Karmann, Alexander; Greßmann, Oliver; Hott, Christian

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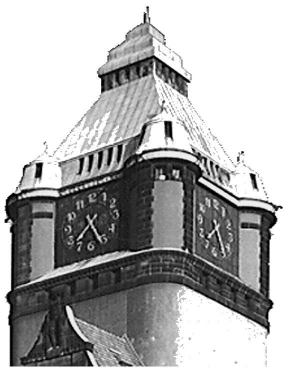
by

Alexander Karmann, Oliver Greßmann and Christian Hott



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Adresse des Autors/Address of the author:

Prof. Dr. Alexander Karmann,
Dresden University of Technology,
Faculty of Business Management and Economics,
Chair for Economics, esp. Monetary Economics
Mommsenstr. 13
D-01062 Dresden

e-mail: Alexander.Karmann@mailbox.tu-dresden.de

Dipl.-Vw. Oliver Greßmann,
Dresden University of Technology,
Faculty of Business Management and Economics,
Chair for Economics, esp. Monetary Economics
Mommsenstr. 13
D-01062 Dresden

e-mail: Oliver.Greßmann@mailbox.tu-dresden.de

Dipl.-Vw. Christian Hott,
Dresden University of Technology,
Faculty of Business Management and Economics,
Chair for Economics, esp. Monetary Economics
Mommsenstr. 13
D-01062 Dresden

e-mail: Christian.Hott@mailbox.tu-dresden.de

Herausgeber/Editors:
Die Professoren der Fachgruppe Volkswirtschaftslehre

Internet:
http://www.tu-dresden.de/wiwi/reihe.htm

Kontakt/Contact:
Dr. rer. pol. Michael Berlemann
Technische Universität Dresden
Fakultät Wirtschaftswissenschaften
Lehrstuhl für Volkswirtschaftslehre,
insbes. Geld, Kredit und Währung
Mommsenstr. 13
D-01062 Dresden
E-Mail: berleman@rcs.urz.tu-dresden.de

Contagion of Currency Crises - Some Theoretical and Empirical Analysis

Alexander Karmann, Oliver Greßmann and Christian Hott
Dresden University of Technology
Faculty of Business Management and Economics
Chair for Economics esp. Monetary Economics

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Abstract

This paper investigates contagion effects. In a model with highly and lowly informed investors we show that a currency crisis in one country can trigger a crisis in another country. Portfolio losses of the highly informed investors in one country will force them to withdraw capital from the other country. The behavior of the lowly informed investors multiplies this effect and the other country becomes more and more vulnerable. In the empirical part we focus on the Asian crisis (1997/98). Using a LOGIT approach we can show that contagion, in the sense of a crisis not explainable by economic fundamentals but by exchange rate losses resulting from investment in other countries, seems to have caused the currency crises of the Philippines and especially of Singapore.

Keywords: Contagion, Currency crises, Asian crisis

JEL Classification: F3, F4

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1 Introduction

The financial crises of the last decade suggest that there might be some contagion effects transmitting a crisis from one country to another. The Asian crisis in 1997/98 is often mentioned in this context. For some countries, e.g. Thailand, there were enough bad fundamentals to justify a crisis but for others, e.g. Singapore, there was not very much that indicated the arising crisis.
In recent literature, there is some common understanding that regional spillover effects played a significant role in the Asian crisis and allow to explain partially why, within a short period of time, many neighboring economies suffered from crises which originated in Thailand. But there is also common belief that fundamentals cannot explain the whole story and that capital redirections initiated by highly exposed international lenders may have caused crises even in countries with an otherwise relatively sound economic environment.
In the presence of high exposure of foreign investors, adopting Calvo's (1999) trigger mechanism, contagion may be the result of different information levels of investors: if informed investors redirect their overall investment due to capital losses in a market which is already collapsed, by mimicking disinvesting behavior, the uninformed may cause crises in other markets. We identify this development as contagion. This is in line with the definition of contagion given by Masson (1998): expectations change without fundamental reasons.
It is the aim of our paper to rationalize this contagion behavior and to analyze empirically the role of contagion in the Asian crisis. Section 2 derives a theoretical foundation. A model of two emerging markets will be developed and it will be shown under which conditions portfolio losses in one country caused by an exchange rate crisis can trigger a currency crisis in the other country.
Given our theoretical reasoning, an empirical investigation should show that exchange rate losses in some countries can be taken as an indicator for contagion which add in explaining currency crises in other countries. In section 3, we present the empirical investigation. Using a LOGIT-model we introduce a contagion indicator and find clear signs that contagion has played a major role for at least two countries considered: Singapore and the Philippines.

2 Theoretical reasoning

The above definition of contagion is that the expectations change without fundamental reasons. The crucial question is: What are the mechanisms that transmit a financial crisis from one country to another one without any fundamental reasons?
Recent theoretical work gives some answers to this question. One refers to the possibility of multiple equilibria in an economy.[1] As far as no one knows which equilibrium would be selected under 'normal' conditions, a crisis in another country could easily be a 'sunspot' for a 'bad' equilibrium.[2]
A different idea is that contagion might have political reasons. Drazen (1998, p. 1) argues that "...when one of a country's principal objectives in maintaining a fixed exchange rate is (explicit or implicit) political integration with its

[1] An often cited framework for multiple equilibria and currency crises is given by Obstfeld (1994).

[2] See e.g. Masson (1998) or Mullainathan (1998)

'neighbors', a devaluation by one of those neighbors will increase speculative pressures on the country. This argument is especially relevant to the EMS, but is not limited to it."

A possible third reason for contagion is shown by Calvo (1999). He develops a model of two different kinds of agents investing in an emerging market. On one side there are informed investors which know the fundamentals behind the distribution of the returns in the emerging market. On the other side there are uninformed investors which only can observe the actions of the informed investors.

If the actions of the informed investors are motivated not only by the expected returns but also by facts that are relevant for them only, the uninformed investors make their decisions in accordance with these possibly misleading signals. Calvo mentions the example that the informed investors might face liquidity problems resulting from another market (e.g. Wall Street). As a consequence these investors are forced to withdraw capital from the emerging market. Calvo shows that it is rational for the uninformed investors to take this action as a bad signal for the expected returns. The uninformed investors then will also withdraw capital from the emerging market, and the liquidity effect is multiplied. This might trigger a crises.

Our approach is in line with this idea. Section 2.1 presents a model of two types of investors: an investor with a high information level who is living in an emerging market (subsection 2.1.1) and reacts on expected returns and an investor with a low information level who is living in an industrial country (subsection 2.1.2) and reacts very mechanically on changes in prices.

In section 2.2 it is shown how the different agents react on a crash in one country and under which conditions these reactions can trigger a crisis in another country.

2.1 The Model

There are two emerging countries i and j. It is assumed that the government of each country tries to fix its exchange rate 1:1 to the currency of a third country by market interventions.[3] The timescale is discrete. In period t the two governments have the foreign exchange reserves $R_t^i \geq 0$ and $R_t^j \geq 0$, respectively. If a country's reserves are exhausted there is a sudden end of the peg and the exchange rate begins to float freely for ever. This is what we call a "crash".

In each emerging country there is one risky asset which is supplied totally inelastic, traded in the corresponding domestic currency and has in t the price P_t^i and P_t^j, respectively. The maturity date of both assets is period T. It is assumed that the return depends on weather the corresponding exchange rate peg prevails or not.[4] For simplicity we assume that the value of an asset in T is 1 if the corresponding exchange rate remains fixed in period T and it is 0 if there is or was a crash.[5]

There are two safe assets which are supplied totally elastic at constant prices.

[3] In the case of the Asian crises this third country would be the US.

[4] These assets could be interpreted as state bonds that are paid in a foreign currency, say US dollar. If the exchange rate drops the government might have difficulties to fulfill its liabilities. Another example might be shares of local enterprises that have borrowed in US dollar. If the dollar becomes more expensive the enterprises might become bankrupt.

[5] Since in each country there is a 1:1 peg to the currency of the third country, it does not matter if these values are denominated in the local or in the foreign currency.

One traded in the currency of country i and one traded in the currency of the third country.[6] For simplicity we assume that both assets have zero interest rate.
There are two different types of investors: one with a high information level and one with only limited information about the fundamentals of the two emerging countries. A good reason for the existence of both highly and lowly informed investors can be seen in the costs linked with the production of information. Calvo (1999, p.3) writes:

> "Fixed costs generate economies of scale and, hence, the financial industry is likely to organize itself around *clusters of specialists.* This makes it plausible to assume that there exists a set of informed and a set of uninformed investors."

The highly informed investor lives in country i. He is interested in the utility from his wealth denominated in the currency of country i and invests his wealth in the assets i and j and the residual in the safe asset of country i.[7] The lowly informed investor lives in the third country. He is interested in the utility from his wealth denominated in the currency of his home country and invests his wealth only in the asset i and the residual in the safe asset of the third country. The contagion mechanism formalized in section 2.2 can be described as follows: A crises in country j leads to losses for the highly informed investor from country i. These losses may induce him to reduce the absolute amount invested in asset i. This would lead to a falling price of asset i.
The investor with limited information will interpret this as a bad signal for the return of asset i. As a consequence he will withdraw capital from this asset and, hence, from the country i. The withdrawals of the foreign investor can lead to a crises in country i, too.
Before we derive the necessary conditions for contagion we have to formalize the behavior of the two investors and to analyze how the prices and the reserves are driven by this behavior.

