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CCSO Working Papers July, 2005

CCSO Working paper 2005/06

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This version: July 2005

Abstract

Indicators of financial crisis generally do not have a good track record. This paper presents an early warning system (EWS) for six countries in Asia in which indicators do work. Our binary choice model, which has been estimated for the period 1970:01–2001.12, has the following features. We extract a full list of currency crisis indicators from the literature, apply factor analysis to combine the indicators, and introduce dynamics. The quality of the EWS is assessed both in-sample and out-of-sample. We find that money growth (M1 and M2), national savings, and import growth correlate with currency crises.

Keywords: financial crises, currency crises, early warning system, panel data, multivariate logit, factor analysis
JEL-code: C33, C35, F31, F34, F47

*The support of the Universitas Catholic Indonesia Atma Jaya is gratefully acknowledged. The present version of the paper benefited from discussions with Mardi Dungey, helpful suggestions from Marcel Fratzscher, Niels Hermes and Elmer Sterken, and comments received at the NAKE Research Day, Amsterdam, October 2002, the SOM Brown Bag Seminar, University of Groningen, November 2002, the Workshop on Southeast Asia, University of Groningen, May 2003, and the NAKE Research Day, De Nederlandsche Bank, Amsterdam, October 2003.

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1 Introduction

Four waves of financial crises have hit international capital markets during the 1990s: the European Monetary System (ERM) crisis in 1992-1993, the collapse of the Mexican peso with 'tequila effects' in 1994-1995, the Asian flu of 1997-1998, and the Russia virus in 1998. These financial crises stimulated theoretical models and empirical analyses on their causes, impact and policy implications. Drawing lessons from these events is essential for the design of new international strategies to avoid future financial crises and to strengthen the international financial structure.

In view of the large costs associated with financial crises the question of how to predict a crisis is crucial. In addition, market indicators of default and currency risks, such as interest rate spreads and changes in credit ratings, hardly provide advance warning of financial crises. This resulted in the construction of a monitoring tool, the so-called *early warning system* (EWS).[1] An EWS consists of a precise definition of a crisis and a mechanism for generating predictions of crises. Typically, an EWS has an empirical structure that forecasts the likelihood of a financial crisis with indicators that show a country's vulnerability to a crisis. EWS models differ widely in terms of the definition of financial crisis, the time span on which the EWS is estimated and forecast horizon, the selection of indicators, and the statistical or econometric method. A common feature of all existing EWS studies is the use of fundamental determinants of the domestic and external sectors as explanatory variables.

[1] For example, the IMF has put a lot of effort in EWS models, see Evans et al. (2000), IMF (2002) and Berg, Borensztein and Pattillo (2004).

The list of studies on EWS of financial crises is long. A full list is beyond the scope of this paper. The literature distinguishes three varieties of financial crises: currency crises, banking crises, and debt crises. Interested readers are referred to Kaminsky, Lizondo and Reinhart (1998) for papers on currency crises prior to the East Asian crisis; Bustelo (2000) and Bukart and Coudert (2002) on the East Asian crisis; and Abiad (2003) for recent studies. Gonzalez-Hermosillo (1996) and Dermirgüç-Kunt and Detragiache (1997) focus on banking crises, while Cline (1995) and Marchesi (2003) survey debt crisis. We restrict our attention in this paper to currency crises.[2]

Several methods have been suggested for EWS models. The most popular one is used in this paper, namely qualitative response (logit or probit) models. Examples are Frankel and Rose (1996) and Frankel and Wei (2005), who study currency crises and Dermirgüç-Kunt and Detragiache (1997, 2000) and Eichengreen and Arteta (2002) on banking crises. Alternatives are cross-country regression models with dummy variables as put forward by Sachs, Tornell and Velasco (1996), graphical event studies as suggested by Eichengreen, Rose and Wyplosz (1995) and Aziz, Caramazza and Saldago (2000) and the signal extraction approach, a probabilistic model proposed by Kaminsky, Lizondo and Reinhart (1998), Goldstein, Kaminsky and Reinhart (2000) and Edison (2003). In the last method values of individual indicators are compared between crisis periods and tranquil periods. If the value of an indicator exceeds a threshold, it signals an impending crisis. Recently, Martinez-Peria (2002), Abiad (2003), and Chauvet and Dong (2004)

[2]Lestano, Jacobs and Kuper (2003) also present early warning systems for bank and debt crises.

proposed a Markov-switching early warning system.

