A comparison of currency crisis dating methods: East Asia 1970-2002

Lestano* and Jan P.A.M. Jacobs
Department of Economics, University of Groningen

December 2004

Abstract

Generally, a currency crisis is defined to occur if an index of currency pressure exceeds a threshold. This paper compares several currency crisis dating methods adopting different definitions of currency pressure indexes and ad-hoc and extreme value based thresholds. We illustrate the methods with data of six East Asian countries for the January 1970–December 2002 period, and evaluate the methods on the basis of the IMF chronology of the Asia crisis in 1997-1998.

Keywords: currency crises, crisis episodes, crisis events, crisis dating, exchange rate market pressure, extreme value theory, Asia crisis
JEL-code: C14, F31

Acknowledgements
This version of the paper benefited from comments received at the NAKE Research Day, Amsterdam, October 2002, and the SOM Brown Bag Seminar, University of Groningen, November 2002.

*Corresponding author: Lestano, Department of Economics, University of Groningen, PO Box 800, 9700 AV Groningen, The Netherlands. Tel.: +31 50 363 7063. Fax: +31 50 363 7337. Email: `lestano@eco.rug.nl`

1 Introduction

The recent financial crises in emerging markets are important macroeconomic events. Several countries experienced large currency depreciations as well as collapses of the financial and productive sector. This triggered many empirical studies on signaling future currency crises, so-called *early warning systems* (EWS), which use fundamental economic determinants as predictor variables and various statistic and econometric techniques. See Kaminsky, Lizondo and Reinhart (1998) for pre-1997 studies and Abiad (2003) for recent studies; for an assessment of EWS models see Borensztein and Pattillo (2004). Other studies look for evidence of the propagation of crises by tracking shifts in correlations and testing contagion channels. See Rigobon (2002) and Dungey, Fry, Gonzalez-Hermosillo and Martin (2003) for overviews. Whatever the techniques and the set of variables used to generate EWS predictions or the evidence of contagion, identifying currency crisis episodes play as crucial role. Binary crisis variables that result from crisis episodes dates enter as pivotal (or dependent) variables in all EWS or contagion models.

Generally, a currency crisis is defined to occur if an index of currency pressure exceeds a threshold. Alternatives 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 (2002) use news-based currency crises. Martinez-Peria (2002) and Abiad (2003) adopt a Markov-switching framework in their EWS model, which yields currency crisis dates. Strictly speaking, currency crisis episodes are identified rather than currency crises, since a currency crisis can reveal itself through many crisis events and crisis episodes. Therefore some authors incorporate exclusion windows ruling out measuring the same crisis more than once. Examples are Eichengreen, Rose, and Wyplosz (1995,1996), Frankel and Rose (1996) and Aziz, Caramazza and Salgado (2000). We do not follow this practice in this paper and use the expressions currency crisis and currency crisis episode interchangeably.

Eichengreen, Rose, and Wyplosz (1995,1996) made an early effort to identify currency crisis episodes. They take changes in exchange rates, international reserves, and interest rates to capture successful as well as unsuccessful speculative attacks. These variables are combined into an index of speculative pressure known as Exchange Market Pressure Index $EMPI$. Kaminsky, Lizondo and Reinhart (1998), Kaminsky and Reinhart (1999) and Goldstein, Kaminsky and Reinhart (2000) followed the concept of Eichengreen et al. fairly closely, but excluded interest rate differentials in their index. Frankel and Rose (1996) confine attention to successful attacks, since unsuccessful ones are hard to detect. They drop international reserves and interest rates differentials from the exchange market pressure index, which results in a currency crash index. Zhang (2001) treats exchange rate and reserve changes separately to avoid averaging and weighting issues altogether and takes time-varying thresholds.

The dating schemes discussed above signal a currency crisis when the exchange market pressure index exceeds a threshold. The threshold is in terms of a number of standard deviations above the mean based on the assumption that the index follows a well-behaved normal distribution. Alternatively, Pozo and Amuedo-Dorantes (2003) and Haile and Pozo (2003) suggest exploiting the information in the tails of the distribution of the index and determine crisis dates from the extreme values.

The objective of this paper is to compare several currency crisis dating methods. We investigate the sensitivity of currency crisis dates to changes in the definition of the exchange market pressure index and choice of the thresholds. We use data on six Asian countries, Indonesia, Malaysia, Philippines, Singapore, South Korea and Thailand, for the period between January 1970 and December 2002. To this purpose we analyze how many currency crisis episodes each method identifies and show distributions over time. We apply extreme value theory to three of the indexes, which indeed have non-normal distributions and need to be filtered to meet the assumptions underlying extreme value theory. In general, extreme value theory identifies a larger number of crises than ad-hoc thresholds equal to two standard deviations or more. The comparison study of Pontines and Siregar (2004) comes to a similar conclusion.

Unfortunately, there is no way to judge the accuracy of currency crisis dating methods, since there is no consensus about a formal definition of currency crisis derived from theory. Moreover, international organizations do not systematically categorize crisis countries or crisis periods, cf. Pozo and Amuedo-Dorantes (2003). So, our final judgment on the methods is a second best one: we confront the crisis chronologies with the official IMF chronology of Asia crisis events in 1997-1998.

This paper is organized as follows. Section 2 discusses the currency crises dating methods of Eichengreen, Rose and Wyplosz (1995), Kaminsky, Lizondo and Reinhart (1998), Frankel and Rose (1996), and Zhang (2001). Section 3 briefly reviews extreme value theory. Section 4 describes the Asian data and lists some test outcomes of time series properties of the data, which guide our implementation of the extreme value theory in Section 5. Section 6 summarizes the crisis chronologies in terms of the total number of crises picked up and their distribution over time, investigates the sensitivity to the definition of the exchange market pressure index and the choice and the value of the threshold, and their ability to track the official IMF currency crisis events chronology. Section 7 concludes.

2 Exchange market pressure indexes and ad-hoc thresholds

Eichengreen, Rose and Wyplosz (1995, 1996)

Eichengreen, Rose and Wyplosz (ERW) assume that a speculative attack exists in the form of extreme pressure in the foreign exchange market, which usually results in a devaluation (or revaluation), or a change in the exchange rate system, *i.e.* to float, fix or widen the band of the exchange rate. Speculative attacks on exchange rates can also be unsuccessful. When facing pressure on its currency, the authorities have the option to raise interest rates or to run down international reserves. ERW's definition of exchange rate pressure is inspired by the monetary model of Girton and Roper (1977). See the appendix for further details. Hence, speculative pressure is measured by an index that is a weighted average of normalized changes in the exchange rate, the ratio of international reserves to M1, and the nominal interest rates. All variables are relative to a reference country, for which a country is selected with a strong currency that serves as an anchor to other countries. We use the US as our reference country. The index of exchange rate pressure is defined as follows:

$$EMPI_{i,t} = \frac{1}{\sigma_e}\frac{\Delta e_{i,t}}{e_{i,t}} - \frac{1}{\sigma_r}\left(\frac{\Delta rm_{i,t}}{rm_{i,t}} - \frac{\Delta rm_{US,t}}{rm_{US,t}}\right) + \frac{1}{\sigma_i}\Delta\left(i_{i,t} - i_{US,t}\right), \qquad (1)$$

where $EMPI_{i,t}$ is the exchange rate market pressure index for country i in period t; $e_{i,t}$ the units of country i's currency per US dollars in period t; $rm_{i,t}$ the ratio of foreign reserves to $M1$ for country i in period t; $i_{i,t}$ the nominal interest rates for country i in period t; $i_{US,t}$ the nominal interest rates for the reference country (US) in period t; σ_e the standard deviation of the relative change in the exchange rate $(\Delta e_{i,t}/e_{i,t})$; σ_r is the standard deviation of the difference between the relative changes in the ratio of foreign reserves and money ($M1$) in country i and the reference country (US) $((\Delta rm_{i,t}/rm_{i,t}) - (\Delta rm_{US,t}/rm_{US,t}))$; and σ_i the standard deviation of the nominal interest rate differential $\Delta(i_{i,t} - i_{US,t})$.

A crisis is identified when the index exceeds some upper bound:

$$\text{Crisis} = \begin{cases} 1 & \text{if } \; EMPI_{i,t} > \beta\sigma_{EMPI} + \mu_{EMPI} \\ 0 & \text{otherwise,} \end{cases}$$

where σ_{EMPI} equals the sample standard deviation of *EMPI* and μ_{EMPI} is the sample mean of *EMPI*. In their 1995 paper, ERW arbitrarily set a threshold of $\beta = 2$, *i.e.* two standard deviations above the mean, while in ERW (1996) they set β equal to 1.5. Note that Eichengreen, Rose and Wyplosz (1995) use an exclusion window of 12 months (shortened 6 months in their 1996 article). As mentioned in the introduction, we do not follow this practice.

Kaminsky, Lizondo and Reinhart (1998)

Kaminsky, Lizondo and Reinhart (KLR) modify the exchange market pressure index of ERW by dropping the links to the reference country and interest rate differential, arguing that interest rates were controlled by central banks in their sample period, the 1970s and 1980s, and multiplying the right-hand-side by the standard deviation of the relative change in the exchange rate:

$$EMPI_{i,t} = \frac{\Delta e_{i,t}}{e_{i,t}} - \frac{\sigma_e}{\sigma_r}\frac{\Delta r_{i,t}}{r_{i,t}}, \tag{2}$$

where $r_{i,t}$ denotes foreign reserves of country i in period t and σ_r the standard deviation of the relative change in the reserves ($\Delta r_{i,t}/r_{i,t}$).

The definition of a currency crisis is the same as in ERW, *i.e.* in terms of a threshold exceeding a number of standard deviations above the mean. However KLR set the threshold for a currency crisis to three standard deviations above the mean.

Below we also implement a modified version of the KLR *EMPI* by including interest rates in the index:

$$EMPI_{i,t} = \frac{\Delta e_{i,t}}{e_{i,t}} - \frac{\sigma_e}{\sigma_r}\frac{\Delta r_{i,t}}{r_{i,t}} + \frac{\sigma_e}{\sigma_i}\Delta i_{i,t}. \quad (3)$$

The threshold is defined as in KLR.