2.1.1 The Highly Informed Investor

Information is costly for any investor, private knowledge is limited, and nobody could know everything. As a result it might be rational for an informed investor to concentrate his attention on a limited set of markets. This subsection describes the behavior of a highly informed investor (h) who lives in country i and concentrates himself on the two risky assets in his region: the assets i and j. At any time t prior T, the highly informed investor infer from his set of information on the ability of the respective country to fix its currency how likely repayment will be at terminal date T. This ability is determined by the foreign exchange reserves R_t^i and R_t^j, respectively. We assume that there is no information to the informed investor that the governments might finance future budget deficits by reserves. Similarly, the informed investor does not expect other investors to change their behavior. Hence, he expects prices and foreign exchange reserves

[6] Such an asset is, of course, safe only for an investor whose goal function depends on his wealth denominated in the corresponding currency.

[7] Therefore, country i could be interpreted as a regional financial center. In the case of the Asian crises this country may be Hong Kong or Singapore.

to remain unchanged before T. Especially, the investor h infer the non-crash probabilities in T, independent of time t, solely from actual reserves R_t^i and R_t^j, respectively. Therefore, $\pi_t^i = \pi^i(R_t^i)$ and $\pi_t^j = \pi^j(R_t^j)$, where ($\pi = \pi^i, \pi^j$ and $R_t = R_t^i, R_t^j$):

$$\pi'(R_t) > 0 \qquad \pi(0) = 0 \qquad \pi(\infty) = 1 \tag{1}$$

These probabilities are uncorrelated. The reader should have in mind that these probabilities π_t differ from the probabilities $\pi_{t,\tau}$ that there is no crash in at τ prior to T because T is the maturity date of the two assets. If the value of the assets paid to foreigners is larger than the remaining reserves, the existence of the exchange-rate regime depends on the ability of the country to issue new assets in T.

The investor h invests his wealth (W_t^h) in three assets to maximize the expected utility from his wealth in period T denominated in the currency of his home country: He invests the fraction f_t^i of his wealth in asset i, the fraction f_t^j in asset j, and the residual $(1 - f_t^i - f_t^j)$ in the safe asset from his home country i. Therefore, his wealth evolves in the following way:

$$W_t^h = \left[1 + f_{t-1}^i \left(\frac{P_t^i}{P_{t-1}^i} - 1\right) + f_{t-1}^j \left(\frac{P_t^j}{P_{t-1}^j} - 1\right)\right] W_{t-1}^h \tag{2}$$

It is further assumed that he has constant relative risk aversion, say a logarithmic utility function.[8] Therefore, his maximization problem at time $T-1$ is:

$$\max_{f_{T-1}^i, f_{T-1}^j} \quad E\left[\ln(W_T^h)\right] \tag{3}$$

W_T^h is given by equation (2) where P_T^i is 1 with probability π_{T-1}^i and 0 with probability $1 - \pi_{T-1}^i$. The corresponding applies for P_T^j. The first order conditions are given by:

$$\frac{dE\left[\ln(W_T^h)\right]}{df_{T-1}^i} =$$

$$\frac{\pi_{T-1}^i \pi_{T-1}^j \left(\frac{1}{P_{T-1}^i} - 1\right)}{1 + f_{T-1}^i \left(\frac{1}{P_{T-1}^i} - 1\right) + f_{T-1}^j \left(\frac{1}{P_{T-1}^j} - 1\right)} + \frac{\pi_{T-1}^i (1 - \pi_{T-1}^j) \left(\frac{1}{P_{T-1}^i} - 1\right)}{1 + f_{T-1}^i \left(\frac{1}{P_{T-1}^i} - 1\right) - f_{T-1}^j}$$

$$- \frac{(1 - \pi_{T-1}^i) \pi_{T-1}^j}{1 - f_{T-1}^i + f_{T-1}^j \left(\frac{1}{P_{T-1}^j} - 1\right)} - \frac{(1 - \pi_{T-1}^i)(1 - \pi_{T-1}^j)}{1 - f_{T-1}^i - f_{T-1}^j} = 0 \tag{4}$$

[8] Under constant relative risk aversion, the fractions f_t^i and f_t^j are independent of the amount invested. Therefore, for a given W_t^h, prices and fractions do not depend on the number of investors sharing this wealth.

and

$$\frac{dE\left[\ln(W_T^h)\right]}{df_{T-1}^j} =$$

$$\frac{\pi^i_{T-1}\pi^j_{T-1}\left(\frac{1}{P^j_{T-1}}-1\right)}{1+f^i_{T-1}\left(\frac{1}{P^i_{T-1}}-1\right)+f^j_{T-1}\left(\frac{1}{P^j_{T-1}}-1\right)} - \frac{\pi^i_{T-1}(1-\pi^j_{T-1})}{1+f^i_{T-1}\left(\frac{1}{P^i_{T-1}}-1\right)-f^j_{T-1}}$$

$$+\frac{(1-\pi^i_{T-1})\pi^j_{T-1}\left(\frac{1}{P^j_{T-1}}-1\right)}{1-f^i_{T-1}+f^j_{T-1}\left(\frac{1}{P^j_{T-1}}-1\right)} - \frac{(1-\pi^i_{T-1})(1-\pi^j_{T-1})}{1-f^i_{T-1}-f^j_{T-1}} = 0 \qquad (5)$$

The optimal investment fractions depend on all prices and probabilities:

$$f^{i*}_{T-1}(\pi^i_{T-1}, P^i_{T-1}, \pi^j_{T-1}, P^j_{T-1}), \qquad f^{j*}_{T-1}(\pi^i_{T-1}, P^i_{T-1}, \pi^j_{T-1}, P^j_{T-1}).$$

Given prices and non-crash probabilities at $T-1$, using backward induction, investor h's maximization problem at $T-2$ is given by:

$$maxE\left\{\ln\left[\left(1+f^i_{T-2}\left(\frac{P^i_{T-1}}{P^i_{T-2}}-1\right)+f^j_{T-2}\left(\frac{P^j_{T-1}}{P^j_{T-2}}-1\right)\right)W^h_{T-2}\right]\right\} \qquad (6)$$

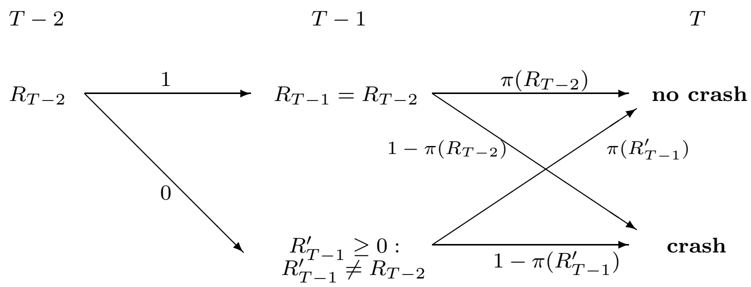

Figure 1: Transition probabilities for the decision of investor h in $T-2$.

Since the investor h does not expect changes of the reserves before T he neither expects changes in the probability of a crash in T, nor changes in prices, nor a crash before T. Hence, the prices in $T-1$ are predetermined and there is no uncertainty about the next period. The first order conditions for an optimal portfolio choice at period $T-2$ are:

$$\frac{d\ln(W^h_{T-1})}{df^i_{T-2}} = \frac{\frac{P^i_{T-1}}{P^i_{T-2}}-1}{1+f^i_{T-2}\left(\frac{P^i_{T-1}}{P^i_{T-2}}-1\right)+f^j_{T-2}\left(\frac{P^j_{T-1}}{P^j_{T-2}}-1\right)} = 0 \qquad (7)$$

$$\frac{d\ln(W^h_{T-1})}{df^j_{T-2}} = \frac{\frac{P^j_{T-1}}{P^j_{T-2}} - 1}{1 + f^i_{T-2}\left(\frac{P^i_{T-1}}{P^i_{T-2}} - 1\right) + f^j_{T-2}\left(\frac{P^j_{T-1}}{P^j_{T-2}} - 1\right)} = 0 \tag{8}$$

Hence, the investor h invests in the two risky assets until their prices in $T-2$ are ex ante equal to their prices in $T-1$. Furthermore, the fractions f^i_{T-2} and f^j_{T-2} the investor h plans to invest at $T-2$ are the same as they are ex ante at $T-1$. The same applies for all periods $t < T-1$. Therefore, substituting the investment fractions from equation (4) and (5), the first order conditions for an optimal portfolio choice at any $t < T$ are given by:

$$\begin{aligned} \Rightarrow \pi^i_t\pi^j_t \frac{\frac{1}{P^i_t} - 1}{1 + f^i_t\left(\frac{1}{P^i_t} - 1\right) + f^j_t\left(\frac{1}{P^j_t} - 1\right)} + \pi^i_t(1-\pi^j_t)\frac{\frac{1}{P^i_t} - 1}{1 + f^i_t\left(\frac{1}{P^i_t} - 1\right) - f^j_t} \\ -(1-\pi^i_t)\pi^j_t \frac{1}{1 - f^i_t + f^j_t\left(\frac{1}{P^j_t} - 1\right)} - (1-\pi^i_t)(1-\pi^j_t)\frac{1}{1 - f^i_t - f^j_t} = 0 \end{aligned} \tag{9}$$

$$\begin{aligned} \Rightarrow \pi^i_t\pi^j_t \frac{\frac{1}{P^j_t} - 1}{1 + f^i_t\left(\frac{1}{P^i_t} - 1\right) + f^j_t\left(\frac{1}{P^j_t} - 1\right)} - \pi^i_t(1-\pi^j_t)\frac{1}{1 + f^i_t\left(\frac{1}{P^i_t} - 1\right) - f^j_t} \\ +(1-\pi^i_t)\pi^j_t \frac{\frac{1}{P^j_t} - 1}{1 - f^i_t + f^j_t\left(\frac{1}{P^j_t} - 1\right)} - (1-\pi^i_t)(1-\pi^j_t)\frac{1}{1 - f^i_t - f^j_t} = 0, \end{aligned} \tag{10}$$

The optimal investment fractions depend only on the current prices and probabilities:

$$f^{i*}_t(\pi^i_t, P^i_t, \pi^j_t, P^j_t), \qquad f^{j*}_t(\pi^i_t, P^i_t, \pi^j_t, P^j_t),$$

where the index t of the parameters π represents the knowledge in period t about the foreign exchange reserves in $T-1$. Since the investor does not expect a change of the foreign exchange reserves, he expect them to be equal to R_t.

