchange rate (dev. from the trend)	-	-0.080 **	-0.026 **	-0.023 **	-0.053 **
Current account/GDP	-	-0.122 **	-0.024	-0.031 *	-0.080 **
Δ Exports	-	-0.021 **	-0.035 **	-0.025 **	-0.005
US money market rate	+	-0.212 **	0.157 **	0.243 **	0.179 **
McFadden's R^2		0.286	0.222	0.223	0.256
Number of observations		1876	1152	1152	1811

a) Asia includes India, Indonesia, Korea, Malaysia, Pakistan, the Philippines, Sri Lanka and Thailand.
b) Latin America includes Argentina, Brazil, Mexico, Uruguay and Venezuela. No data for early-warning periods exist for Chile and Colombia; therefore, these countries have been excluded in this method.
c) 12-month early-warning period.
d) 18-month early-warning period.
All estimates using fixed effects.
Δ = Change from the previous year in percent.
*/** Significant at a level of 10 %/1 %.

The regression encompassing these subsamples once again backs up the results presented above. It confirms the hypothesis postulated at the beginning that important fundamentals behave differently prior to currency crises than in periods of tranquillity. However, there are some noteworthy "flaws": In the subsample covering the Asian countries, the US money market rate is significant, but does not have the expected sign (Column 1).[56] There are two conceivable explanations for this behaviour. For one, the sample covers some South Asian economies which impose considerable restrictions on international capital flows (e.g. India, Pakistan, Sri Lanka). However, this rationale does not explain the significance of the

[56] This result is no different even if the early-warning period is extended to 18 months.

correlation we have revealed. For another, the Japanese interest rates, too, may be of greater importance especially to the Asian economies than, say, to Latin America. Substituting the US interest rate with a short-term Japanese interest rate, while simultaneously excluding the three aforementioned South Asian economies, reveals that the foreign interest rate has a significantly positive effect.

The results of the second subsample, encompassing Latin America (column 2), do confirm the preceding findings, yet here, too, two flaws show up which we will now discuss briefly. First, growth of domestic credits does not show the expected sign despite the continually significant influence. Secondly, a conspicuous pattern for the current account position prior to currency turbulences in Latin America cannot be detected. However, both (somewhat problematic) findings are found to react quite sensitively to the early-warning period defined *a priori* (column 3). If this time span prior to currency turbulences is extended from 12 months to 18 months, then the sign of the growth of credits remains implausible, yet the null hypothesis that the parameter value does not differ from zero, and that consequently this variable may not exert a statistical influence, cannot be rejected. Moreover, for the current account position the expected sign can be confirmed and the variable also proves to be significant at the 10 % level of significance under this alternative specification. All other variables remain unaffected by the extension of the early-warning period; they retain both their plausible sign and, by and large, their level of statistical significance.

The regression covering all countries over a sample period from 1985 (column 4) illustrates the fact that the fundamental structural relationships have not been changed notably by the advancing globalisation of the financial markets since the mid-eighties, as was hypothesised earlier. Given an early-warning phase of 12 months, there is only a lack of empirical evidence regarding the influence exerted by growth in exports. But here, too, one is able to re-establish a statistically significant relationship by extending the early-warning period to 18 months at the 5 % level.

On balance, therefore, the multivariate regression calculations, too, buttress the hypothesis that numerous macroeconomic variables behave differently prior to speculative attacks and currency crises than in periods of tranquillity. Regardless of the underlying sample, prior to typical episodes of currency turbulence the real exchange rate seems to be overvalued, foreign exchange reserves are unusually low, and the inflation differential is relatively high. Moreover, the various test calculations also provide logical evidence that high current account deficits, lower-than-average export growth and high world interest rates increase the vulnerability of emerging markets to currency crises. Regarding the immediate economic policy stance (e.g. towards growth of domestic credit), however, only cautious conclusions

can be drawn from the multivariate analysis, since both the sign and the significance of the estimated results depend at times on the chosen specification.