Frankel and Rose (1996)

Frankel and Rose (FR) confine attention to successful speculative attacks. In their opinion international reserves are too rough a proxy to measure policy actions in defense of a currency and raising interest rates and exhausting international reserves is not standard practice to deal with speculative attacks in most developing countries.

The FR method defines a currency crash as a nominal depreciation of the currency of at least 25 percent which is accompanied by an increase in the rate of depreciation of at least 10 percent. The latter cut-off point is used to avoid registering periods with high inflation, which are usually followed by a large depreciation. So, a currency crash is defined by

$$\text{Crisis} = \begin{cases} 1 \;\; \text{if} \;\; \%\Delta e_{i,t} > 25\% \;\; \text{and} \;\; \%\Delta e_{i,t} - \%\Delta e_{i,t-1} > 10\% \\ 0 \;\; \text{otherwise} \end{cases} \quad (4)$$

Note that we do not copy the three-year exclusion window that FR use to avoid that a currency crash is counted more than once.

Zhang (2001)

Zhang (Z) points at two problems with ERW's and KLR's definitions of exchange market pressure. First, changes in international reserves and interest rates may cancel against each other if the speculative attack is successful. For example, a positive change in the exchange rate (in anticipation of a devaluation) may trigger a fall in the interest rate and an increase in international reserves. Secondly, movements in international reserves and exchange rate can be volatile in some periods and relatively tranquil in other periods. Thus, an event that results in high volatility dominates the whole sample.

To tackle these problems, Zhang decomposes ERW's exchange rate market pressure index and uses time-varying thresholds for each component. He excludes interest rate variables from the index and also drops the link to the reference country

$$\text{Crisis} = \begin{cases} 1 \quad \text{if} & \begin{cases} \Delta e_{i,t}/e_{i,t} > \beta_1 \sigma'_{e,t} + \mu_{e,t} \quad \text{or} \\ \Delta r_{i,t}/r_{i,t} < \beta_2 \sigma'_{r,t} + \mu_{r,t} \end{cases} \\ 0 \quad \text{otherwise} \end{cases} \tag{5}$$

where $\sigma'_{e,t}$ is the standard deviation of $(\Delta e_{i,t}/e_{i,t})$ in the sample of $(t-36, t-1)$, and $\sigma'_{r,t}$ the standard deviation of $(\Delta r_{i,t}/r_{i,t})$ in the sample of $(t-36, t-1)$. Zhang arbitrarily sets the thresholds to $\beta_1 = 3$ and $\beta_2 = -3$.

Below we extend Zhang's method by including interest rates changes to proxy the index of ERW. The currency crises dating scheme then becomes

$$\text{Crisis} = \begin{cases} 1 \ \ \text{if} \begin{cases} \Delta e_{i,t}/e_{i,t} > \beta_1 \sigma'_{e,t} + \mu_{e,t} \ \ \text{or} \\ \Delta r_{i,t}/r_{i,t} < \beta_2 \sigma'_{r,t} + \mu_{r,t} \ \ \text{or} \\ \Delta i_{i,t} > \beta_3 \sigma'_{i,t} + \mu_{i,t} \end{cases} \\ 0 \ \ \text{otherwise.} \end{cases}$$

where $\sigma'_{i,t}$ is the standard deviation of $\Delta i_{i,t}$ in the sample of $(t-36, t-1)$ and set β_3 to 3.

3 Extreme value theory

The dating methods discussed above are all based on some index of exchange market pressure. The tails of the distribution of the *EMPI* are interpreted as results of (un)successful speculative attacks against the currency of the country and have direct links to currency crises dates. With the exception of FR, a currency crisis is signaled if the index exceeds a threshold, defined in terms of a number of standard deviations above the mean. This threshold is based on the arbitrary assumption that the index follows a well-behaved normal distribution. However, the normality condition need not necessarily hold due to fat tails in the data, and skewness. Alternatively, Pozo and Amuedo-Dorantes (2003) suggest exploiting the information in the tails of the distribution using extreme value theory, following Koedijk, Schafgans and De Vries (1990). For a general introduction of extreme value theory see Embrechts, Kluppelberg and Mikosch (1997). Here, extreme values of *EMPI* determine the crisis dates without the need to set an arbitrary threshold value.

The distribution of *EMPI* can be characterized by a tail parameter α. The tail parameter is an indicator of the tail fatness. With extremal analysis, one can estimate the value for the tail parameter (α) and make inferences about the distribution from which the data comes because different distributions correspond to different values of the tail parameter. For example, the normal distribution has an α below two and the Student t-distribution has an α equal to two and more. We use this approach to characterize the distribution of *EMPI*. Moreover, we are able to identify extreme observations and thereby find currency crisis episodes.

Akgiray, Booth and Seifert (1988) suggest to estimate the tail parameter by maximum likelihood estimation (MLE) to distinguish between the different types of distributions, but Koedijk, Stork and De Vries (1992) have shown that the Hill estimator (Hill, 1975) is more efficient and produces higher standard errors. The Hill estimator works as follows. The series $EMPI_1, \ldots, EMPI_n$ is ordered according to size: $EMPI_{(1)} \leq \ldots \leq EMPI_{(n)}$. Suppose that we want to include m extreme observations from the right tail. The Hill estimator of the reciprocal of α is defined by

$$\frac{1}{\hat{\alpha}} \equiv \hat{\gamma} = \frac{1}{m}\left[\sum_{t=1}^{m}\left(\ln EMPI_{(n+1-t)} - \ln EMPI_{(n-m)}\right)\right]. \tag{6}$$

The optimal choice of m is nontrivial. For finite samples three procedures have been proposed. The first uses Hill plots, where $1/\hat{\alpha}$ is plotted for different values of m, and selects the value of m for which $1/\hat{\alpha}$ is stable. For details see Embrechts, Kluppelberg and Mikosch (1997) and Drees, de Haan and Resnick (2000). Alternatives are recursive least squares and Monte Carlo experiments. In recursive least squares $1/\hat{\alpha}$ is regressed on a constant and trend, and observations are deleted successively starting from the most extreme one which yields a series of fitted values for $1/\hat{\alpha}$. A stable estimate of $1/\hat{\alpha}$ is obtained if for a certain value of m the recursive residuals fall outside the two standard errors bands. Monte Carlo experiments, as proposed by Koedijk, Schafgans and De Vries (1990) and Longin and Solnik (2001), can also yield employed to find the optimal value of m without bias and inefficiency. The minimum MSE criterion of $\hat{\gamma}$ is used to select m for given number of observations n and degrees of freedom.

In this paper, we follow Koedijk, Stork and Vries (1992) and Pozo and Amuedo-Dorantes (2003) and use the Hill estimator to obtain the number of extreme (crisis) observations for the exchange market pressure indexes of ERW, KLR and our modification of KLR. To verify that we indeed obtain stable tail parameters, we employ recursive least squares. An important prerequisite of the Hill estimator is stationary and serially uncorrelated *EMPI* series. From the time series properties tests we conclude that the series need to be filtered before we can apply the Hill estimator. We illustrate the extreme value theory for the filtered series. Details will be provided below.

4 Data

4.1 Source

The main source of all data is International Financial Statistics of IMF. We use monthly data from January 1970 to the end of 2002, covering six Asian countries, Indonesia, Malaysia, Philippines, Singapore, South Korea, and Thailand. We follow the choices made by Kaminsky, Lizondo and Reinhart (1998) and Kaminsky and Reinhart (1999) in selecting historical data. We expanded their 1970–1995 sample up to including the end of 2002. The selection of these countries is motivated by the recent Asian financial crisis, which is clustered in this group of countries. We exclude countries like Taiwan, Hong Kong and China, for which we could not find comparable or reliable data for the whole period under analysis. Missing data are supplemented with information from Thompson-Datastream and various reports of the country's central banks. We end up with a balanced panel data set of 396 months for 6 countries, which makes a total of 2,376 observations.

Exchange rates used to calculate the indexes of all methods are defined in terms of US dollars and market rates, except for Malaysia and Thailand where the official rate is used. The money base (M1) is converted into US dollars. In the ERW method domestic interest rate changes are measured relative to US Treasury Bill rate. For all methods, international reserves are measured as total reserves minus gold. The domestic interest rate is the deposit rate, except for Malaysia where we use the official rate.