2.1.2 The Lowly Informed Investor

This subsection describes the behavior of a lowly informed investor (l) who lives in the third country. We assume that he invests only in the emerging market i and follows a simple rule: He buys the winners and sells the losers.[9]
The investor from the third country maximizes the expected utility from his wealth in period T denominated in his local currency. It is assumed that he has the same log-utility function as the investor h. At t he has the wealth W^l_t, invests the fraction f^l_t in the risky asset of country i and the residual $(1 - f^l_t)$ in the save asset of his home country (the third country). Therefore, his wealth evolves in the following way:

[9]See e.g. Borensztein and Gelos (2000) and Kaminsky, Lyons and Schmukler (1999).

$$W_t^l = \left[1 + f_{t-1}^l \left(\frac{P_t^i}{P_{t-1}^i} - 1\right)\right] W_{t-1}^l \tag{11}$$

The investor l knows nothing about the fundamentals, he only observes the development of the asset prices.[10] He estimates the non-crash probability for country i, $\hat{\pi}_t(P_{t-1}^i, \hat{\pi}_{t-1})$, by using public information P_{t-1}^i and adapting his prior probability $\hat{\pi}_{t-1}$. We assume that $\hat{\pi}_t$ depends positively on both parameters and that $\hat{\pi}_t = \hat{\pi}_{t-1}$ if $P_{t-1}^i = P_{t-2}^i$. In $T-1$ his maximization problem is:

$$maxE[\ln(W_T^l)] = \hat{\pi}_{T-1} \ln \left[\left(1 + f_{T-1}^l \left(\frac{1}{P_{T-1}^i} - 1\right)\right) W_{T-1}^l\right]$$
$$+(1 - \hat{\pi}_{T-1}) \ln \left[\left(1 - f_{T-1}^l\right) W_{T-1}^l\right] \tag{12}$$

His optimal investment fraction is easily computed as:

$$f_{T-1}^{l*}(\overset{+}{\hat{\pi}_{T-1}}, \overset{-}{P_{T-1}^i}) = \frac{\hat{\pi}_{T-1} - P_{T-1}^i}{1 - P_{T-1}^i} \tag{13}$$

Since the investor l also does not expect changes of his information set, i.e. the prices, in period $T-2$ he invests ex ante the same fraction of his wealth in the risky asset i as in $T-1$. The same holds for all periods $t < T-1$. Hence, the optimal investment fraction at any $t < T$ is given by:

$$f_t^{l*}(\overset{+}{\hat{\pi}_t}, \overset{-}{P_t^i}) = \frac{\hat{\pi}_t - P_t^i}{1 - P_t^i} \tag{14}$$

2.1.3 The Asset Prices

The supply of the two risky assets is totally inelastic. For simplicity, we assume that, for both assets, the respective volume issued is 1. Hence, the asset price is equal to the value of the entire volume of the issue. The market-clearing conditions require that the value of each asset equals the value of the entire capital invested. Therefore, the prices of the two assets are given by:

$$P_t^i = f_t^{i*} W_t^h + f_t^{l*} W_t^l \tag{15}$$

and:

$$P_t^j = f_t^{j*} W_t^h \tag{16}$$

In both equations, the exchange rates do not matter because in each country there is either a 1:1 peg or the corresponding asset price is 0 because $\pi_t^i(0) = 0$ and $\pi_t^j(0) = 0$, respectively.

[10] As shown by Calvo (1999), it is rational for uninformed investors to take signals emitted by the informed investors as a good indicator for the development of the fundamentals.

2.1.4 The Foreign Exchange Reserves

There are net capital outflows from a country if a foreign investor sells domestic assets to a domestic investor and invests the capital abroad. In our model this could happen in country i, only. The investor from the third country can sell some of his assets from country i to the investor living in country i and invest the received capital in the safe asset of his home country.
In period t the volume of the asset i held by investor l is given by $f_t^l W_t^l / P_t^i$ and in $t-1$ by $f_{t-1}^l W_{t-1}^l / P_{t-1}^i$. Therefore, the volume of the asset i he buys in period t from investor h is:

$$\frac{f_t^l W_t^l}{P_t^i} - \frac{f_{t-1}^l W_{t-1}^l}{P_{t-1}^i}.$$

The value of this purchase, denominated in currency of country i, is identical to the net capital inflows to country i, given by:

$$\left[\frac{f_t^l W_t^l}{P_t^i} - \frac{f_{t-1}^l W_{t-1}^l}{P_{t-1}^i}\right] P_t^i$$

In order to fix the exchange rate, the government has to compensate for these net capital imports. It will accumulate reserves when they are positive and disinvest reserves when there are capital outflows. The reserves of country i evolve in the following way:

$$R_t^i = R_{t-1}^i + \left[\frac{f_t^l W_t^l}{P_t^i} - \frac{f_{t-1}^l W_{t-1}^l}{P_{t-1}^i}\right] P_t^i \tag{17}$$

In our model there are no net capital in- or outflows for country j. But we assume that its government might face a budget deficit (D_t^j), to be financed by reserves.[11] Therefore, the reserves of country j evolve in the following way:

$$R_t^j = R_{t-1}^j - D_t^j \tag{18}$$

As assumed in the beginning the investing agents do not expect budget deficits to occur. Therefore, they do not expect changes of the foreign exchange reserves and a crash to happen in country j before T.

2.2 The Crash

This section investigates the effects of a "crash" in emerging market j. As shown by Krugman (1979) and Flood and Garber (1984) a government which implements a policy that is not consistent with a peg of the exchange rate, will gradually lose reserves.[12] This development will end in a crash. Krugman (1979, p.319) writes:

[11] Krugman (1979) and Flood and Garber (1984) show in which way budget deficits lead to declining exchange reserves.

[12] A policy that is not consistent with the policy of fixing the exchange rate is for example a budget deficit financed by issuing money. This example is also mentioned by Krugman (1979) and Flood and Garber (1984).

> "There comes a point when the problem becomes a 'crisis': speculators, anticipating an abandonment of the fixed exchange rate, seek to acquire the government's reserves of foreign money. This crisis always comes before the government would have run out of reserves in the absence of speculation."

It is now assumed that there is this kind of crash in country j in period $\tau < T-1$ caused by excessive exhaustion of exchange rate reserves, say for financing deficits. This means that country j's government may be seen as self responsible for the crash in its own country. Furthermore, we assume that the prices of the two risky assets were unchanged until period $\tau - 1$. To see what happens to country i after that crash, the reactions of the highly and the lowly informed investor have to be analysed.

2.2.1 The Crash in Country j at Period τ

According to equation (17), after the crash in country j, expected utility of holding asset j is zero. One can easily show that now the optimal investment fraction f^j_τ and the price P^j_τ are also zero. Investor h's new wealth is given by:

$$W^h_\tau = \left[1 + f^i_{\tau-1}\left(\frac{P^i_\tau}{P^i_{\tau-1}} - 1\right) - f^j_{\tau-1}\right] W^h_{\tau-1} \tag{19}$$

$\Leftrightarrow$

$$W^h_\tau = \left[1 + f^i_{\tau-1}\left(\frac{P^i_\tau}{P^i_{\tau-1}} - 1\right)\right] W^h_{\tau-1} - P^j_{\tau-1} \tag{20}$$

Hence, the investor h loses everything he has invested in the risky asset of country j. This loss is equal to the price of the asset in period $\tau - 1$.
The following examines in which way the crash in country j affects the asset price and the reserves in country i.