This paper develops an econometric EWS for six Asian countries, Malaysia, Indonesia, Philippines, Singapore, South Korea and Thailand. These countries have been selected because the Asian flu hit Thailand and spread to other countries in the region—except Singapore—almost instantaneously. We set up logit models for currency crises with indicators extracted from a broad set of potentially relevant financial crisis indicators. The models are estimated using panel data for the January 1970–December 2001 period.

The set-up of our EWS is similar to Kamin, Schindler and Samuel (2001) and Bussiere and Fratzscher (2001), who also adopt a binomial multivariate qualitative response approach. However, while the final result of their (unreported) specification search is combinations of indicators as explanatory variables, we apply factor analysis to reduce the information set. An additional novelty of our model is that we do not only include the level of the factors, but also the change therein.[3] The development of the factors over time has important consequences for the probability of a currency crisis to occur. The factor analysis outcomes in combination with the estimation results and the ex post and ex ante track record allow the general conclusion that (some) indicators of financial crises do work, at least in our EWS of Asia. This finding is in contrast with IMF (2002) and Edison (2003), who conclude that the performance of EWS is generally poor and at best mixed. Our method—the combination of factor analysis and logit modeling—enables us to answer the question posed by Bustelo (2000) whether additional indica-

[3]Recently, Cippollini and Kapetanios (2003, 2005) and Chauvet and Dong (2004) applied dynamic factor models.

tors have explanatory power for financial crises. It also allows the dismissal of uninformative indicators.

The organization of the paper is as follows. Section 2 describes how we date currency crises. The results—dummy variables indicating dates of various crises—are used in binary choice models that explain the probability of crises. Section 3 describes our set of indicators, while Section 4 presents factor analysis and factors. Section 5 presents the binomial multivariate logit models for currency crises. We analyze the performance of the models in-sample and out-of-sample in Section 6. Section 7 concludes.

2 Dating currency crises

Generally, a currency crisis is defined to occur if an index of currency pressure exceeds a threshold.[4] Eichengreen, Rose and Wyplosz (1995) made an important early effort to develop a method to measure currency pressure and to date currency crises. Their definition of exchange rate pressure is inspired by the monetary model of Girton and Roper (1977). The exchange rate is under pressure if the value of a constructed index exceeds a certain threshold. The index consists of weighted relative changes of the nominal exchange rate, international reserves and interest rates to capture successful

[4] Alternatives to dating schemes with thresholds are event based methods or Markov switching models. Event based methods are commonly used in the contagion literature to date crisis from high volatility exchange rate events or news recorded by newspapers and journals, academic reviews and reports of international organizations. Examples of the former are Granger, Huang, and Yang (2000) and Ito and Hashimoto (2002); Kaminsky and Schmukler (1999), Glick and Rose (1999) and Dungey and Martin (2004) use news based currency crises. Martinez-Peria (2002), Abiad (2003) and Chauvet and Dong (2004) adopt a Markov switching framework in their EWS model, which yields currency crisis dates.

as well as unsuccessful speculative attacks. All variables in their index are relative to a reference country and their threshold is time-independent. For the dating of currency crises they set the exchange market pressure index threshold to two standard deviations from the mean. The method of Eichengreen et al. was heavily criticized which led to alternatives based on the same methodology. Kaminsky, Lizondo and Reinhart (1998) and Kaminsky and Reinhart (1999) followed the concept of Eichengreen et al. fairly closely, but they excluded interest rate differentials in their index and comparisons to a reference country. In this paper we identify episodes of currency crisis in East Asia with our own version of Kaminsky, Lizondo and Reinhart in which we include interest rates in the index. This choice is based on a more extensive evaluation of currency crises dating methods (Lestano and Jacobs, 2004). In addition, experimentation with different currency crisis concepts revealed that the concept used here performed best in an in-sample signal extraction experiment (Jacobs, Kuper and Lestano (2004)).