Figure 1: Eichengreen, Rose and Wyplosz

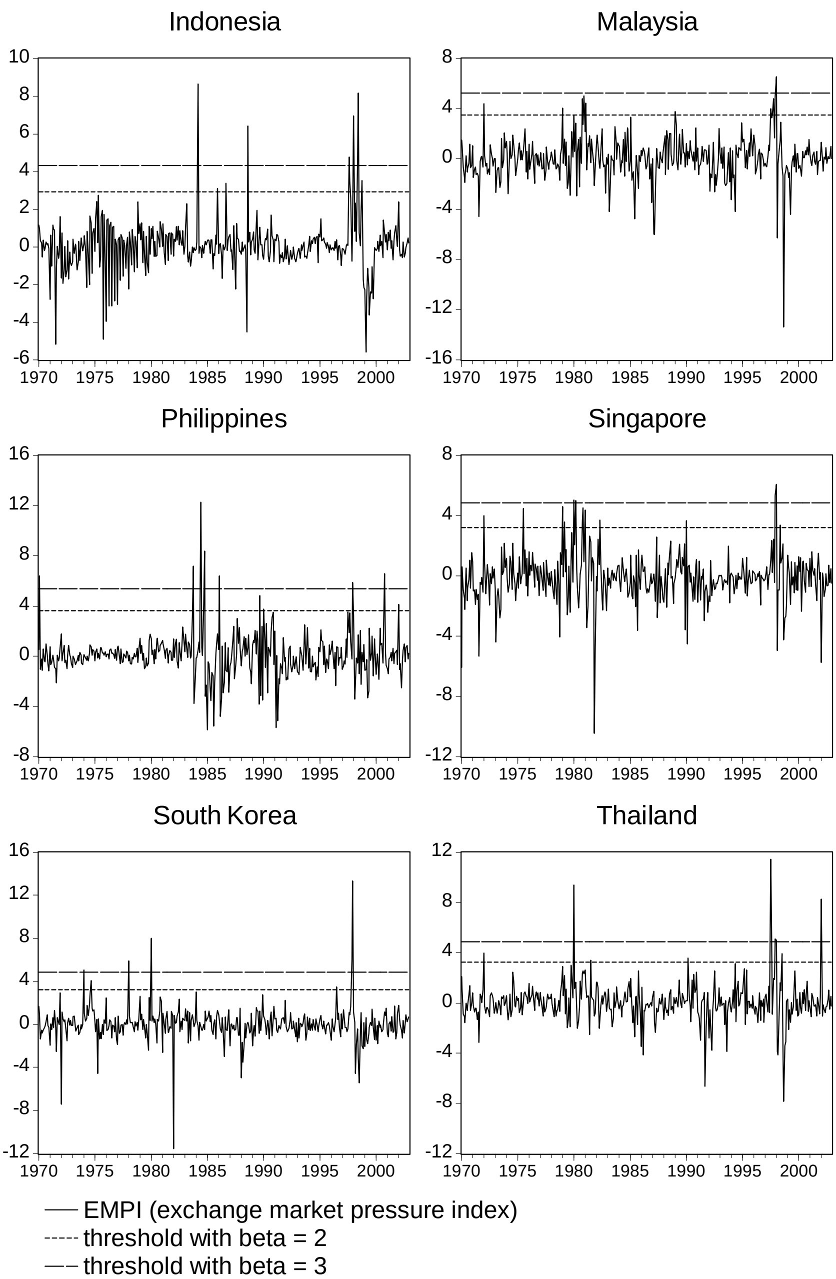


Figure 2: Kaminsky, Lizondo and Reinhart: original

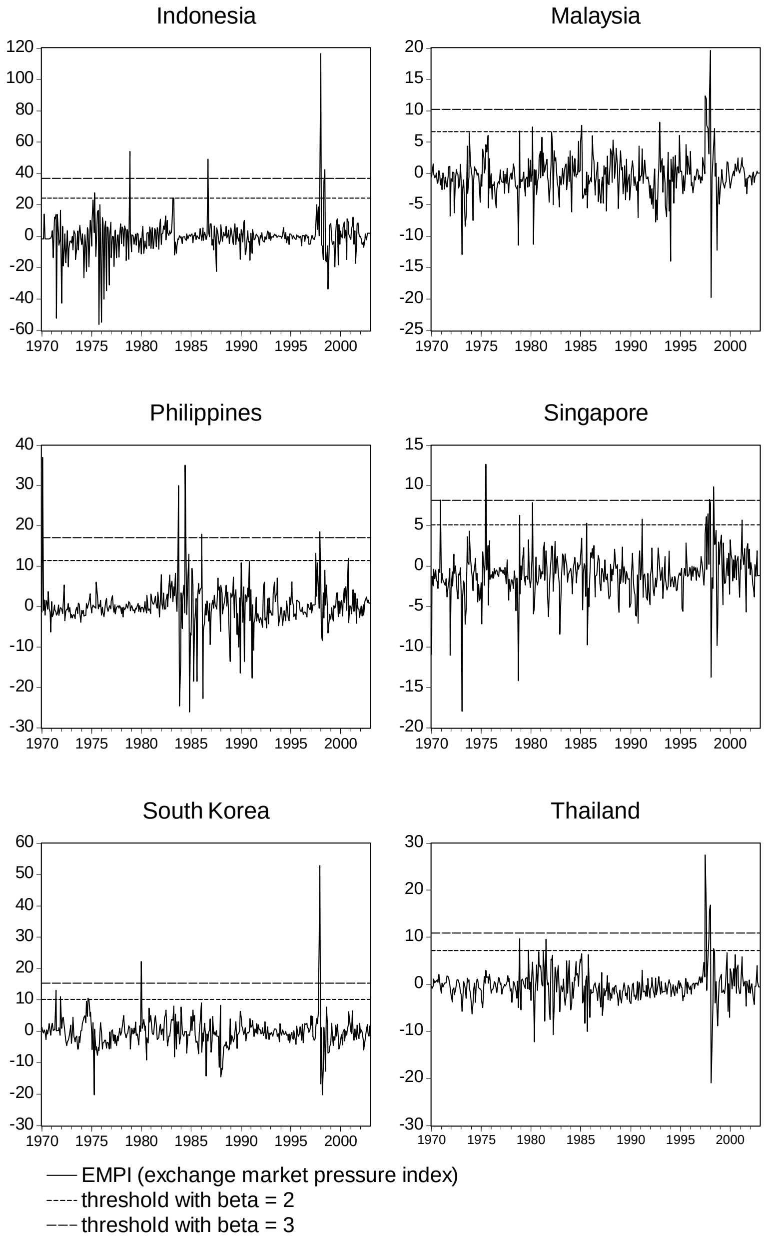


Figure 3: Kaminsky, Lizondo and Reinhart: modified

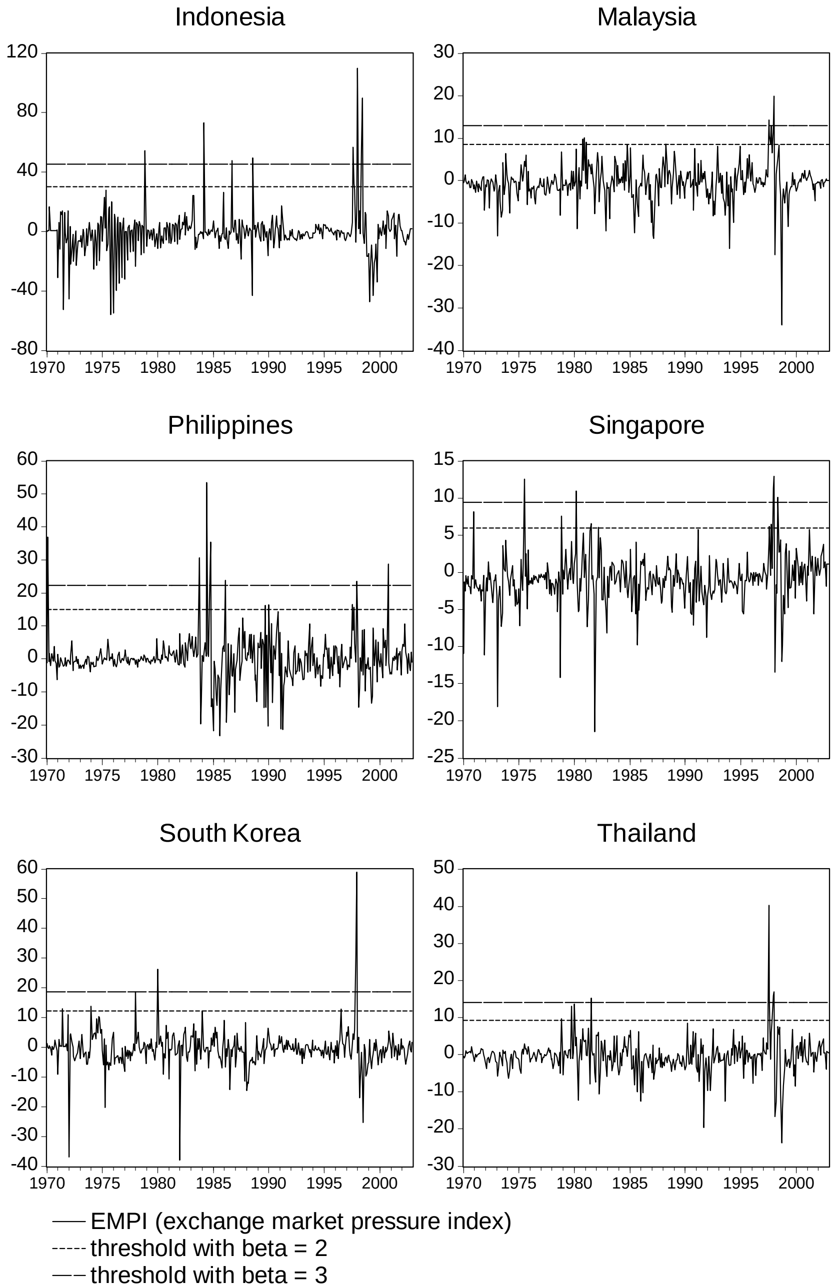
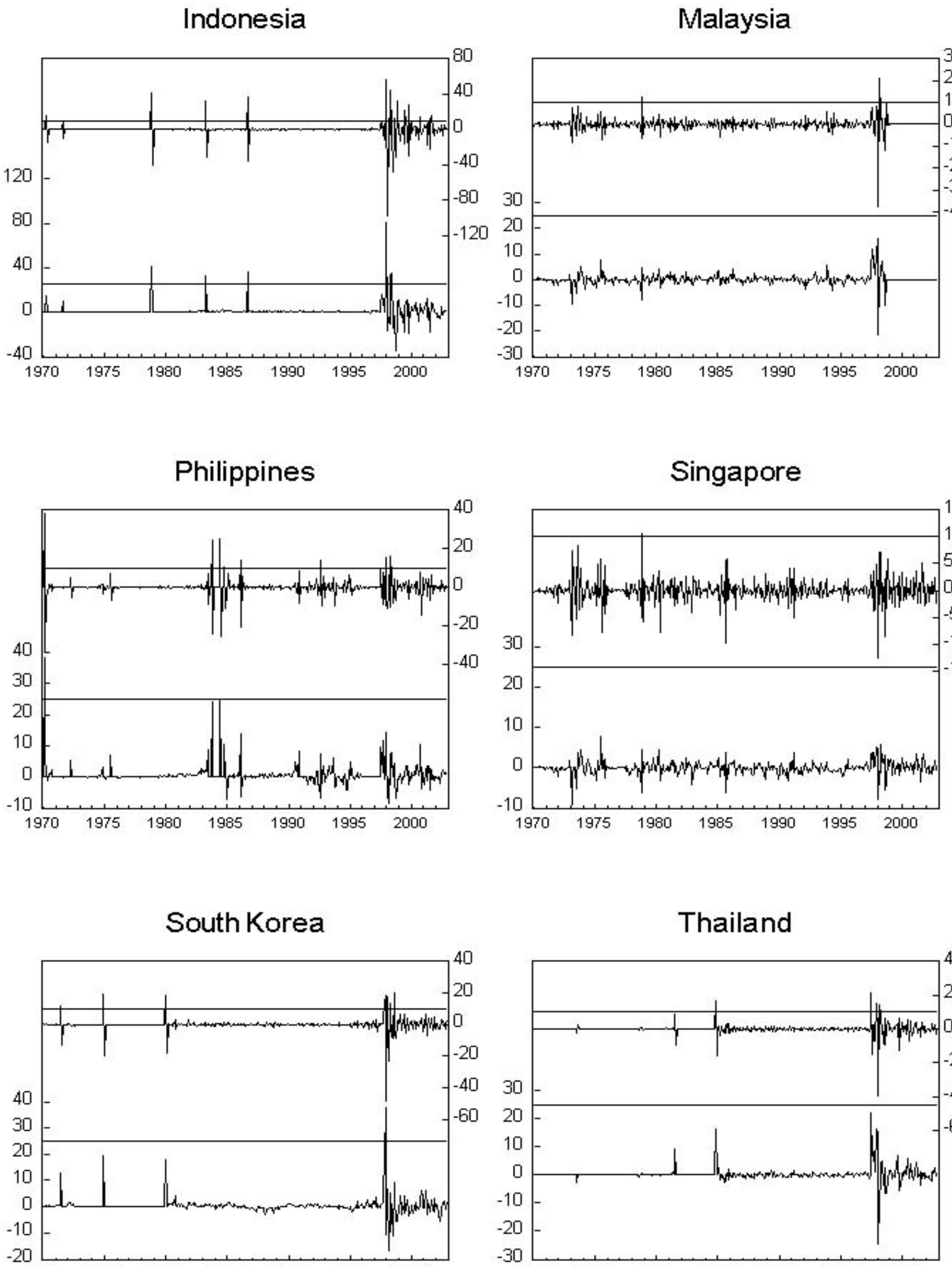