2.2.2 Country i in Period τ

In period τ the investor h invests only in the risky asset i and in the save asset of his home country. Therefore, his optimal investment fraction in τ can be written, similarity to equation (14), by:

$$f^i_\tau = \frac{\pi^i_\tau - P^i_\tau}{1 - P^i_\tau} \tag{21}$$

The new price of the risky asset i is given by:

$$P^i_\tau = f^i_\tau W^h_\tau + f^l_\tau W^l_\tau \tag{22}$$

$\Leftrightarrow$

$$P^i_\tau = f^i_\tau \left[1 + f^i_{\tau-1}\left(\frac{P^i_\tau}{P^i_{\tau-1}} - 1\right) - f^j_{\tau-1}\right] W^h_{\tau-1} + f^l_\tau \left[1 + f^l_{\tau-1}\left(\frac{P^i_\tau}{P^i_{\tau-1}} - 1\right)\right] W^l_{\tau-1} \tag{23}$$

In the following we write $P^i_\tau = \beta_\tau P^i_{\tau-1}$. Hence, equation (23) can be reformulated as:

$$\beta_\tau P^i_{\tau-1} = f^i_\tau \left[1 + f^i_{\tau-1}(\beta_\tau - 1) - f^j_{\tau-1}\right] W^h_{\tau-1} + f^l_\tau \left[1 + f^l_{\tau-1}(\beta_\tau - 1)\right] W^l_{\tau-1} \quad (24)$$

From replacing the fractions f^i_τ and f^l_τ by equation (21) and (14) we get:

$$\beta_\tau P^i_{\tau-1}\left[1 - P^i_{\tau-1} + \left(1 - f^j_{\tau-1} - \frac{\pi^i_\tau}{P^i_{\tau-1}} f^i_{\tau-1}\right) W^h_{\tau-1} + \left(1 - \frac{\hat{\pi}_\tau}{P^i_{\tau-1}} f^l_{\tau-1}\right) W^l_{\tau-1}\right]$$
$$= \pi^i_\tau (1 - f^i_{\tau-1} - f^j_{\tau-1}) W^h_{\tau-1} + \hat{\pi}_\tau (1 - f^l_{\tau-1}) W^l_{\tau-1} \quad (25)$$

We want to analyze whether if the price of asset i rises, falls or remains unchanged in period τ.

$$\beta_\tau \begin{matrix} < \\ = \\ > \end{matrix} 1 \quad \begin{matrix} \text{price falls} \\ \text{no effect} \\ \text{price rises} \end{matrix} \quad (26)$$

If the price in τ is lower than in $\tau - 1$, the crash in country j leads to a price reduction in country i. This may lead to contagion. If the prices are equal there is no effect and if it is higher than in $\tau - 1$ there is some kind of 'negative contagion'.
Let us examine the case of a price reduction. Equation (25) can be rewritten in the following way:

$$P^i_{\tau-1}\left[1 - P^i_{\tau-1} + \left(1 - f^j_{\tau-1} - \frac{\pi^i_\tau}{P^i_{\tau-1}} f^i_{\tau-1}\right) W^h_{\tau-1} + \left(1 - \frac{\hat{\pi}_\tau}{P^i_{\tau-1}} f^l_{\tau-1}\right) W^l_{\tau-1}\right]$$
$$> \pi^i_\tau (1 - f^i_{\tau-1} - f^j_{\tau-1}) W^h_{\tau-1} + \hat{\pi}_\tau (1 - f^l_{\tau-1}) W^l_{\tau-1} \quad (27)$$

$$\Leftrightarrow P^i_{\tau-1} > \frac{\pi^i_\tau - P^i_{\tau-1}}{1 - P^i_{\tau-1}} (1 - f^j_{\tau-1}) W^h_{\tau-1} + \frac{\hat{\pi}_\tau - P^i_{\tau-1}}{1 - P^i_{\tau-1}} W^l_{\tau-1} \quad (28)$$

Following section 2.1.2 investor l only changes his inferred non-crash probability $\hat{\pi}_\tau$ if the price of asset i has changed in the last period. Since we have assumed that prices remain unchanged until period $\tau - 1$ the likelihood $\hat{\pi}_\tau$ is equal to $\hat{\pi}_{\tau-1}$. Hence, the coefficient of $W^l_{\tau-1}$ in equation (28) is equal to the fraction $f^l_{\tau-1}$ and we can write:

$$f^i_{\tau-1} W^h_{\tau-1} > \frac{\pi^i_\tau - P^i_{\tau-1}}{1 - P^i_{\tau-1}} (1 - f^j_{\tau-1}) W^h_{\tau-1} \quad (29)$$

$$\Rightarrow f^i_{\tau-1} > \frac{\pi^i_\tau - P^i_{\tau-1}}{1 - P^i_{\tau-1}} (1 - f^j_{\tau-1}) \quad (30)$$

The fraction on the right hand side of condition (30) corresponds with the fraction f^i_τ. Since this fraction depends negatively on the price, the condition is fulfilled if holds:

$$\frac{f^i_{\tau-1}}{f^i_\tau} > (1 - f^j_{\tau-1}) \quad (31)$$

Hence, condition (31) is equivalent to stating that the crash in country j leads to a lower price in country i. And (31) holds if the portfolio reaction on the crash in j is not too intense (left hand side) and if the losses from the crash in country j were very large (right hand side). The fact that the investor h loses the possibility to diversify his portfolio favors the first argument. Hence, he will reduce the total fraction of his wealth he has invested in the risky assets if the price and reserves do not change. The second argument seems quite plausible: in the 1997 crisis in Thailand the Dollar price in baht mounted at a rate of over 100 percent. Hence, portfolio losses were very high.
From a portfolio-theoretical approach, exchange rate losses should be a valid indicator for contagion. This argument will be verified by our empirical investigation in section 3.
In the following we assume that the condition (31) is fulfilled, hence, the price of the asset in country i falls ($0 < \beta_\tau < 1$). In τ the foreign exchange reserves of country i are:

$$R^i_\tau = R^i_{\tau-1} + \left[\frac{f^l_\tau W^l_\tau}{\beta_\tau P^i_{\tau-1}} - \frac{f^l_{\tau-1} W^l_{\tau-1}}{P^i_{\tau-1}}\right] \beta_\tau P^i_{\tau-1} \tag{32}$$

$$\Rightarrow R^i_\tau = R^i_{\tau-1} + f^l_\tau W^l_\tau - \beta_\tau f^l_{\tau-1} W^l_{\tau-1} \tag{33}$$

They are larger than in $\tau - 1$ if the following condition holds:

$$f^l_\tau W^l_\tau > \beta_\tau f^l_{\tau-1} W^l_{\tau-1}$$

$$\Leftrightarrow f^l_\tau (1 + f^l_{\tau-1}(\beta_\tau - 1)) W^l_{\tau-1} > \beta_\tau f^l_{\tau-1} W^l_{\tau-1}$$

$$\Leftrightarrow f^l_\tau (1 - f^l_{\tau-1}) > \beta_\tau f^l_{\tau-1} (1 - f^l_\tau)$$

$$\Leftrightarrow \frac{\hat{\pi}_\tau - \beta_\tau P^i_{\tau-1}}{1 - \beta_\tau P^i_{\tau-1}} \frac{1 - \hat{\pi}_{\tau-1}}{1 - P^i_{\tau-1}} > \beta_\tau \frac{\hat{\pi}_{\tau-1} - P^i_{\tau-1}}{1 - P^i_{\tau-1}} \frac{1 - \hat{\pi}_\tau}{1 - \beta_\tau P^i_{\tau-1}} \tag{34}$$

Following subsection 2.1.2 $\hat{\pi}_\tau$ only changes if the price in $\tau - 1$ was different from the price in $\tau - 2$. But as assumed above the prices were unchanged until period $\tau - 1$. Therefore the condition (34) holds because by our assumption, $\beta < 1$, and the reserves increase from $\tau - 1$ to τ. This increase is no surprise since in τ the price only falls if the investor h sells the asset to the foreign investor l, and this raises the foreign exchange reserves of country i.

2.2.3 Country i in period $\tau + 1$

The investor l can observe the reaction of the investor h indirectly by looking at the changes of the asset price. As mentioned in section 2.1.2, he computes his probability estimation $\hat{\pi}_\tau$ from the development of the price. As assumed in the last subsection, the price of the asset in country i falls, hence the investor l reduces his own probability. This leads to a further drop of the price P^i in $\tau + 1$. We will next show that in $\tau + 1$ this drop induces a drop of foreign exchange reserves.

In order to see this we observe that the foreign exchange reserves evolve as follows:

$$R^i_{\tau+1} = R^i_\tau + \left[\frac{f^l_{\tau+1}W^l_{\tau+1}}{P^i_{\tau+1}} - \frac{f^l_\tau W^l_\tau}{P^i_\tau}\right] P^i_{\tau+1} \tag{35}$$

Hence, a fall of the foreign exchange reserves means that:

$$\left[\frac{f^l_{\tau+1}W^l_{\tau+1}}{P^i_{\tau+1}} - \frac{f^l_\tau W^l_\tau}{P^i_\tau}\right] P^i_{\tau+1} < 0$$

The left side of this inequation is the net value of the assets the foreign investor l buys from the domestic investor h. This value must be equal to the net value of the assets the domestic investor sells to the foreign investor.

$$\left[\frac{f^i_\tau W^h_\tau}{P^i_\tau} - \frac{f^i_{\tau+1}W^h_{\tau+1}}{P^i_{\tau+1}}\right] P^i_{\tau+1} < 0$$

Analogously to the derivation of condition (34) from (32), above condition is equivalent to:

$$P^i_\tau \frac{\pi^i_{\tau+1} - P^i_{\tau+1}}{1 - P^i_{\tau+1}} \frac{1 - \pi^i_\tau}{1 - P^i_\tau} > P^i_{\tau+1} \frac{\pi^i_\tau - P^i_\tau}{1 - P^i_\tau} \frac{1 - \pi^i_{\tau+1}}{1 - P^i_{\tau+1}}$$

$$\Leftrightarrow P^i_\tau(\pi^i_{\tau+1} - P^i_{\tau+1})(1 - \pi^i_\tau) > P^i_{\tau+1}(\pi^i_\tau - P^i_\tau)(1 - \pi^i_{\tau+1})$$

$$\Leftrightarrow g(\pi^i_{\tau+1}) = P^i_\tau \pi^i_{\tau+1}(1-\pi^i_\tau) - P^i_{\tau+1}\pi^i_\tau(1-\pi^i_{\tau+1}) + P^i_\tau P^i_{\tau+1}(\pi^i_\tau - \pi^i_{\tau+1}) > 0 \tag{36}$$

If this condition is fulfilled, the foreign exchange reserves fall in $\tau + 1$. It is easy to see that $g' > 0$. Moreover, at π^i_τ holds $g(\pi^i_\tau) > 0$, if and only if $P^i_\tau - P^i_{\tau+1} > 0$, and the latter relation holds.
Now, from $P^i_{\tau+1} < P^i_\tau$ follows $g(\pi^i_{\tau+1}) > 0$, i.e. condition (36) is fulfilled. Suppose to the contrary that $g(\pi^i_{\tau+1}) \leq 0$. Then the reserves do not fall in $\tau + 1$ ($R^i_{\tau+1} \geq R^i_\tau$). Hence, following (1) this leads to $\pi^i_{\tau+1} \geq \pi^i_\tau$. As $g' > 0$, $g(\pi^i_\tau) \geq g(\pi^i_{\tau+1}) > 0$ which is a contradiction.
Therefore , the foreign exchange reserves decline if the price of asset i falls in $\tau + 1$, which is fulfilled because the investor l reduces his non-crash probability in $\tau + 1$.
Our result shown so far is no surprise. The foreign investor l, misled by the price signal from the previous period, sells some of his assets to the domestic investor h. This leads to declining prices and falling reserves in country i. The latter reduces the non-crash probability and thereby enforces the drop of the asset price.
In the next period the foreign investor will then interpret this as a further bad signal for the returns of the asset. This process recurs in the next periods.