5. Conclusions

The present paper examined the statistical features of a broad spectrum of rather easily available macroeconomic variables, based on a comprehensive and comparatively homogeneous sample of emerging markets having sufficiently well-developed domestic financial markets, regarding the behaviour of these variables prior to currency turbulences. On balance, the empirical analysis underpins the hypothesis presented at the outset that speculative attacks and currency crises in those countries are generally not random events resulting from actions taken by fickle speculators which are completely detached from economic fundamentals but that, in fact, macroeconomic imbalances were frequently clearly looming on the horizon in the run-up of turbulences. The behaviour of a number of macroeconomic variables prior to turbulences varied significantly from their behaviour in periods of tranquillity; an overall indicator devised on the basis of such variables produces fairly reliable results. In nearly 90 % of the episodes, the indicator signals conspicuous behaviour in the year prior to currency turbulences, and in the majority of countries, too, with sufficient accuracy. On the whole, undesirable macroeconomic trends in the past are likely to bear at least partial responsibility for many turbulences in the foreign exchange markets of the emerging economies.

In detail, it is remarkable that each of the applied statistical methods provides weighty evidence that currency turbulences were typified by excessive real appreciation of the currency, low levels of foreign exchange reserves and sub-par export growth. The analysis thus underpins important findings of earlier analyses (Frankel and Rose 1996; Kaminsky et al. 1998). In addition, along the lines of Frankel and Rose (1996) various test statistics indicate that US interest rates, too — and thus factors beyond the control of the economic policy makers in the emerging markets — may increase emerging markets' vulnerability to speculative attacks. Both the rather balanced distribution of currency turbulences across time and the merely average performance of this variable in the "extended" signal approach, however, indicate that rising foreign interest rates can hardly be blamed for triggering speculative attacks. Rather, they tend only to exacerbate tensions in those countries where other fundamental imbalances already exist, such as by impinging on those countries' debt service. Whereas Frankel and Rose (1996) were unable to ascertain a significant correlation regarding the current account position, this paper furnished empirical evidence that the current-account deficits were disproportionately large prior to currency turbulences. As opposed to the current account position, the trade balance and import growth variables

perform quite poorly. By contrast, most of the empirical evidence also favours a relatively high inflation differential in the run-up to speculative attacks. Here, though, the low level of forecast accuracy in the signal approach gives reason to assume that the statistical features may be influenced by some "outliers".

As regards monetary and fiscal policy, only very cautious conclusions may be drawn from the present study. Granted, the univariate test method does indicate significantly higher values prior to currency turbulences in both the growth of domestic credits and of claims by the central bank on the central government (a rudimentary variable with which to capture fiscal policy). The event studies also show that these variables tend to rise in the early-warning period (albeit at a lower level of significance). However, those variables show only a mediocre performance in the signal approach and show rather sensitive behaviour to alternative specifications of the multivariate logit approach. In the change in various monetary aggregates as a percentage of GDP the sign expected in theory is not determined unambiguously and empirically varies, also depending on the specification of the sample selected. This may also reflect the fact that currency substitution is more widespread in some regions than in others. For that matter, neither credit growth to the private sector nor the money demand variables allow conclusions regarding a peculiar behaviour prior to currency turbulences. However, these findings may owe something to the fact that the money demand in many emerging markets was unstable during the period under review and that therefore the simple approach chosen here is inappropriate. The real economic determinants do not yield a clear picture, either.

Despite the comprehensive data and the numerous procedures applied in this analysis, there is still substantial scope for extending and outlining these methods in greater detail. For instance, only rather coarse approximations are used for some variables with considerable forecasting ability. Both the use of more ambitious methods of empirically assessing the exchange rate relations and the refinement of statistical methods to determine persistent current account deficits might possibly improve the results even further. Some other conceivable influencing factors are left out of this analysis. For one thing, owing to the lack of available data, for instance, the debt structure of the emerging markets is not included. Even if it will hardly be possible to reconstruct data so far back in the past that they could be integrated into a related statistical analysis, the efforts introduced so far to gather such data more systematically should be continued unfailingly so that in future, if necessary, such insights can be added to an assessment of emerging markets' vulnerability to currency turbulences as a qualitative complement. For another thing, some elements are excluded because they are laden with major difficulties with regard to their definition and delineation. The political stability, the fragility of the domestic banking system or contagion effects emanating from currency crises

are likely to have an impact on a country's vulnerability to speculative attacks. Consistently taking these factors into account may also enhance the explanatory content of the aforementioned calculations. Finally, in terms of the methodology, out-of-sample forecasts may be useful in order to better substantiate the postulated relationships. Here, an interesting idea would be to apply the methods to the Asian currency crisis, for which data only existed for a very few observations for the early-warning period as this sample was being compiled.

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