Table 1 summarizes the distribution of the currency crises over the six Asian countries in our sample. The total number of currency crises identified with our method is 58 (2.52 percent of the sample observations), distributed more or less evenly over the six countries.

[Table 1 about here.]

3 Indicators

This study focuses on indicators of macroeconomic development and external shocks. Worsening of these indicators affects the stability of financial system and may result in a financial crisis. The indicators are selected on the basis of economic theory and recent findings of empirical studies on financial crises. See Jacobs, Kuper and Lestano (2005) for details and references. Another major consideration was the data availability on a monthly basis for our country coverage and sample. For convenience, the indicators are clustered into four major groups:

- *External:* Real exchange rates (REX), export growth (EXG), import growth (IMP), terms of trade (TOT), ratio of the current account to GDP (CAY), the ratio of M2 to foreign exchange reserves (MFR) and growth of foreign exchange reserves (GFR).

- *Financial*: M1 and M2 growth (GM1 and GM2), M2 money multiplier (MMM), the ratio of domestic credit to GDP (DCY), excess real M1 balances (ERM), domestic real interest rate (RIR), lending and deposit rate spread (LDS), commercial bank deposits (CBD), and the ratio of bank reserves to bank assets (RRA).

- *Domestic (real and public)*: The ratio of fiscal balance to GDP (FBY), the ratio of public debt to GDP (FBY), growth of industrial production (GIP), changes in stock prices (CSP), inflation rate (INR), GDP per capita (YPC), and growth of national saving (NSR).

- *Global*: Growth of world oil prices (WOP), US interest rate (USI), and OECD GDP growth (ICY).

The main source of all data is the International Financial Statistics of the IMF for the macroeconomic and financial indicators and the World Bank

Development Indicators for the debt variables. We use monthly data, covering six Asian countries, Indonesia, Malaysia, Philippines, Singapore, South Korea and Thailand, from January 1977 to the end of 2001. Missing data are supplemented from Thompson Datastream and various reports of the countries' central banks. All data in local currency units are converted into US dollars. Some annual indicators are interpolated to obtain a complete monthly database.

The Appendix lists definitions, sources and transformations of our crises indicators. Two types of transformations are applied to make sure that the indicators are free from seasonal effects and stationary, 12-months percentage changes and deviation from linear trends. In case the indicator has no visible seasonal pattern and is non-trending, its level form is maintained. Some unavailable indicators are proxied by closely related indicators, for example OECD GDP is substituted by industrial production of industrial countries.

4 Factor analysis

As already mentioned in the Introduction, the aim of this paper is to calculate the probability of a currency crisis. However, the set of economic indicators that is informative on whether or not a crises will occur is huge. It is not feasible to include all indicators in the logit model because of too few observations and multicollinearity among the indicators. So, for each country we reduce the information set into a limited number of factors using factor analysis. These factors are then used as explanatory variables in the logit model.

Technically speaking, factor analysis transforms a set of random variables linearly and orthogonally into new random variables.[5] The first factor is the normalized linear combination of the original set of random variables with maximum variance; the second factor is the normalized linear combination with maximum variance of all linear combinations uncorrelated with the first factor; and so on. By construction factors are uncorrelated. The eigenvalue for a given factor measures the variance in all the variables which is accounted for by that factor. A factor with a low eigenvalue may be ignored, because other factors are more important in explaining the variance in the set of variables under consideration.

Unfortunately, there is no "best" criterion for dropping the least important factors. The so-called Kaiser criterion drops all factors with eigenvalues below one. The Cattell scree test is a graphical method in which the eigenvalues are plotted on the vertical axis and the factors on the horizontal axis. The test suggests to select the number of factors that corresponds to the place of the curve where the smooth decrease of eigenvalues appears to level off to the right of the plot. In general, the scree test provides a lower bound on the number of relevant factors. In this paper we use the Kaiser criterion.

Table 2 lists eigenvalues and the total variance explained by the factors for each country. For most countries, eight factors emerge with an eigenvalue above unity.[6]

[Table 2 about here.]