Figure 4: Frankel and Rose



Note: lower $\%\Delta e_{i,t} > 25\%$ (left scale), upper graphs show $\%\Delta e_{i,t} - \%\Delta e_{i,t-1} > 10\%$ (right scale).

Figure 5: Zhang: Indonesia and Malaysia

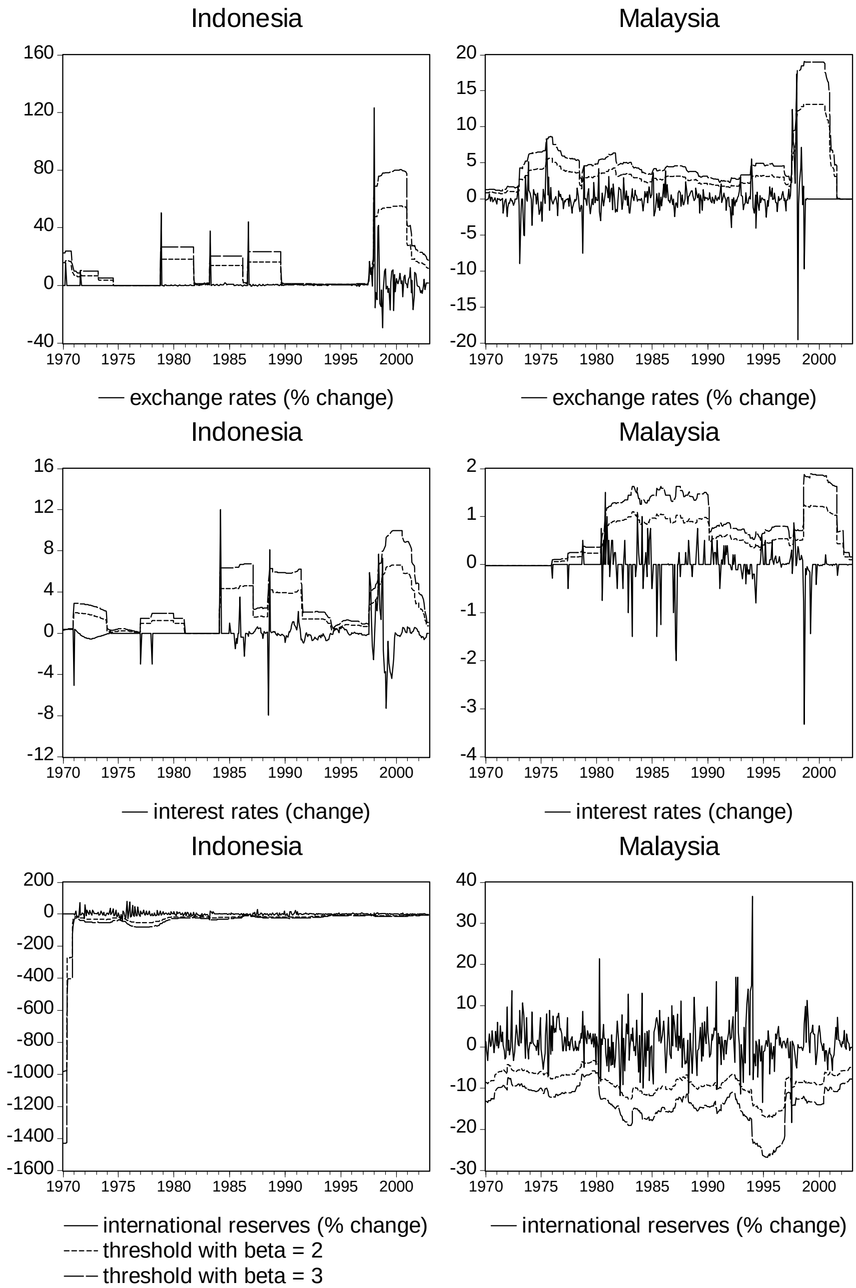


Figure 5 (continued) Zhang: Philippines and Singapore

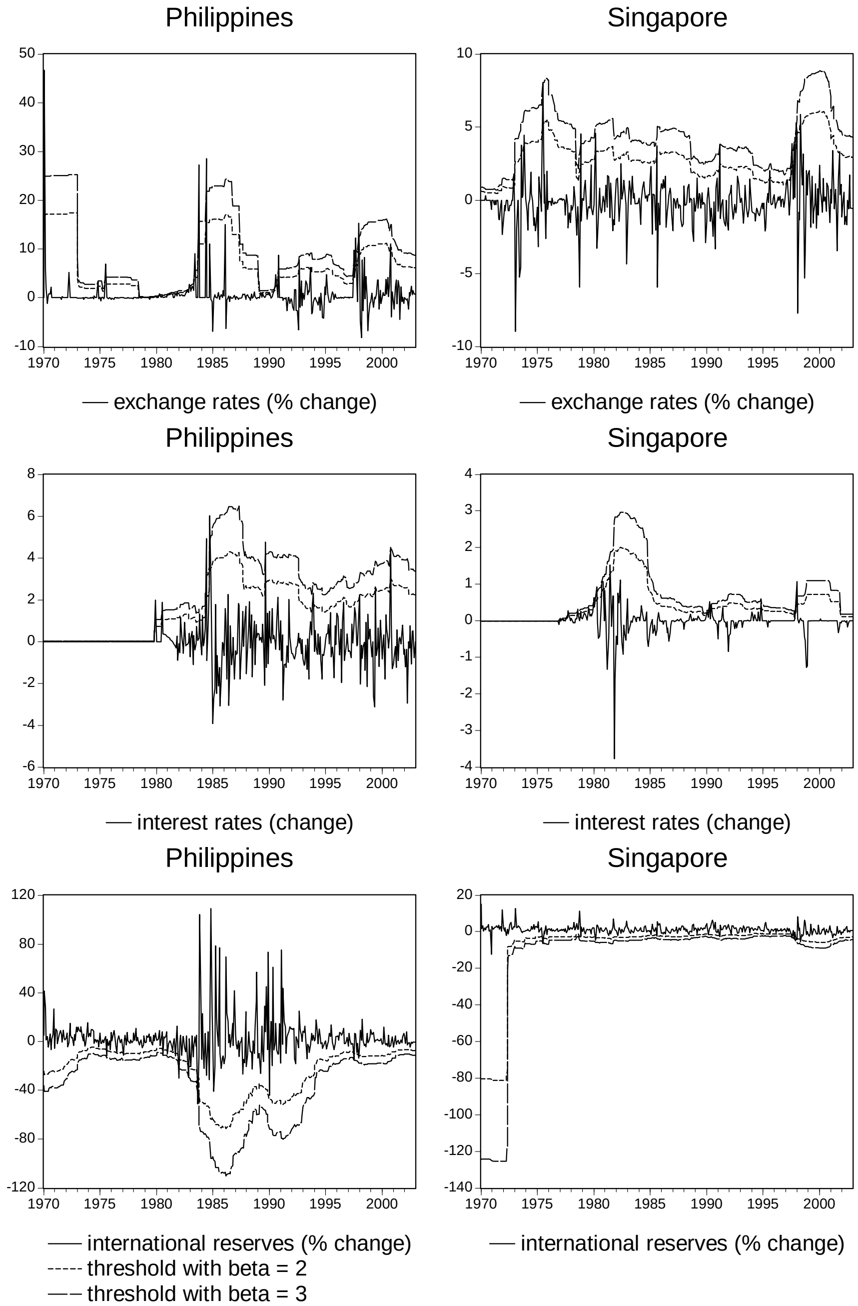
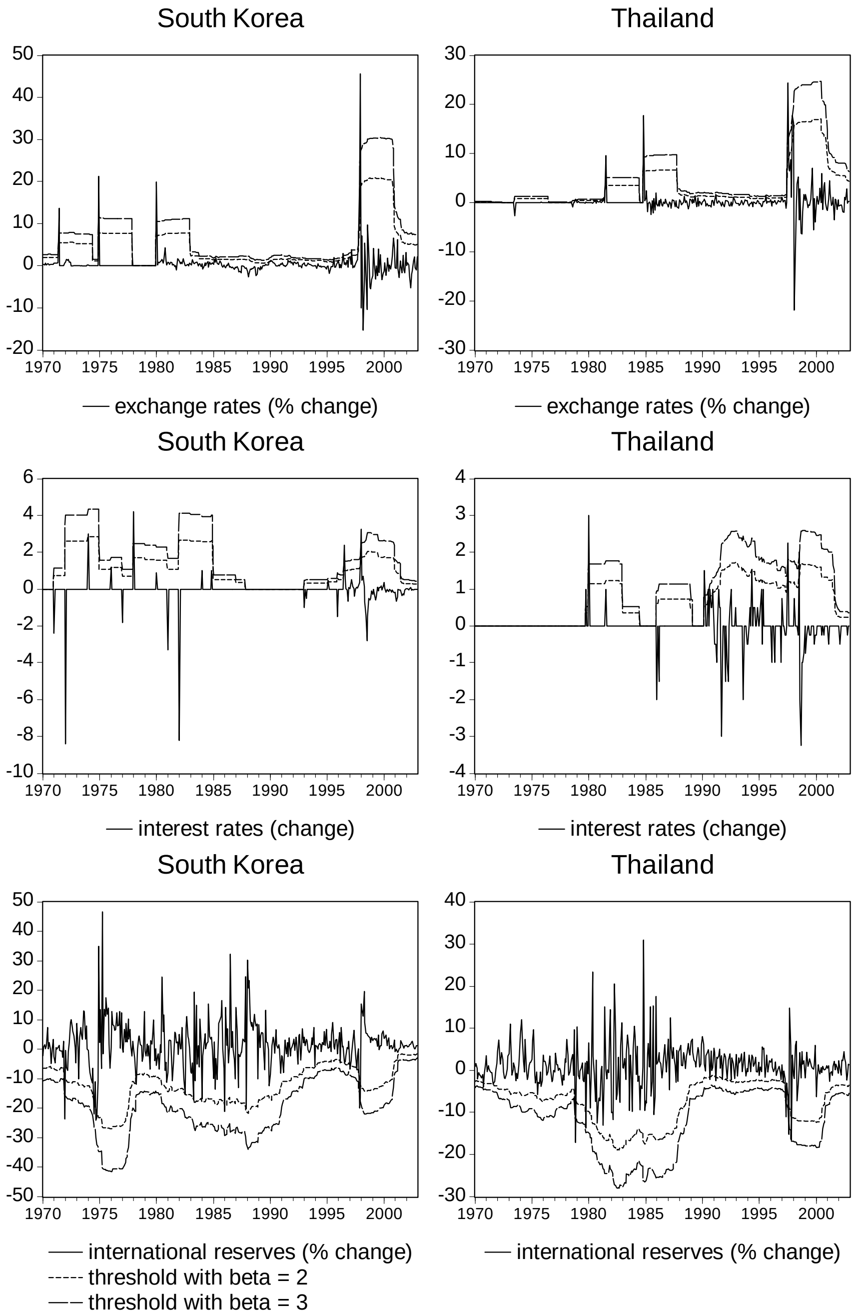