2.2.4 Contagion

As shown in section 2.2.2 the crash in country j could lead to a reduction of the asset price in country i if the domestic investor sells the asset to the foreign investor. Following equation (32) this implies a rise in the foreign exchange reserves in country i and, following (1), in the probability π_τ^i which is a good signal for the non-crash likelihood at period T. But this does not stimulate the demand of the lowly informed foreign investor to buy asset i because he only follows price signals from the past, and prices remained constant till $\tau - 1$.

In the next period the reduction of the asset price will be interpreted by the foreign investor as a bad signal for the asset return. This will lead to a further reduction of the asset price but this time the foreign investor sells the asset to the domestic investor. Following subsection 2.2.3 this implies also a decline of the foreign exchange reserves of country i.

This process recurs in the next periods and leads to lower and lower foreign exchange reserves in country i. As we can see from equation (17), these capital outflows can not exhaust the foreign exchange reserves totally. But the country i gets more and more vulnerable to speculative attacks. There might be a speculative attack if the foreign exchange reserves fall under a critical value, which leads to a crash in country i, too.

Summarizing, the crash in country j could trigger two price effects. The direct effect derives from the reduction of the wealth of the highly informed investor from country i who may be forced to withdraw capital from the asset i. The indirect effect derives from the price signal that triggers some kind of herding behavior of the lowly informed foreign investor. This multiplies the direct effect on the asset price but also reduces the foreign exchange reserves of country i and raises the likelihood of a speculative attack and a crash.

The increase of the crash probability of country i was triggered by the crash in country j. This is what we identify as the case of contagion.

With regard to the Asian crisis in 1997 the country j, experiencing an unexpected and fundamental crisis, could be Thailand. Hence, capital outflows are not necessarily the origins of the crisis. The infected country i could be any country whose fundamentals were not bad enough to justify a crisis, e.g. Singapore.[13]

Borensztein and Gelos (2000) examine the behavior of emerging market mutual funds. They found that there were no sizeable capital outflows from Thailand before its crisis, outflows even diminished. But looking at the whole Asian sample Borensztein and Gelos observed that the funds withdrew large sums and there were net outflows prior the crisis. The authors write (p. 11):

> "To some extent, this is not surprising, since a withdrawal of investors is exactly what brings about a crisis."

This is in line with our results.

[13]See section 3.

3 Empirical Research

3.1 Aim of the investigation

The aim of this part is to find evidence for contagion effects in the case of the Asian crisis. We will compute a contagion indicator that is able to indicate a crisis which cannot be explained by the development of fundamental economic indicators. This is in the line with the definition of contagion given by Masson (1998, p. 3)

> "... a crisis in one country may conceivably trigger a crisis elsewhere for reasons unexplained by macroeconomic fundamentals..."

In our approach the contagion indicator is a signal of considerable investment losses in one currency which by itself causes high devaluation of another currency. A potential transmission mechanism thereby may be the mimicing behavior of less informed international investors, as explained above. Using a LOGIT-Model we will show that though the major part of the Asian crisis can be explained by bad fundamentals there are also cases of contagion where the development of the fundamentals does not provide full explanation of the observed crisis. In those cases, the implementation of a contagion indicator will help to explain the crisis, and the estimation results will be improved.

3.2 Defining a Currency Crisis

An important step of the empirical investigation is to define a proper crisis variable as the variable to be explained. In the literature, many different methods are used. In general, the crisis variable is dichotomous and becomes 1 if a currency crisis appears in the corresponding year (this means a predefined threshold value is exceeded) and 0 otherwise.[14]
The major difference among the various crisis definitions is the design of the respective dummy variable. Up to three indicators[15] are used to define a crisis event. Kaminsky, Lizondo and Reinhart (1998) for example introduce an "Index of Exchange Market Pressure" built on the exchange rate and the foreign exchange reserves.
Also the definition of the threshold value is quite different within literature. While early approaches often use simple threshold values like a fixed percentage rate for the currency devaluation[16] recent studies often apply threshold values based on the mean μ and the standard deviation σ of the past realization of the respective variables.
Our crisis indicator reflects solely the development of the nominal US-Dollar exchange rate. A currency crisis is defined as an intense and abrupt change in the nominal exchange rate. Like Esquivel and Larrain (1998) we exclude unsuccessful speculative attacks from our crisis definition, hence, we depart from foreign exchange reserves observation.
The corresponding threshold value is computed by using weighted values of the country-specific mean μ^i and the overall standard deviation $\overline{\sigma}$ as follows:

[14] For a notable exception see Eliasson and Kreuter (2001) using a continuous crisis variable.
[15] Exchange rate, foreign exchange reserves and interest rates, see e.g. Eichengreen, Rose and Wyplosz (1994).
[16] See Frankel and Rose (1996).

$$Crisis_t^i = \begin{cases} 1 & \text{if} \quad \left(\frac{ER_t^i}{ER_{t-1}^i} - 1\right) > 0,5\overline{\sigma} + 3,5\mu^i \\ 0 & \text{otherwise} \end{cases} \tag{37}$$

where ER_t^i is the nominal US-Dollar exchange rate[17] of country i in period t. This definition is similar to the definitions used by e.g. Kaminsky and Reinhart (1998). Kaminsky and Reinhart put more weight on the standard deviation than we do. The reason is that Kaminsky and Reinhart employ "Early Warning Systems" for currency crises where the specific starting date of a crisis is much more important. Our indicator produces a rather stable signal for the whole crisis period, which is more applicable to our procedure to explain the occurrence rather to forecast the beginning of crises. Since we want to investigate contagion effects we decide to put more weight on the country-specific μ such that the crisis variable is influenced to a lower extend by $\overline{\sigma}$, the average deviations of all countries in the sample.
Because of the dramatic devaluations during all crisis periods the pattern of the crisis indicator is rather robust w.r.t. changes of the weights used to define this variable.[18] The figures 2 to 7 show the annual growth rate of the nominal US-$ exchange rates for the relevant time span and the country-specific threshold.

3.3 Regression Method

Since the dependent variable $Crisis_t^i$ is dichotomous and our data sample has a time series and a cross section dimension it is reasonable to use a LOGIT model for our estimation. This allows to deploy as much information from the sample as possible.[19]
We suppose that there is an unobservable variable $Crisis_t^{i*}$ which can be described as follows:

$$Crisis_t^{i*} = \beta X_t^i + \epsilon_t^i$$

where X_t^i is the vector of the independent variables of country i in period t, β the vector of the coefficients to be estimated and ϵ_t^i the corresponding error term.
We assume that the observed crisis indicator $Crisis_t^i$ behave as follows:

$$Crisis_t^i = \begin{cases} 1 & \text{if} \quad Crisis_t^{i*} > 0 \\ 0 & \text{otherwise} \end{cases} .$$

Then the corresponding LOGIT Model has the following form:

$$L(Crisis_t^i) = \alpha + \beta X_t^i.$$

3.4 Data sample and explanatory variables

3.4.1 Data sample

Countries
As our study focuses on the East-Asian crisis our country sample contains

[17]Domestic currency per US-Dollar (IFS line RF).
[18]Our robustness result is in line with similar findings known in literature (see e.g. Frankel and Rose(1996)).
[19]See Esquivel and Larrain (1998).

only Asian countries. Taiwan, Hong-Kong and China were left out because of missing data. Furthermore, Japan was excluded because, following our crisis definition, there was no crisis within the respective time span.
Hence, the sample consists of six Asian countries: Singapore, Korea, Malaysia, Indonesia, Thailand and the Philippines. All these countries were hit by the Asian crisis in 1997/98.

Explanatory Variables
To examine contagion effects, the beginning and the duration of each crisis are decisive factors. The use of yearly data would lead to a loss of important information: regardless whether the crisis starts in January or December, by using yearly data the crisis always starts in the same year. Given the rather narrow period of crisis events any attempt to use annual data in modelling contagion was misleading. Thus we decided to use indicators available on a monthly base. The advantage of using monthly data is illustrated by figures 2 to 7. While the crisis in Thailand started in August 1997, the crises in the other countries started between October and December 1997. Using yearly data would concentrate all events to be analyzed on the same point in time.
Despite the fact that there are available data for a longer time horizon we restricted the sample period to 1990 - 2000. One reason is that before 1990 there were almost no crises in the Asian region. Another reason is that enlarging the sample period would further reduce the ratio of crisis to non-crisis events below a level of 10% and thus effect the explanatory power of the approach.