[5] For a detailed exposition of factor analysis including references see *e.g.*, Venables and Ripley (2002, Chapter 11).

[6] For Singapore and Thailand we maintain eight factors although only seven factors have an eigenvalue above unity.

5 Logit model

Since our dependent variable is a binary variable (where 0=no crisis and 1=crisis) we use a binary choice model. Two popular versions are the probit and the logit model. The major difference is that the probit model is based on the normal distribution, whereas the logit model uses an S-shaped logistic function to constrain the probabilities to the [0,1] interval. Predicted probabilities calculated by these models differ only slightly in practice. We opt for the logit model

$$P = F(Z) = \frac{1}{1+e^{-Z}} = \frac{1}{1+e^{-(\alpha+\beta X)}},$$

where P is the probability that Z takes the value 1 and F is the cumulative logistic probability function; X is the set of regressors and α and β are parameters. It can be shown that the regression equation is equal to

$$\ln\left(\frac{P}{1-P}\right) = Z = \alpha + \beta X.$$

In our model, the vector of explanatory variables X consists of the eight factors rather than the full list of economic indicators themselves. However since the change in the factors may affect the probability of a currency crisis to occur, we also include differences in the factors which reduces the number of observations for each country by one. Finally, testing for fixed effects rejects the null of common effects in all models except the ERW and FR types of currency models. The results are presented in Table 3. Intercepts and country-specific intercepts (fixed effects) are not reported.

[Table 3 about here.]

From the likelihood ratio statistics, which test the joint null hypothesis that all slopes coefficient except the constant are equal to zero, we conclude that the explanatory variables (factors in levels and in differences) contribute significantly to the explanation of the variation in the crises dummies. Also, tests whether the first differences of the factors contribute significantly to the explanation of the variation in the crises dummies (not reported), leads us to conclude that this indeed is the case. In addition, we observe that factor 1 has the largest impact on the predicted probability of a currency crises; it is significantly different from zero at the 1% level. In addition, the first difference of factor 8 is significant at 1%.

Factor 1 has by far the largest contribution to predicting crises probabilities. Although interpretation of the estimated coefficients in terms of the underlying indicators is not trivial, the eigenvector of factor 1 is informative, since factor 1 is a linear combination of the indicators with weights given by the first eigenvector. These weights are presented in Table 4. The largest weights in factor 1 are related to the growth of money (M1 and M2), supporting Kamin, Schindler and Samuel (2001),the growth of national saving, the rate of growth of GDP per capita, and import growth. These variables are dominant for all countries in our sample. Other variables that have an impact in some countries are commercial bank deposits, growth of foreign exchange reserves, export growth, and to a lesser extent domestic real interest rate, terms of trade, and growth of world oil prices.

[Table 4 about here.]

6 Performance

The logit models discussed above produce estimated probabilities of crises. High probabilities signal crises, low probabilities tranquil periods. The model might give false signals, *i.e.*, a crisis does not take place despite the logit model producing a high probability. There are four possibilities. A model may indicate a crisis (high estimated probability) when a crisis indeed occurs ($P(1,1)$) or it may indicate a crisis when no crisis actually takes place ($P(1,0)$). It is also possible that the model does not signal a crisis (low estimated probability) where in fact a crisis does occur ($P(0,1)$). The final possibility ($P(0,0)$) is a situation in which the model does not predict a crisis and no crisis occurs. Table 5 lists the four possibilities.

[Table 5 about here.]