Figure 5 (continued) Zhang: South Korea and Thailand



Figures 1–5 show the *EMPI*s of ERW, KLR, KLR modified, FR and the components of the Zhang's indexes. The graphs illustrate the difficulties one meets in converting the indexes into binary crisis dummies. We have added two values of the threshold to illustrate the sensitivity, cf. Section 6 below.

4.2 Time series properties of *EMPI*s

We have noted above that a threshold of two or three standard deviations above the mean is based on the assumption that the series is characterized by a well-behaved normal probability density function. Table 1 lists some descriptive statistics of the ERW, KLR original and KLR modified *EMPI* series for our sample. Comparing Figure 1 to Figures 2 and 3 it comes as no surprise that the ERW indexes have smaller means (and medians) compared to the KLR indexes. Standard deviations diverge considerably across countries and *EMPI* definitions. According to the standard deviation of the ERW *EMPI* (1.40) Indonesia experienced the smallest market turbulence. However, standard deviations of both the original KLR (12.21) and the modified KLR index (15.03) suggest that Indonesia went through the severest currency pressure compared to the other countries.

The skewness and kurtosis results in Table 1 indicate that the *EMPI* distributions have fat tails. Most of the *EMPI* series are skewed to the right with kurtosis coefficients exceeding the value of three found for the normal distributions. Jarque-Bera statistics give overwhelming evidence that the normality null hypothesis is rejected in all cases. So, we conclude that the statistical basis under the choice of the threshold values in the dating methods

Table 1: Descriptive statistics of *EMPI*s, 1970-2002

EMPI	Mean	Median	Standard deviation	Skewness	Kurtosis	Jarque-Bera
ERW						
Indonesia	0.06	0.08	1.40	1.13	12.88	1,694.42
Malaysia	0.02	0.00	1.72	−1.18	13.61	1,948.96
Philippines	0.10	0.04	1.75	1.30	12.01	1,450.20
Singapore	-0.13	−0.10	1.65	−0.48	8.66	543.32
South Korea	0.03	0.02	1.61	0.62	24.17	7,422.46
Thailand	0.07	−0.03	1.63	1.23	14.51	2,284.17
KLR original						
Indonesia	-0.32	−0.12	12.21	1.83	28.24	10,731.62
Malaysia	-0.44	−0.45	3.50	0.04	9.79	760.24
Philippines	0.15	−0.16	5.57	0.97	16.56	3,094.47
Singapore	-0.98	−1.02	3.02	−0.47	8.81	571.84
South Korea	-0.32	−0.47	5.17	2.97	34.47	16,927.94
Thailand	-0.34	−0.36	3.70	1.21	15.76	2,781.65
KLR modified						
Indonesia	-0.44	−0.12	15.03	1.67	17.12	3,473.64
Malaysia	-0.51	−0.46	4.45	−0.97	13.06	1,731.89
Philippines	0.18	−0.20	7.32	1.64	14.35	2,301.40
Singapore	-0.97	−0.99	3.47	−0.62	9.83	795.00
South Korea	-0.52	−0.64	6.32	1.43	30.13	12,283.06
Thailand	-0.36	−0.24	4.77	1.24	19.09	4,375.71

Note: The critical value of Jarque-Bera statistic with two degrees of freedom is 5.99.

of ERW, KLR, and modified KLR is weak, again no surprise if we look at Figures 1–3.

The extreme value theory as reviewed in Section 3 assumes stationary and serially uncorrelated series, two testable assumptions. Table 2 shows the results of two types of unit root tests, the Augmented Dickey-Fuller (ADF) which tests the null that *EMPI* has a unit root against the stationary alternative and the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test which tests stationarity against the unit root alternative. The general conclusion from the table is that all *EMPI* series can be treated as stationary. The unit root null hypothesis of the ADF test is rejected at the 5% level for all countries and *EMPI* definitions. With three exceptions—the no-trend specifications of the KLR original *EMPI*s of Indonesia (0.50) and Singapore (0.66) and the KLR modified *EMPI* for Singapore (0.60)—the outcomes of the KPSS test in Table 2 support the null hypothesis that these series are stationary.

Table 2: Augmented Dickey-Fuller and KPSS tests of *EMPI*s, 1970-2002

EMPI	Augmented DF statistics				KPSS statistics	
	no trend	(lag(s))	trend	(lag(s))	no trend	trend
ERW						
Indonesia	−7.70	(2)	−7.78	(2)	0.14	0.05
Malaysia	−10.53	(1)	−10.53	(1)	0.05	0.05
Philippines	−18.48	(0)	−18.46	(0)	0.06	0.06
Singapore	−18.40	(0)	−18.37	(0)	0.09	0.10
South Korea	−17.11	(0)	−17.10	(0)	0.07	0.03
Thailand	−16.28	(0)	−16.26	(0)	0.09	0.06
KLR original						
Indonesia	−5.45	(5)	−5.74	(5)	0.50	0.06
Malaysia	−17.58	(0)	−17.71	(0)	0.25	0.04
Philippines	−19.84	(5)	−19.82	(5)	0.07	0.07
Singapore	−18.15	(5)	−18.39	(5)	0.66	0.12
South Korea	−10.74	(5)	−10.73	(5)	0.07	0.06
Thailand	−15.65	(5)	−15.65	(5)	0.16	0.13
KLR modified						
Indonesia	−5.70	(7)	−5.88	(7)	0.24	0.05
Malaysia	−10.47	(1)	−10.50	(1)	0.10	0.03
Philippines	−18.83	(0)	−18.80	(0)	0.05	0.05
Singapore	−16.76	(0)	−16.97	(0)	0.60	0.14
South Korea	−16.17	(0)	−16.15	(0)	0.03	0.03
Thailand	−15.23	(0)	−15.22	(0)	0.08	0.08

Note: The number of lags for the unit root tests is based on Schwarz Information Criterion. At the 5 percent level, the ADF test critical values with trend and without trend for individual countries are -3.42 and -2.87, respectively. The critical values of the KPSS test at 5 percent level are 0.46 and 0.15 for no trend and trend specifications, respectively.

Table 3 reports test results of serial correlation and ARCH effects for the *EMPI* series at 1, 12 and 24 lag(s). For most cases, the Ljung-Box Q-statistic and Breusch-Godfrey LM test outcomes reject the null of no serial

Table 3: Serial correlation and ARCH effect tests of *EMPI*s, 1970-2002

EMPI	Ljung-Box Q-statistics lag(s)			Breusch-Godfrey LM lag(s)			ARCH LM lag(s)		
	1	12	24	1	12	24	1	12	24
ERW									
Indonesia	5.21	106.35	194.06	5.17	74.52	97.76	7.22	39.80	45.63
Malaysia	21.04	52.30	59.37	20.88	37.44	41.46	3.11	31.28	36.45
Philippines	1.96	22.81	35.37	1.94	23.42	35.01	3.73	49.52	59.93
Singapore	3.31	27.69	35.29	3.29	26.80	29.76	12.74	32.17	44.69
South Korea	8.63	29.08	39.28	8.57	27.87	42.27	3.72	7.01	23.09
Thailand	15.39	33.10	56.02	15.26	33.23	54.76	6.04	16.66	34.38
KLR original									
Indonesia	0.39	85.45	136.29	0.38	61.32	69.84	1.96	14.56	15.61
Malaysia	5.69	31.24	36.39	5.65	24.46	30.18	92.69	112.08	113.33
Philippines	0.00	44.36	84.87	0.00	41.01	65.72	10.13	77.59	92.81
Singapore	4.14	8.02	30.89	4.11	7.09	23.08	4.81	18.01	26.74
South Korea	20.26	41.53	46.61	20.11	40.38	44.41	44.93	54.14	53.40
Thailand	21.55	49.75	57.37	21.39	49.96	62.48	70.30	116.25	121.59
KLR modified									
Indonesia	2.53	99.30	169.61	2.51	77.33	100.68	3.49	78.09	81.66
Malaysia	22.13	74.80	83.65	21.96	45.86	57.09	6.11	42.83	56.00
Philippines	1.06	27.81	43.50	1.06	27.65	41.16	3.14	47.93	53.89
Singapore	12.41	26.84	35.70	12.33	22.35	29.78	11.34	26.83	34.62
South Korea	16.10	36.01	51.20	15.99	33.58	46.69	13.67	20.48	23.89
Thailand	26.43	59.25	81.24	26.24	52.72	65.81	13.87	33.39	54.45

Note: Ljung-Box Q-statistic and Breusch-Godfrey LM (Lagrange multiplier) test the null hypothesis of no autocorrelation; ARCH LM (Lagrange multiplier) tests the null hypothesis of conditional homoscedasticity. All three test statistics follow a χ^2 distribution with degrees of freedom equal to number of lags. At the 5 percent level, the critical values of all tests for lag(s) 1, 12 and 24 are 3.84, 21.03 and 36.42.

correlation at the 5 percent level. Outcomes of the Lagrange multiplier test for ARCH effects show that ARCH effects are found for almost all *EMPI*s, with the exception of the ERW index for South Korea (all lags) and KLR original index for Indonesia (all lags) and Singapore (at 12 land 24 lags), and the KLR modified *EMPI* for South Korea (at 12 land 24 lags).