3.4.2 The Explanatory Variables

As mentioned above there are two restrictions for the data to enter the sample. The variable must reflect the development of the economic fundamentals and it must be available on a monthly base.
This led to six variables we will discuss now in more detail:[20]

- Real Exchange Rate Index (-)

  Flood and Garber (1984) develop the concept of a shadow exchange rate. This is an exchange rate which would be realized without interventions by the government. Flood and Garber show that at least if the shadow exchange rate falls below the nominal exchange rate a speculative run on the currency will occur.
  Assuming that the real exchange rate index is a good indicator for the shadow exchange rate, a decline of this variable will provide a higher incentive to speculate against the currency.
  Therefore we expect a negative relationship between the real exchange rate index and the probability of a currency crisis.

  - $DJPMREX_t^i$ = growth rate of the JPMorgan real broad effective exchange rate index

[20] The sign of the regression coefficient expected from theoretical reasoning is given in brackets following the respective variable. All variables except JPMorgan Real Exchange Rate Index are taken from the IMF International Financial Statistics (IFS).

$$DJPMREX_t^i = \frac{JPMREX_t^i}{JPMREX_{t-1}^i} - 1$$

where $JPMREX_t^i$ is the JPMorgan real broad effective exchange rate index.[21]

- M2 Multiplier (+)

  The transmission of a banking crisis to a currency crisis is often mentioned in the theoretical literature, see e.g. Krugman (1998) or Flood and Marion (2000). A growing money multiplier can be interpreted as a sign for financial liberalization accompanied by declining minimum reserves held at the central bank. In countries with insufficient banking supervision this may lead to higher vulnerability of the banking sector.
  Therefore we expect a positive relation.

  – $M2MULTI_t^i$ = Ratio of M2 (IFS line 34 plus line 35) to base money (IFS line 14)

$$M2MULTI_t^i = \frac{MONEY_t^i + QMONEY_t^i}{RMONEY_t^i}$$

where

$MONEY_t^i$ = Money (IFS line 34)
$RMONEY_t^i$ = Base Money (IFS line 14)
$QMONEY_t^i$ = Quasi Money (IFS line 35).

- Foreign Exchange Reserves (-)

  The amount of foreign exchange reserves plays an important role if the government wants to influence the exchange rate by intervening on the foreign exchange market. In an extrem example the government may try to peg the currency to e.g. the US-Dollar. Then a decline in foreign exchange reserves reduces the government´s ability to maintain the exchange rate and provides an incentive to speculate against the currency.[22]
  From a theoretical point of view we expect a negative relation between the amount of foreign exchange reserves and the probability of a currency crisis.

  – $DFOREX_t^i$ = growth rate of the Foreign Exchange Reserves

$$DFOREX_t^i = \frac{FOREX_t^i}{FOREX_{t-1}^i} - 1$$

where $FOREX_t^i$ are the Foreign Exchange Reserves (IFS line 1D).

[21] Published by J.P. Morgan Chase & Co. under www.jpmorgan.com.
[22] This is explained also in first generation models like Krugman (1979) or Flood and Garber (1984) and in second generation models like Obstfeld (1994).

- Deposit Rate (-)

  According to interest rate parity a growing deposit rate will lead to an appreciation of the currency. Therefore we expect a negative relationship between deposit rate and currency crisis.

  - $DEPOSIT_t^i$ = Deposit Rate (IFS line 60L)

- Exports (-)

  The role of exports is twofold and relates to the development of the foreign exchange reserves as well as to the production volume of the domestic economy.
  First, higher exports (capital import, respectively) will increase the foreign exchange reserves. The expected impact of this effect is negative.
  Second, growing exports may indicate growing national income.[23] The latter may raise the attractiveness for foreign investments and induce capital inflows. This implies a negative effect, too.

  - $DEXUS_t^i$ = growth rate of the export value denominated in US-$

$$DEXUS_t^i = \frac{EXUS_t^i}{EXUS_{t-1}^i} - 1$$

where $EXUS_t^i = \frac{EXPORT_t^i}{ER_t^i}$

if the exports are denominated in national currency, and

$$EXUS_t^i = EXPORT_t^i \text{ otherwise}$$

where $EXPORT_t^i$ is the export value (IFS line 70).

- Consumer Price Index (+)

  According to purchasing power parity, a growing CPI should lead to a declining exchange rate. Keeping the exchange rate level fixed leads to a loss of foreign exchange reserves and to a higher crisis probability.
  Beside this fact there is also an output effect. Inflation along with a fixed exchange rate makes domestic goods more expensive abroad. The national economy looses competitiveness and the government might be forced to devaluate the currency.[24]

  - $DCONPRI_t^i$ = growth rate of the Consumer Price Index

$$DCONPRI_t^i = \frac{CONPRI_t^i}{CONPRI_{t-1}^i} - 1$$

where $CONPRI_t^i$ is the Consumer Price Index (IFS line 64).

[23] See ISXM-equation.

[24] Obstfeld (1994) develops a second generation crisis model where missing an output target leads to a self-fulfilling prophecy and, hence, to a crisis.

3.4.3 The Contagion Indicator

Our contagion indicator is aimed to represent a factor causing crises which can not or not fully be explained by macro variables as considered above: the contagion effect. Our theoretical reasoning in section 2 suggests that given two countries i and j the crisis probability for country i is the higher, the higher the losses of an investor in country j are. For simplicity we assume that the investment losses in country j can be described simply by the exchange rate losses.

Our definition of the contagion indicator is based on this line of arguments. The contagion indicator for country i has to reflect the exchange rate losses of the international investor in all the other countries of our sample. We assume that a loss of 15% in a particular country is high enough to induce the investor to change his portfolio. The more neighboring countries cause losses for the investor, the higher the signal of our contagion indicator will be. Admittedly, this is a simple approach to build a contagion indicator. But since this 15% threshold substantially differs from the country-specific thresholds computed to define a crisis[25] the contagion indicator does not simply mimic the summation of the crisis variable. Hence, our contagion indicator is computed as follows:

- Contagion Indicator (+)

  The indicator aggregates the number of neighboring countries suffering substantial exchange rate devaluations. Hence, we expect a positive relation to the crisis probability.

  - $Cont15_t^i$ = Contagion Indicator of $Crisis15_t^i$

$$Cont15_t^i = \left(\sum_{k=1}^{6} Crisis15_t^k \right) - Crisis15_t^i$$

where

$$Crisis15_t^i = \begin{cases} 1 & \text{if} \quad \left(\frac{ER_t^i}{ER_{t-1}^i} - 1 \right) > 0,15 \\ 0 & \text{otherwise} \end{cases} .$$

3.5 Estimation and Empirical Results

Our first regression is build on the six macro indicators considered above, excluding the contagion indicator. The result is given in table 1. All coefficients are significant and have the expected signs.

[25] The threshold for e.g. Korea is 38%, for Indonesia is 114% and for Thailand is 32%.

Indicator	Regression Coeff.	Coeff./S.E.	P-Value
DFOREX	-,057	-3,460	0,00
DJPMREX	-,277	-6,991	0,00
DEXUS	-,099	-4,211	0,00
DCONPRI	,175	2,513	0,01
M2MULTI	,238	1,938	0,05
DEPOSIT	-,274	-2,687	0,01
INTERCEPT	-3,938	-3,902	0,00
-2Log-Likelihood	106,966		
Nagelkerkes R^2	0,809		
Cox & Snell R^2	0,362		
Chi-Square	334,077	DF = 6	P-Value = 0,00
Pearson Goodness-of-Fit	χ^2 = 279,074	DF = 737	P-Value = 1,00

Table 1: Results of regression 1[26]

The classification table (table 2) shows the hits and misses of this regression using a threshold value of 0.50.[27] Accordingly, 98% of the non-crisis events and 80% of the crisis events are predicted properly by our regression equation.

	predicted 0	predicted 1	correct result in %
observed 0	671	8	98,8%
observed 1	13	52	80,0%
total percentage			97,2%

Table 2: Hits and misses for regression 1

The light-gray bands in the figures 8 to 13 represent the predicted probabilities from the first regression without the contagion indicator in comparison with our crisis variable (pictured by the white band). As we can see the results for Singapore and the Philippines are not satisfactory. This suggests to ask whether the crises as observed for Singapore and the Philippines are the results of contagion rather than of macro fundamentals. This question is answered by the next regression including the contagion indicator.
The result from the regression with the contagion indicator (table 3) is as follows: the coefficients of the macro fundamentals have the expected signs. The coefficient of the contagion indicator $CONT15$ is highly significant with the expected sign. Admittedly, w.r.t. the P-Values, the coefficient for $DEXUS$ is significant on a 10% level and $DFOREX$ misses this level marginally.

[26]Note that the Null-Hypothesis for the Chi-Square test is H_0: Coefficients = 0 and for the Pearson Goodness-of-Fit test H_0: observed and estimated distributions are equal.
[27]See e.g. Esquivel and Larrain (1998), p.34.