Once we generate time series of crisis probabilities, we can evaluate the forecasting ability of the model. Instead of carrying out a standard signaling experiment along the lines of e.g. Frankel and Rose (1996) and Berg and Pattillo (1999) which both require an ad-hoc assumption on the translation of estimated crisis probabilities into crisis dummies, we use the quadratic probability score (QPS) and the log probability score (LPS) proposed by Diebold and Rudebusch (1989). Both scores give an indication of the average closeness of the predicted probabilities and the observed realizations, as measured by a dummy variable that takes on a value of one when there is a crisis and zero otherwise. Let P_t is the prediction probability of the occurrence of crisis or no crisis event by the model at date t and R_t is zero-one dummy variable, that is equal to 1 if the event occurs in the actual data and equal to zero otherwise. The QPS and LPS are then given by

$$
\begin{aligned}
QPS &= \frac{1}{T}\sum_{t=1}^{T} 2(P_t - R_t)^2 \\
LPS &= -\frac{1}{T}\sum_{t=1}^{T} ((1-R_t)\ln(1-P_t) + R_t \ln(P_t)).
\end{aligned}
$$

The QPS ranges from 0 to 2, with a score of 0 corresponding to perfect accuracy. The LPS takes value between zero and infinity, with 0 being perfect accuracy.

We evaluate in-sample (1970.01–2001.12) and out-of-sample (2002.01–2002.12) crisis probabilities. Table 6 reports the accuracy of the model. The second and the third column report in-sample performance, while the last two columns examine out-of-sample forecast performance. Recall that the closer the score statistics in Table 6 are to zero, the more accurate the forecasts. For all countries, the model performs quite well in-sample, except for Singapore with an LPS score of 0.11. The out-of-sample forecasts are significantly better than the in-sample projections. This should not come as a complete surprise considering the fact that hardly any currency crisis occur in the forecast period.

[Table 6 about here.]

7 Conclusion

This paper builds an econometric EWS of six Asian countries, Malaysia, Indonesia, Philippines, Singapore, South Korea and Thailand. We set up a qualitative choice—in our case logit—model. From the literature we extract a broad set of potentially relevant financial crisis indicators which are combined into factors using factor analysis. These factors are used as explanatory variables in a panel covering the period January 1970–December 2001.

The factor analysis outcomes in combination with the estimation results of the logit model and the in-sample and out-of-sample performance allow the general conclusion that (some) indicators of financial crises do work, at least in our EWS of six Asia countries. We find that the growth rates of money (M1 and M2), GDP per capita, national savings, and imports correlate with currency crises. Other variables that have an impact in some countries are growth rates of commercial bank deposits, foreign exchange reserves, exports, and to a lesser extent domestic real interest rates, terms of trade, and world oil prices changes. So, our method—the combination of factor analysis and logit modeling—offers a solution to the bad performance (mixed and weak in timing of crisis) of EWS as noted by IMF (2002) and Edison (2003). A second, important conclusion is that first differences in indicators add to explaining probabilities of currency crises. Including dynamics in the factors improves the fit of EWS models making it a more powerful surveillance instrument for policy makers.

An early warning system provides insights into which variables signal the likelihood of countries experiencing a financial crisis. The models should be used with care though. Applying our EWS to developed economies could easily produce a result similar to what The Economist (2003) reported, the US being at risk according to *Damocles*, Lehman Brothers' EWS (Subbaraman, Jones, and Shiraishi, 2003). To avoid pitfalls like these, EWS analyses should be accompanied by country risk assessments.

Appendix. Explanatory variables

Indicator	Code	Definition and source	Transformation
External sector (current account)			
Real exchange rate	REX	Nominal exchange rate is local currency unit (LCU) per USD, IFS-AE. The CPI is IFS-64. The real exchange rate is the ratio of foreign (US CPI) to domestic prices (measured in the same currency). Thus, REX = eP_f/P, where e = nominal exchange rate, P = domestic price (CPI), and P_f = foreign price (US CPI). A decline in the real exchange rate denotes a real appreciation of the LCU.	Deviation from trend
Export growth	EXG	IFS-70.D	12 month percentage change
Import growth	IMP	IFS-71.D	12 month percentage change)
Terms of trade	TOT	Unit value of exports divided by the unit value of imports. Unit value of exports is IFS-74.D. Import unit value for country (IFS-75.D) is not available, instead exports prices of industrialized countries is used, IFS-110.74.D.	12 month percentage change
Ratio of the current account to GDP	CAY	Current account (IFS-78AL) divided by nominal GDP (interpolated of IFS-99B).	-
External sector (capital account)			
Ratio of M2 to foreign exchange reserves	MFR	Ratio of M2 (IFS-34 plus IFS-35) and international reserves (IFS-1L.D). M2 is converted into USD.	12 month percentage change
Growth of foreign exchange reserves	GFR	IFS-1L.D	12 month percentage change