5 Extreme values

The Hill estimator to obtain extreme observations is consistent and asymptotically normal for i.i.d. series. However, the test outcomes of Table 3 show that this assumption does not (necessarily) hold. Following Resnick and Cătălin (1995) and Mikosch, Gadrich, Kluppelberg and Adler (1995) we estimate AR(p) and GARCH(p,q) models and apply the Hill estimator to the estimated residuals. Resnick and Cătălin (1995) confirm that this method produces more stable Hill estimates of the tail estimator $\frac{1}{\alpha}$ than using unfiltered data.

Table 4 summarizes our filtering. The second column lists which model is estimated. The optimal orders of the GARCH and AR models are based on Schwartz information criteria. We use AR models for the series which do not exhibit ARCH effects in Table 3—the ERW index of South Korea and KLR original *EMPI* of Indonesia—and GARCH(1,1) with AR(1) models for the other series with one exception: for the KLR original *EMPI* of Thailand we set up a GARCH(2,2) with AR(3) model. The last four columns of the table illustrate whether our filtering has been successful and presents test outcomes for serial correlation and ARCH effects for the filtered series. We observe that filtering results in smaller Ljung-Box Q statistics, although in some cases serial correlation is still present. ARCH effects have disappeared except for the KLR modified index of South Korea.

We select the optimal number of extreme observations with recursive least squares, successively dropping observations from the regression of $1/\hat{\alpha}$

Table 4: Filtering serial correlation and ARCH effects of *EMPI*s, 1970-2002

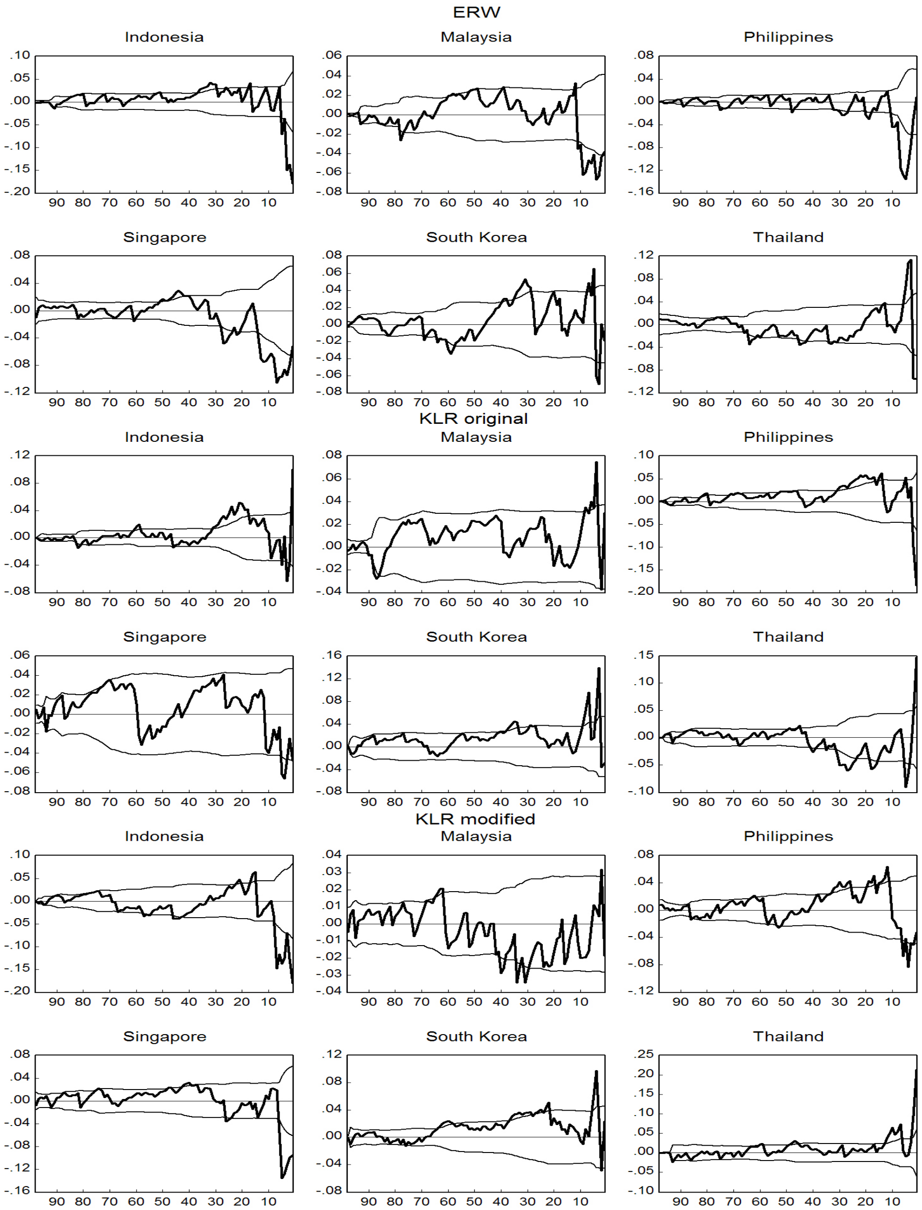
EMPI	Model	Ljung-Box Q-statistics lags		ARCH LM tests lags	
		12	24	12	24
ERW					
Indonesia	GARCH(1,1) with AR(1)	76.15	140.46	2.51	5.85
Malaysia	GARCH(1,1) with AR(1)	17.41	22.90	5.13	13.24
Philippines	GARCH(1,1) with AR(1)	9.93	14.82	11.77	21.41
Singapore	GARCH(1,1) with AR(1)	15.41	19.06	2.95	10.49
South Korea	AR(2)	18.70	28.53	6.47	27.70
Thailand	GARCH(1,1) with AR(1)	18.40	33.11	1.60	3.60
KLR original					
Indonesia	AR(1)	70.67	111.89	2.74	3.48
Malaysia	GARCH(1,1) with AR(1)	18.90	28.39	5.43	13.67
Philippines	GARCH(1,1) with AR(1)	25.76	43.09	9.43	10.66
Singapore	GARCH(1,1) with AR(1)	2.58	19.28	3.72	17.05
South Korea	GARCH(1,1) with AR(1)	18.53	29.96	6.79	6.46
Thailand	GARCH(2,2) with AR(3)	17.98	36.74	8.88	24.90
KLR modified					
Indonesia	GARCH(1,1) with AR(1)	61.49	107.13	9.48	14.20
Malaysia	GARCH(1,1) with AR(1)	19.56	28.12	3.64	25.67
Philippines	GARCH(1,1) with AR(1)	15.24	23.91	7.64	14.57
Singapore	GARCH(1,1) with AR(1)	8.08	15.38	4.25	13.23
South Korea	GARCH(1,1) with AR(1)	15.17	30.45	27.40	35.17
Thailand	GARCH(1,1) with AR(1)	17.38	33.40	0.98	2.23

Note: The Ljung-Box Q-statistics test the null hypothesis of no autocorrelated disturbances. The ARCH LM test the null hypothesis that the disturbance is conditionally homoscedastic. At the 5 percent level, the critical values of all tests for model AR(1) and GARCH(1,1) with AR(1) at lags 12 and 24 are 19.68 and 35.17. For model GARCH(2,2) with AR(3) with lags 12 and 24 is 16.92 and 32.67. For model AR(2) with lags 12 and 24 is 18.31 and 33.93.

on a constant and trend.[1] The derived recursive residuals are plotted in Figure 6 with two standard error bandwidths. We start with the 100 largest observations, and moving from left to right in the graph delete observations from the top. The optimal m is then chosen as 100 minus the observation where the recursive residuals intersect the two standard error boundary. For example, the recursive residuals of the ERW index for Indonesia passes the confidence boundary at the tenth largest observation.

[1]Pontines and Siregar (2004), following Huisman, Koedijk, Kool and Palm (2001), estimate this equation by GLS to take into account heteroscedasticity. In our sample, GLS outcomes are similar to OLS outcomes.

Figure 6: Recursive residuals of filtered *EMPI*'s ERW, KLR original and KLR modified



Note: Vertical axis: recursive residuals (bold lines) and ± two standard errors (solid lines). Horizontal axis: 100 minus the number of extreme observations m.

Table 5 lists optimal values of m and accompanying values of $\hat{\alpha}$. Currency crises are then identified by the corresponding *EMPI* observations. We observe that the KLR *EMPI*s pick up much more number of extreme observations than the ERW index, except for Singapore and Thailand. In the next section we will analyze these outcomes in more detail. In all cases, the values obtained for $\hat{\alpha}$ is larger than two, which suggests Student-t distributions for all *EMPI*s.