Indicator	Regression Coeff.	Coeff./S.E.	P-Value
DFOREX	-,058	-1,582	0,11
DJPMREX	-,396	-2,939	0,00
DEXUS	-,041	-1,632	0,10
DCONPRI	,768	2,696	0,01
M2MULTI	,585	1,983	0,05
DEPOSIT	-1,143	-2,587	0,01
CONT15	2,976	3,271	0,00
INTERCEPT	-13,629	-3,192	0,00
-2Log-Likelihood	39,346		
Nagelkerkes R^2	0,933		
Cox & Snell R^2	0,417		
Chi-Square	401,697	DF = 7	P-Value = 0,00
Pearson Goodness-of-Fit	$\chi^2 = 46{,}965$	DF = 736	P-Value = 1,00

Table 3: Results of regression 2[28]

Comparing the classification tables with and without contagion indicator (tab.2 and tab.4) it is obvious that the number of hits is considerably larger for the second regression than for the first one.

	predicted 0	predicted 1	correct result in %
observed 0	674	5	99,3%
observed 1	2	63	96,9%
total percentage			99,1%

Table 4: Hits and misses for regression 2

Comparing the predicted probabilities of the two regressions (figures 8 to 13, where the dark-gray bands represent the results of regression 2) we note that for Singapore and the Philippines the predicted probabilities fit better the dependent crisis variable while the results for the other countries fit as good as in the first regression or slightly better. This result confirms the argument that contagion did matter in the Asian crisis.

3.6 Summary of the regression results

As we can see from the predicted probabilities, the variables in regression 1 are suitable to explain the crises in Indonesia, Malaysia, Thailand and Korea. The results for Singapore and the Philippines led to the suspicion that contagion effects have caused these crises. This was confirmed by introducing the contagion variable.

We conclude that the crises in Singapore and the Philippines are not driven

[28]Note that the Null-Hypothesis for the Chi-Square test is H_0: Coefficients = 0 and for the Pearson Goodness-of-Fit test H_0: observed and estimated distribution are equal.

merely by the development of the economic fundamentals. They are (at least partly) triggered by contagion effects.
In the case of the Philippines this result is in line with the findings of e.g. Berg and Pattillo (2000). They point out that this crisis can not be explained sufficiently by standard macro variables. The results for Singapore are supported by e.g. Masson (1998) who identifies "obvious signs" for contagion effects in this country.

4 Summary

This paper investigates contagion effects in the case of the Asian crisis. Following Masson (1998, p.3) the definition of contagion is a crisis triggered "...for reasons unexplained by economic fundamentals..."
Following the theoretical part of this paper, contagion effects can be triggered by portfolio losses originated from a crisis in another country. Herding behavior of the lowly informed investor reinforces this effect and may thereby cause a currency crisis.
With respect to the theoretical examinations we construct a contagion indicator. Using this indicator the empirical research in the second part of the paper suggests that the crises in Singapore and the Philippines are (at least partly) caused by contagion effects. In these cases the predicted probabilities for the occurrence of a crisis were noticeable lower without using the contagion indicator.

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A Graphical Representation

Figures 2 to 7 show the growth rates of the exchange rate for each country (national currency per US-Dollar). The period of time is January 1990 till April 2000. The gray horizontal line is the respective threshold value for each country. Above this threshold level the crisis variable $Crisis_t^i$ is 1, and 0 otherwise.
The Figures 8 to 13 show the time paths of our crisis variable $Crisis_t^i$ and the estimated crisis probabilities resulting from the two regressions. The white band describes the crisis variable (per definition with the value 0 or 1), the dark gray band depicts the results from the regression with the contagion indicator while the light gray band shows the results from the regression without the contagion indicator. The period shown covers the "crisis relevant" time horizon from June 1997 to January 1999.