to be continued

Indicator	Code	Definition and source	Transformation
Financial sector			
M1 growth	GM1	IFS-34	12 month percentage change
M2 growth	GM2	IFS-35	12 month percentage change
M2 money multiplier	MMM	Ratio of M2 (IFS-34 plus IFS-35) to base (reserve) money (IFS-14).	12 month percentage change
Ratio of domestic credit to GDP	DCY	Total domestic credit (IFS-32) divided by nominal GDP (interpolated of IFS-99B).	12 month percentage change
Excess real M1 balance	ERM	Percentage difference between M1 (IFS-34) deflated by CPI (IFS-64) and estimated demand for M1. Demand for real M1 is estimated as function of real GDP, nominal interest rates (IFS-60L), and a time trend. If monthly real GDP data is not available for a country, then its annual counterpart (IFS-99BP) is interpolated to monthly data.	Based on estimated money demand equation
Domestic real interest rate	RIR	6 month time deposit (IFS- 60L) deflated by CPI (IFS-64)	-
Lending and deposit rate spread	LDS	Lending interest rate (IFS-60P) divided by 6 month time deposit rate (IFS-60L)	-
Commercial bank deposits	CBD	Demand deposit (IFS-24) plus time, savings and foreign currency deposits (IFS-25) deflated by CPI (IFS-64)	12 month percentage change
Ratio bank reserves to bank assets	RRA	Bank reserves (IFS-20) divided by bank assets (IFS-21 plus IFS-22a to IFS-22f)	-

to be continued

Indicator	Code	Definition and source	Transformation
Domestic real and public sector			
Ratio of fiscal balance to GDP	FBY	Government budget balance (IFS-80) divided by nominal GDP (interpolated IFS-99B).	-
Ratio of public debt to GDP	PBY	Public and publicly guaranteed debt (World Bank) divided by nominal GDP (interpolated IFS-99B).	-
Growth of industrial production	GIP	Industrial production index for Country is not available, then index of primary production (crude petroleum, IFS.66AA) is used	12 month percentage change
Changes in stock prices	CSP	IFS-62	12 month percentage change
Inflation rate	INR	IFS-64.	12 month percentage change
GDP per capita	YPC	GDP (interpolated IFS-99B) divided by total population (interpolated IFS-99Z).	12 month percentage change
National savings	NSR	public (IFS-91F) and private consumption (IFS-96F) subtracted from GDP (interpolated IFS-99B).	12 month percentage change
Global economy			
Growth of world oil prices	WOP	IFS-176.AA	12 month percentage change
US interest rate	USI	US treasury bill rate (IFS-111.60C)	12 month percentage change
OECD GDP growth	ICY	Proxied by industrial production (IFS-66).	12 month percentage change

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List of Tables

Table 1: Currency crises: distribution over countries

	Currency crises
Indonesia	9 (2.34%)
Malaysia	10 (2.60%)
Philippines	12 (3.13%)
Singapore	11 (2.86%)
South Korea	7 (1.82%)
Thailand	9 (2.34%)
All countries	58 (2.52%)

The number between parentheses shows the frequency of crisis occurrence which is calculated by dividing the total number of crisis months by the total number of observations.

Table 2: Eigenvalues and the cumulative proportion of the variance explained by the factors (h^2)

Eigenvalues	Indonesia	Malaysia	Philippines	Singapore	South Korea	Thailand
factor 1	5.93	7.79	5.58	7.88	7.55	6.69
factor 2	3.40	3.19	3.71	3.28	3.37	3.96
factor 3	2.84	2.38	2.60	2.78	2.60	3.37
factor 4	2.01	2.15	2.41	1.91	1.85	2.22
factor 5	1.91	1.93	1.72	1.66	1.63	1.72
factor 6	1.46	1.34	1.52	1.37	1.39	1.42
factor 7	1.20	1.12	1.11	1.01	1.25	1.34
factor 8	1.06	1.05	1.05	0.92	1.10	0.78
h^2	0.76	0.81	0.76	0.83	0.80	0.83

Table 3: Estimation results of the binomial logit model (fixed effects not reported) with Huber-White robust standard errors.