Table 5: Optimal values of m and its corresponding $\hat{\gamma}$ and $\hat{\alpha}$

	ERW			KLR original			KLR modified		
	m	$\hat{\gamma}$	$\hat{\alpha}$	m	$\hat{\gamma}$	$\hat{\alpha}$	m	$\hat{\gamma}$	$\hat{\alpha}$
Indonesia	10	0.35	2.86	20	0.31	3.23	27	0.39	2.56
Malaysia	9	0.31	3.23	12	0.35	2.86	24	0.31	3.23
Philippines	11	0.35	2.86	20	0.32	3.13	16	0.38	2.63
Singapore	20	0.27	3.70	8	0.33	3.03	10	0.30	3.33
South Korea	7	0.31	3.23	24	0.29	3.45	26	0.25	4.00
Thailand	26	0.34	2.94	9	0.33	3.03	9	0.41	2.43

6 Comparison

In this section we compare the currency crisis dating methods on the basis of crisis chronologies for six Asian countries for the period 1970–2002. Table 6 lists the total number of crisis episodes the methods with ad-hoc thresholds generate. We use the thresholds of the original articles, *i.e.* two standard deviations above the mean for ERW, three for KLR and Zhang, and the combined 25% and 10% threshold for first and second-order exchange rate changes for FR. The thresholds in modified KLR and Zhang follow the originals.

Table 6: Asian currency crisis episodes, 1970-2002

	ERW	KLR		FR	Z	
		original	modified		original	modified
Indonesia	10	4	8	5	13	20
Malaysia	10	4	2	0	4	8
Philippines	11	5	7	2	16	24
Singapore	14	4	5	0	6	17
South Korea	7	3	4	1	10	13
Thailand	10	4	5	3	8	13
threshold (s.d)	2	3	3		3	3

The table shows that FRs idea to exclude unsuccessful attacks from the concept of exchange market pressure results yields the lowest number of crises, with Indonesia as notable exception. ERW find more crises than the KLR indexes, while Zhang's method generally picks up most crises. Differences can arise from the definition of the exchange market pressure index or the value of the threshold, a topic we turn to next.

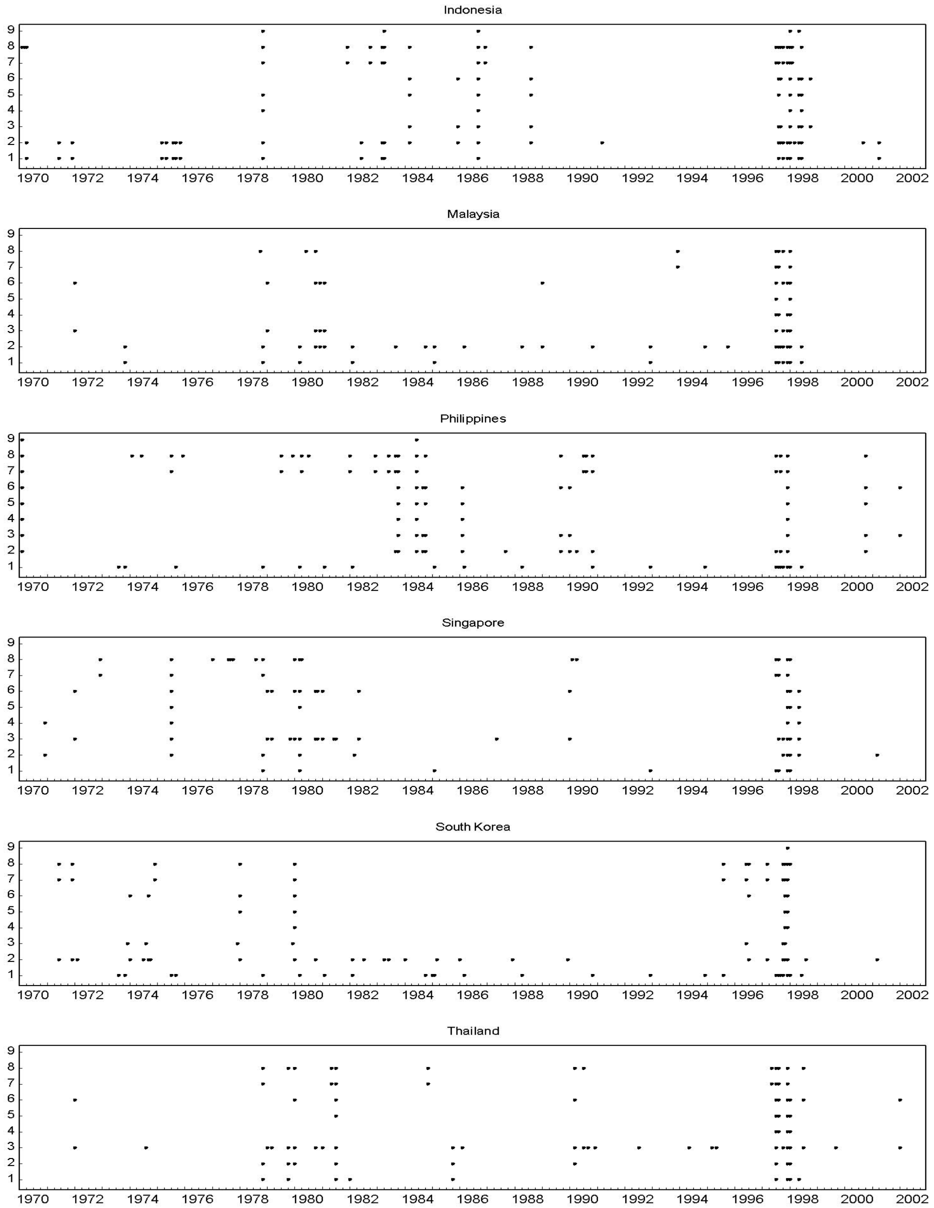
Table 7 lists currency crises totals for different values of the threshold for all indexes, except FR. From Figure 4 we conclude that FR is not very sensitive to changes in especially the first condition of their threshold which runs in exchange rate changes. We observe that the higher the value of the threshold, the lower the number of crises as expected. ERW and KLR produce more or less the same number of crises for equal threshold values. If we adopt the KLR threshold value of three (standard deviations above the mean) for the ERW index, we find six crises episodes for Indonesia, one for Malaysia, seven for Philippines, four for Singapore, five for South Korea, and five for Thailand, outcomes which are quite close to the original and modified KLR ones.

The fact that different methods generate a different number of currency crises is of course important information, but one may also want to know how the distribution of the crises over time is affected. Figure 7 shows the currency crisis distribution of nine dating methods: FR, Zhang modified, Zhang original, ERW, KLR modified, KLR original, with the ad-hoc thresholds from Table 6 and extreme value theory applied to filtered ERW, KLR modified, and KLR original indexes. The crisis episodes are not randomly distributed. The figure shows a clustering of crises around 1997-1998: every method picks up crisis events around the Asia crisis. This clustering of crises events is consistent with theories of speculative attack and policy responses that consider the possibility of contagious spillovers across countries. In addition to the Asia crisis, the November 1978, March 1983 and September 1986 devaluations in Indonesia are identified, the February 1970 devaluation and a major revision of the exchange rate regime in 1983–1984 in the Philippines, the July 1975 devaluation in Singapore, the January 1980 devaluation in South Korea, and the July 1981 devaluation in Thailand.

Table 7: Asian currency crisis episodes (1970-2002): sensitivity to *EMPI* and threshold

	Threshold	ERW	KLR		Z	
			modified	original	modified	original
Indonesia	1.5	17	15	13	63	39
	2	10	9	7	44	27
	2.5	6	8	6	29	19
	3	6	8	4	20	13
	EV	10	27	20		
Malaysia	1.5	19	22	19	193	182
	2	10	10	11	31	21
	2.5	7	4	4	21	15
	3	1	2	4	8	4
	EV	9	24	12		
Philippines	1.5	18	16	14	85	60
	2	11	12	9	52	38
	2.5	8	7	5	35	26
	3	7	7	5	24	16
	EV	11	16	20		
Singapore	1.5	16	18	17	54	27
	2	14	11	12	33	16
	2.5	8	6	6	26	12
	3	4	5	4	17	6
	EV	20	10	8		
South Korea	1.5	15	12	13	51	46
	2	7	7	6	27	21
	2.5	6	4	4	15	11
	3	5	4	3	13	10
	EV	7	26	24		
Thailand	1.5	21	15	19	45	35
	2	10	9	10	22	17
	2.5	6	7	7	17	12
	3	5	5	4	13	8
	EV	26	9	9		

Figure 7: Distribution of currency crises over time



Note: 9 stands for the method Frankel and Rose; 8 Zhang modified; 7 Zhang original; 6 Eichengreen, Rose and Wyplosz; 5 Kaminsky, Lizondo and Reinhart modified; 4 Kaminsky, Lizondo and Reinhart original; 3, 2 and 1 Extreme observation applied to filtered EMPI of Eichengreen, Rose and Wyplosz, Kaminsky, Lizondo and Reinhart modified and Kaminsky, Lizondo and Reinhart original, respectively.

It is hard to judge the quality of currency crisis dating methods on the basis of total crisis observations and their distribution over time. A minimum requirement of any currency crisis dating method is whether well-documented crisis events are picked up. Unfortunately, a full chronology of currency crises events is not available. So, we confront the crisis observations of the methods of Figure 7 to the official IMF chronology of the 1997–1998 Asia crisis, see Lindgren *et al.* (1999). We excluded the dating scheme of FR from this comparison, because their concept of successful speculative attacks is too restrictive; not all crisis events involve a large currency depreciation.

We observe that the dating methods work reasonably well in the Asia crisis. Some events, like the pressure on the Ringgit in Malaysia and the Thailand Baht float in July 1997, are picked up by all methods. Other events are found by at least two methods. The least number of events, five out of ten, is found by the method of KLR original; most events, eight of ten, are picked up by applying KLR modified, Zhang original and extreme values applied to KLR modified. These three methods perform equally well. However, the Zhang original index identifies the July 1997 crisis event in Indonesia but misses January 1998 in Thailand, whereas the KLR modified indexes methods do it the other way round. Putting more weight on the latter event, we prefer the KLR modified index based methods.