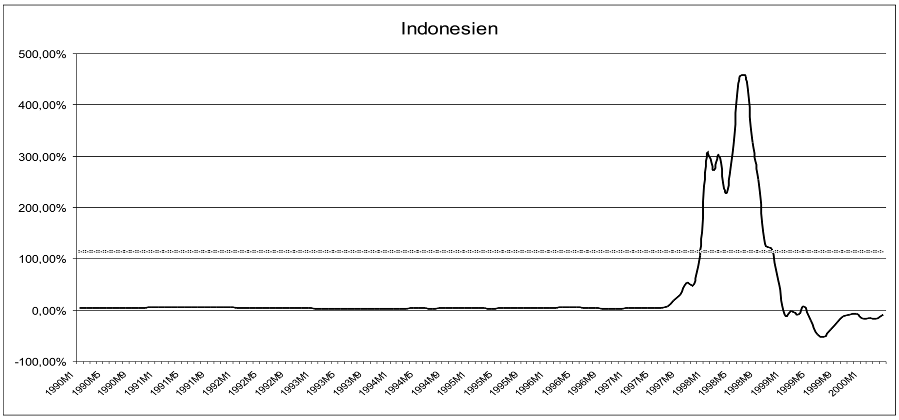

Figure 2: Exchange rate growth in Indonesia

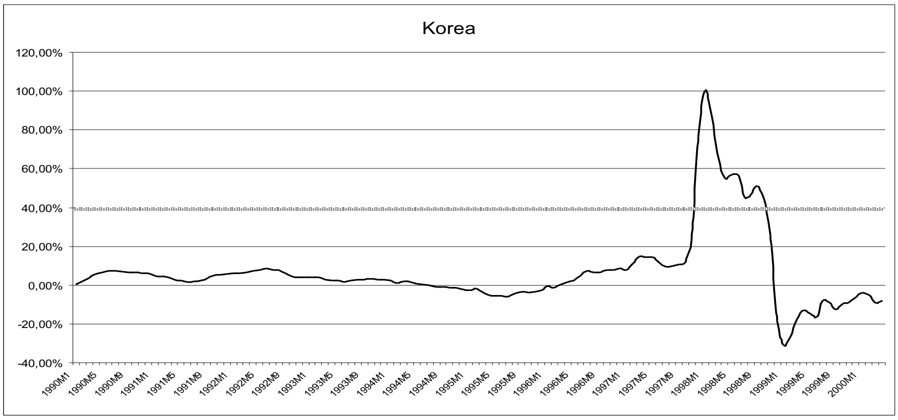

Figure 3: Exchange rate growth in Korea

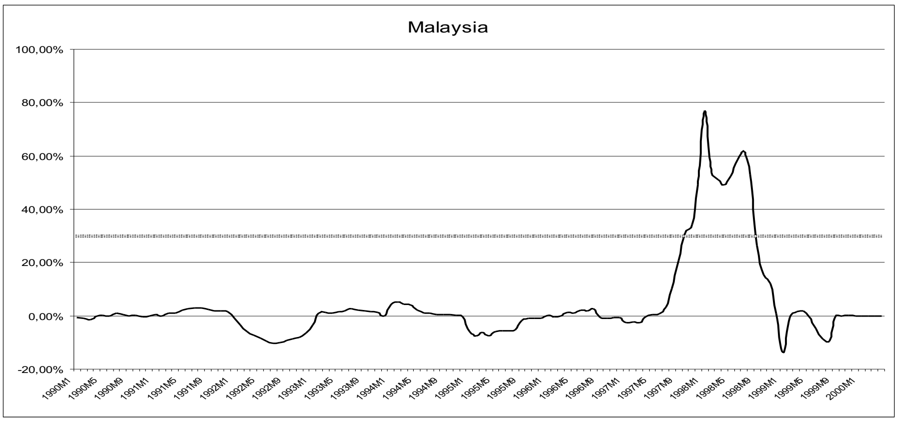

Figure 4: Exchange rate growth in Malaysia

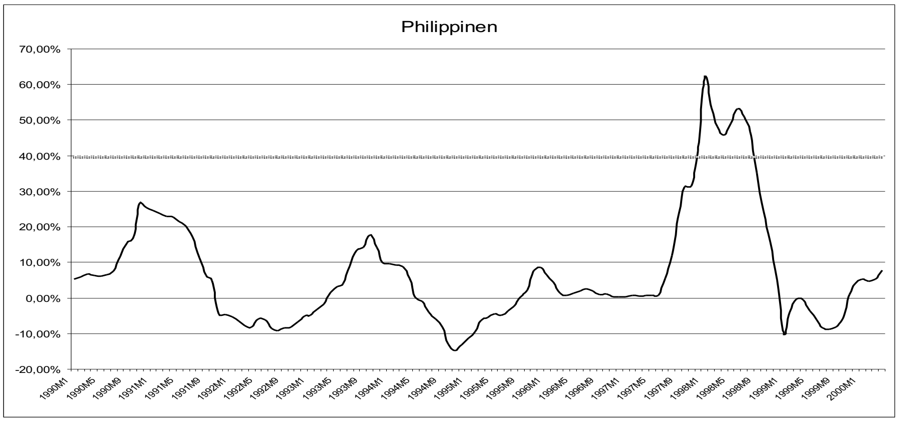

Figure 5: Exchange rate growth in the Philippines

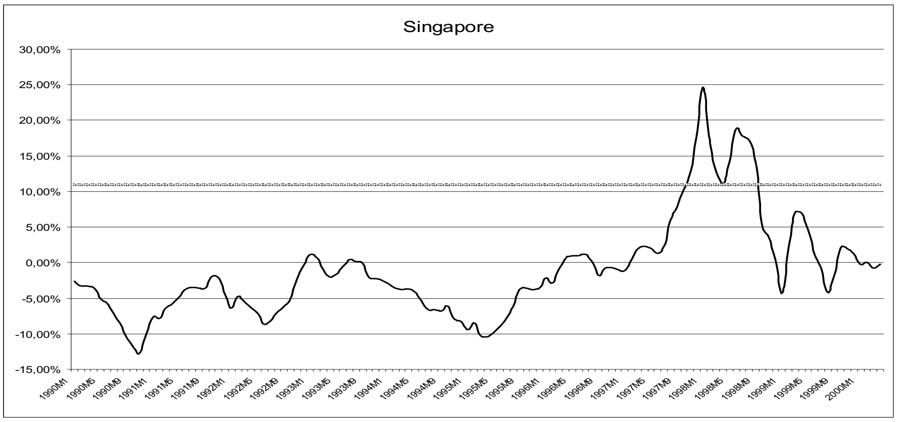

Figure 6: Exchange rate growth in Singapore

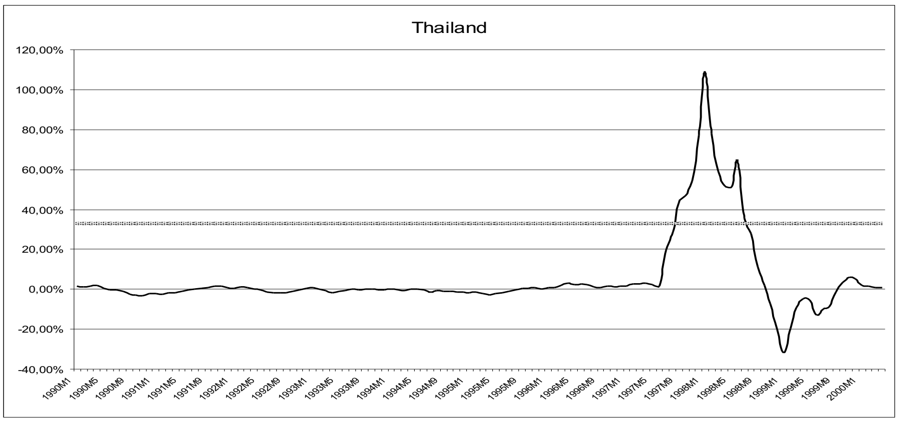

Figure 7: Exchange rate growth in Thailand

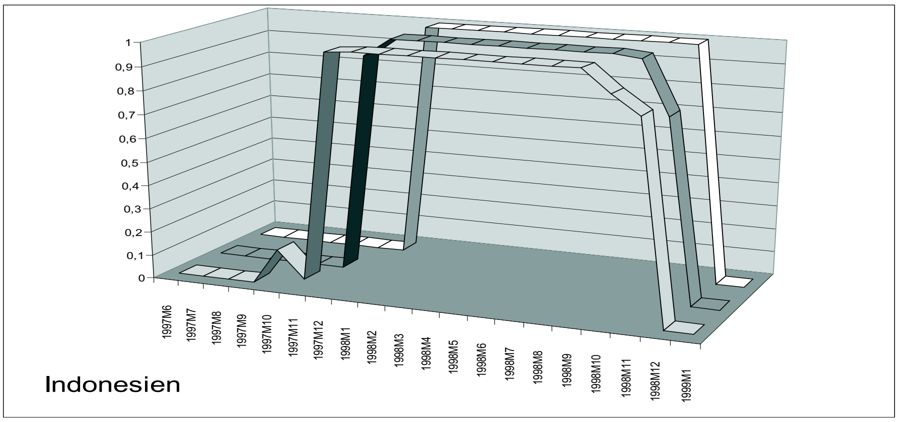

Figure 8: Regression results for Indonesia

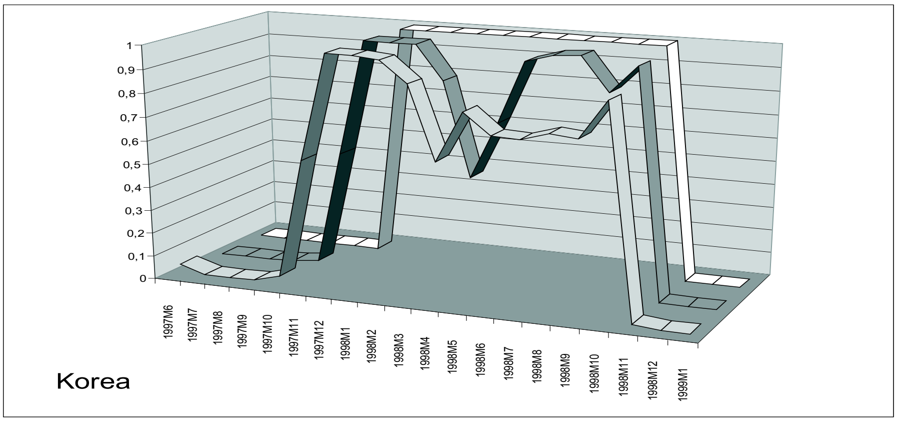

Figure 9: Regression results for Korea

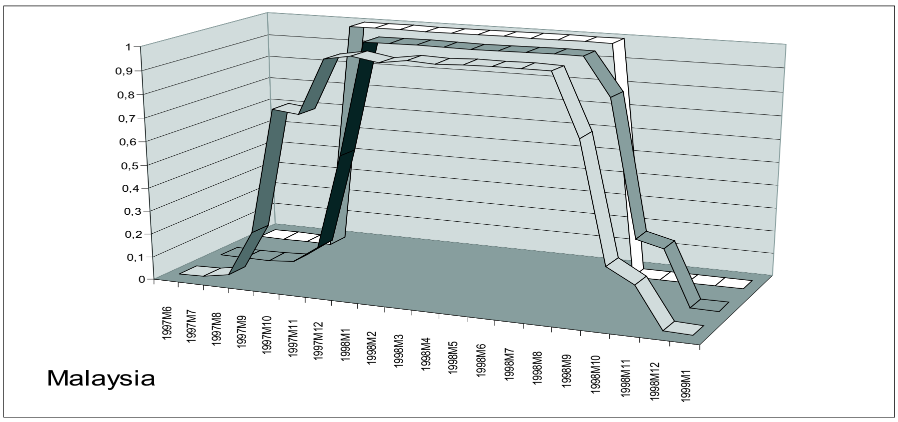

Figure 10: Regression results for Malaysia

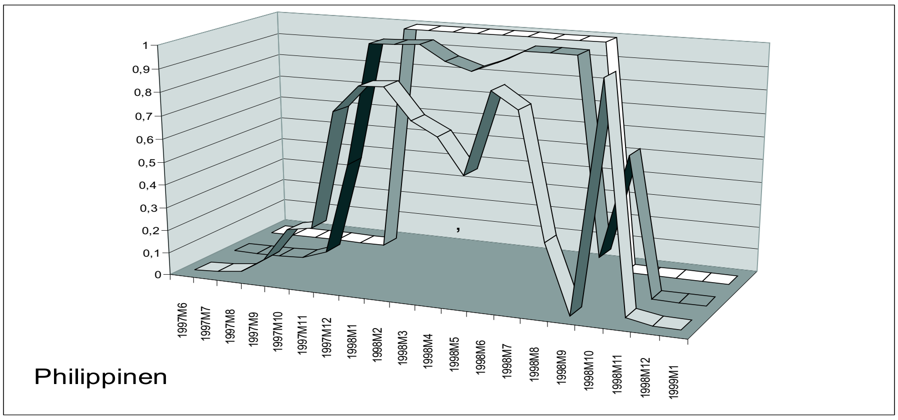

Figure 11: Regression results for the Philippines

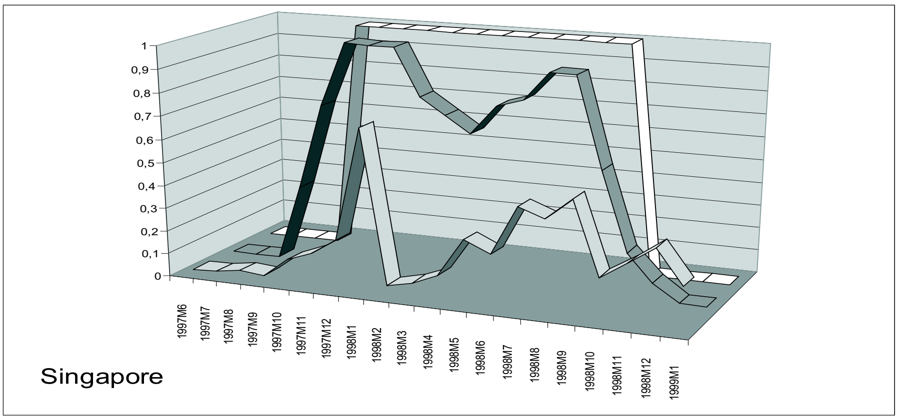

Figure 12: Regression results for Singapore

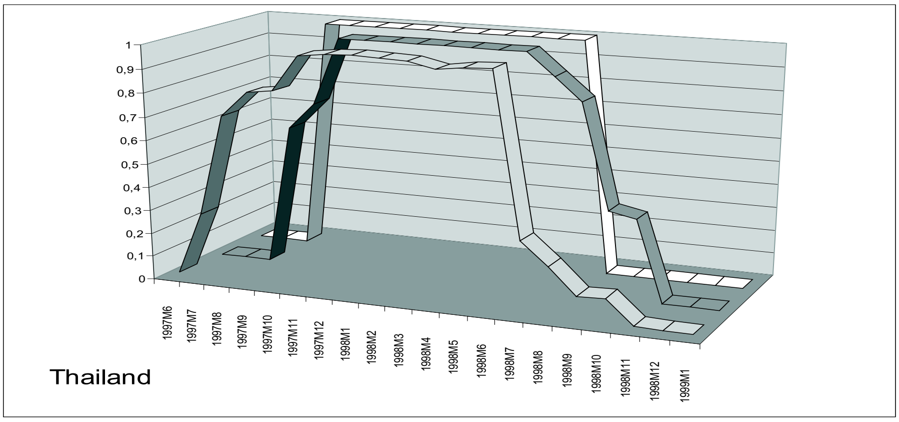

Figure 13: Regression results for Thailand