	Coefficient	z-statistic
factor 1	−0.27	−4.14
Δ(factor 1)	−1.78	−7.03
factor 2	0.09	0.80
Δ(factor 2)	−0.52	−1.71
factor 3	0.22	2.03
Δ(factor 3)	−0.13	−0.39
factor 4	0.39	3.31
Δ(factor 4)	0.15	0.58
factor 5	0.19	1.67
Δ(factor 5)	0.53	1.63
factor 6	0.07	0.50
Δ(factor 6)	0.60	2.22
factor 7	0.14	1.22
Δ(factor 7)	0.06	0.24
factor 8	−0.10	−0.61
Δ(factor 8)	0.80	3.83
McFadden R^2		0.38
Observations with $Z = 1$		58
Likelihood ratio statistic, χ^2(16 d.f.)		202.66

Critical values of the z-statistic at the 1% and 5% level are 2.57 and 1.96, respectively. The critical value of the likelihood ratio test at 1% (16 d.f.) is 32.00.

Table 4: Weights of the first factor

Indicator	Indonesia	Malaysia	Philippines	Singapore	South Korea	Thailand
CAY	0.01	0.00	0.00	0.01	0.04	0.00
CBD	0.02	0.08	0.06	0.07	0.01	0.05
CSP	0.01	0.05	0.00	0.00	0.00	0.02
DCY	0.01	0.05	0.01	0.00	0.00	0.02
ERM	0.01	0.00	0.01	0.01	0.01	0.02
EXG	0.07	0.06	0.09	0.03	0.08	0.06
FBY	0.01	0.01	0.00	0.02	0.00	0.02
GFR	0.06	0.03	0.03	0.00	0.02	0.07
GIP	0.03	0.07	0.02	0.00	0.05	0.04
GM1	0.11	0.09	0.09	0.12	0.06	0.09
GM2	0.10	0.10	0.09	0.12	0.06	0.10
ICY	0.01	0.04	0.02	0.01	0.01	0.01
IMP	0.05	0.07	0.08	0.09	0.08	0.09
INR	0.01	0.00	0.03	0.00	0.07	0.02
LDS	0.00	0.00	0.00	0.00	0.04	0.01
MFR	0.00	0.00	0.00	0.00	0.00	0.01
MMM	0.00	0.04	0.01	0.00	0.02	0.01
NSR	0.09	0.11	0.10	0.13	0.10	0.12
PBY	0.06	0.00	0.01	NA	0.00	0.02
REX	0.00	0.01	0.02	0.06	0.02	0.04
RIR	0.03	0.01	0.05	0.01	0.05	0.02
RRA	0.04	0.03	0.01	0.00	0.08	0.00
TOT	0.07	0.01	0.05	0.05	0.02	0.01
USI	0.02	0.03	0.04	0.05	0.04	0.02
WOP	0.06	0.01	0.04	0.06	0.03	0.03
YPC	0.10	0.10	0.10	0.13	0.10	0.12
Total	1.00	1.00	1.00	1.00	1.00	1.00

Indicator codes are listed in the Appendix.

Table 5: The probabilities of right and wrong crisis predictions

		Crisis ($Z = 1$)	No crisis ($Z = 0$)
Estimated probability	high	$P(1, 1)$	$P(1, 0)$
	low	$P(0, 1) = 1 - P(1, 1)$	$P(0, 0) = 1 - P(1, 0)$

Table 6: Model performance

	In sample		Out sample	
	QPS	LPS	QPS	LPS
Indonesia	0.032	0.067	0.003	0.030
Malaysia	0.031	0.068	0.003	0.033
Philippines	0.036	0.074	0.001	0.012
Singapore	0.051	0.107	0.003	0.028
South Korea	0.024	0.061	0.001	0.011
Thailand	0.028	0.063	0.002	0.024

Note: QPS and LPS stand for the quadratic probability score and the log probability score, respectively.