Table 8: Chronology of events with corresponding currency dates

Date	Country	Event	ERW	KLR		Zhang		Extreme observations		
				original	modified	original	modified	ERW	KLR original	KLR modified
July 1997	Indonesia	Widening of the rupiahs band				X	X			
	Malaysia	Severe pressure on Ringgit. Defence of the ringgit is abandoned	X	X	X	X	X	X	X	X
	Philippines	Peso is allowed more flexibility			X	X			X	X
	Thailand	Baht is floated and depreciates by 15-20 percent	X	X	X	X	X	X	X	X
August 1997	Indonesia	Authorities abolish band for rupiah, which plunges immediately	X		X	X	X	X	X	X
November 1997	South Korea	Exchange rate band widened and Won falls sharply	X	X	X	X	X	X		X
December 1997	South Korea	Authorities let the won float as requested by the IMF	X	X	X	X	X		X	X
January 1998	Thailand	Authorities lifts currency restrictions reunifying the spot market	X	X	X			X	X	X
February 1998	Indonesia	President Suharto reelected. Doubts about future of financial sector program grow stronger amid political uncertainty. Rupiah depreciates further and currency board is debated				X	X			
May 1998	Indonesia	Widespread riots. Rupiah depreciates, deposit runs intensify and authorities must provide liquidity. President Suharto steps down	X		X			X	X	X

7 Conclusion

This paper compared currency crisis dating methods, defining a currency crisis when an exchange market pressure index exceeds some threshold. We investigated the sensitivity of currency crisis dates to the definition and the choice and value of the threshold for six Asian countries over the period 1970–2002. Crisis chronologies differ substantively between methods. Different thresholds have a huge impact too. To judge the quality of a method, we investigated whether the crisis events of the 1997–1998 Asia crisis were picked up.

Researchers and policy makers would greatly benefit from generally accepted chronologies of financial crises. An attempt has been made in this direction by the dating of equity and housing price cycles presented in the IMF's World Economic Outlook in April 2003, IMF (2003). Extension of this work to both other financial markets and a broader range of economies, including developing markets, would be of immense assistance for economic researchers and policy makers alike.

Appendix. A model of exchange market pressure

After the break-down of the Bretton-Woods system, attention in the determination of exchange rates shifted from the balance of payments to the monetary approach. The monetary model of exchange market pressure of Girton and Roper (1977) is a fine example. The model clarifies that a change in both international reserves and prices of foreign exchange can affect the foreign exchange market or the pressure on the external position of a country. Many empirical studies apply the model to a country or group of countries, for instance, Weymark (1997) for Canada, Oskooee and Bernstein (1999) for the G-7 countries, and Pentecost, Poeck and Hooydonk (2001) for the EU. Eichengreen, Rose and Wyplosz (1995, 1996) used the model to capture the notion of (un)successful attack in developed countries.

This appendix presents a slightly adapted version of the original Girton and Roper (1977) exchange market pressure model. Consider a home economy in which money demand is determined by the level of real income (Y), price level (P), wealth of non-bank private sector (W), and three kinds of interest rates, a short-term rate for money balances (Φ), and the returns on domestic and foreign long-term assets, u and u^f, respectively. The latter interest rates relate inversely with money demand. The general demand model for nominal money balances is given by

$$M_t^d = f(P_t, Y_t, W_t, \Phi_t, u_t, u_t^f) \tag{A.1}$$

The supply of base money (M^s) is simply a fraction of net foreign assets (F) and domestic credit (D)

$$M_t^s = m\left(F_t + D_t\right). \tag{A.2}$$

The stock of foreign assets is the sum of the flows of international reserves and consists of primary assets (R) and foreign exchange (R^f)

$$F_t = \int_{-\infty}^{t} E_t \dot{R}_t dt + \int_{-\infty}^{t} E_t^f \dot{R}_t^f dt, \tag{A.3}$$

where m is the money multiplier, assumed constant and equal to one and E and E^f denote the currency values of R and R^f, respectively. The dots over the variable denote time derivatives.

The equilibrium in the money market is given by

$$M_t^s = M_t^d \tag{A.4}$$

Taking time differentials of Equation (A.1) and Equation (A.2), and substituting Equation (A.3) the money market equilibrium becomes

$$a_t + r_t + d_t = \varepsilon_p p_t + \varepsilon_y y_t + \varepsilon_w w_t + \varepsilon_\phi \phi_t + \varepsilon_u \rho_t + \varepsilon_u^f \rho_t^f \tag{A.5}$$

where $a_t = \frac{\dot{m}_t}{m_t}$, $r_t = \frac{E_t \dot{R}_t}{F_t + D_t} + \frac{E_t^f \dot{R}_t^f}{F_t + D_t}$, $d_t = \frac{\dot{D}_t}{F_t + D_t}$, $y_t = \frac{\dot{Y}_t}{Y_t}$, $p_t = \frac{\dot{P}_t}{P_t}$, $w_t = \frac{\dot{W}_t}{W_t}$, $\phi_t = \frac{\dot{\Phi}_t}{\Phi_t}$, and $\rho_t = \frac{\dot{u}_t}{u_t}$, $\rho_t^f = \frac{\dot{u}_t^f}{u_t^f}$ and the ε_p, ε_y, ε_w, ε_ϕ, ε_u and ε_u^f are the money demand elasticities with respect to price level, income, private non-bank wealth, and returns on money balances, domestic and foreign assets, respectively.

Now consider a foreign country with the same structure as the home economy. We can rewrite the home money market equilibrium, Equation (A.5), for the foreign economy as

$$a_t^f + r_t^f + d_t^f = \varepsilon_p p_t^f + \varepsilon_y y_t^f + \varepsilon_\phi \phi_t^f + \varepsilon_u \rho_t^f + \varepsilon_u^f \rho_t, \tag{A.6}$$

where the elasticity of money demand with respect to the return on domestic (local) and foreign assets are denoted by ε_u and ε_u^f, respectively. The domestic and foreign money markets are linked by means of the purchasing power parity condition

$$e_t = p_t - p_t^f + \theta_t \tag{A.7}$$

where $e_t = \frac{\dot{E}_t}{E_t}$, $\theta_t = \frac{\dot{Q}_t}{Q_t}$, E_t = nominal exchange rate, and Q_t= real exchange rate. This condition says that deviations between the rates of change of the nominal exchange rate (e_t) and the inflation differential ($p_t - p_t^f$) are determined by the rates of change of the real exchange rate (θ_t).

Subtracting Equation (A.5) from (A.6) and using Equation (A.7), we obtain

$$\begin{aligned}(a_t - a_t^f) + (d_t - d_t^f) - \varepsilon_y(y_t - y_t^f) - (\varepsilon_u - \varepsilon_u^f)(\rho_t - \rho_t^f) + \varepsilon_p\theta_t = \\ \varepsilon_p e_t + \varepsilon_\phi(\phi_t - \phi_t^f) - (r_t - r_t^f)\end{aligned} \tag{A.8}$$

The right-hand side of Equation (A.8) captures exchange market pressure. Rates of change of domestic and foreign output and credit, interest rate differentials, money multiplier differentials and real exchange rate (domestic competitiveness) are triggering determinants of devaluations and speculative attacks. Successful speculative attacks push exchange rate pressure up, which is indicated by exchange rate depreciation. Authorities can also intervene in the foreign exchange market to defend their currencies from attacks. The intervention involves either losing international reserves or raising domestic interest rates.

References

Abiad, A. (2003), "Early warning systems: a survey and a regime-switching approach", *IMF Working Paper* 32, International Monetary Fund, Washington, D.C.

Akgiray, V., G.G. Booth, and B. Seifert (1988), "Distribution properties of Latin American black market exchange rates", *Journal of International Money and Finance*, **7**(1), 37–48.

Aziz, J., F. Caramazza, and R. Salgado (2000), "Currency crises: in search of common elements", *IMF Working Paper* 67, International Monetary Fund, Washington, D.C.

Berg, A., E. Borensztein, and C. Pattillo (2004), "Assessing early warning systems: how have they worked in practice?", *IMF Working Paper* 52, International Monetary Fund, Washington, D.C.

Drees, H., L. de Haan, and S. Resnick (2000), "How to make a Hill plot", *Annals of Statistics*, **28**(1), 254–274.

Dungey, M., R. Fry, B. Gonzalez-Hermosillo, and V.L. Martin (2003), "Empirical modelling of contagion: a review of methodologies", *Working Papers* 8, Cambridge Endowment for Research in Finance, Cambridge.

Dungey, M. and V.L. Martin (2002), "Measuring contagion in the East Asian currency crisis", *Mimeo*, The Australian National University, Canberra, Australia.

Eichengreen, B., A.K. Rose, and C. Wyplosz (1995), "Exchange rate mayhem: the antecedents and aftermath of speculative attacks", *Economic Policy*, **21**, 251–312.

Eichengreen, B., A.K. Rose, and C. Wyplosz (1996), "Contagious currency crises", *Scandinavian Journal of Economics*, **98**(4), 463–484.

Embrechts, P., C. Kluppelberg, and T. Mikosch (1997), *Modelling Extremal Events for Insurance and Finance*, Springer-Verlag, Berlin.

Frankel, J.A. and A.K. Rose (1996), "Currency crashes in emerging markets: an empirical treatment", *Journal of International Economics*, **41**(3-4), 351–366.

Girton, L. and D. Roper (1977), "A monetary model of exchange market pressure applied to the postwar Canadian experience", *American Economic Review*, **67**(4), 537–548.

Glick, R. and A.K. Rose (1999), "Contagion and trade: why are currency crises regional?", *Journal of International Money and Finance*, **18**(4), 603–617.

Goldstein, M., G. Kaminsky, and C. Reinhart (2000), *Assessing Financial Vulnerability: an early warning system for emerging markets*, Institute for International Economics, Washington, D.C.

Granger, C.W.J., B.N. Huang, and C.W. Yang (2000), "Bivariate causality between stock prices and exchange rates in Asian countries", *The Quarterly Review of Economics and Finance*, **40**(3), 337–354.

Haile, F.D. and S. Pozo (2003), "Exchange rate regimes and currency crises: an evaluation using extreme value theory", *Mimeo*, Department of Economics, Western Michigan University, Kalamazoo, Michigan.

Hill, B.M. (1975), "A simple general approach to inference about the tail of a distribution", *Annals of Statistics*, **3**(5), 1163–1174.

Huisman, R., K.G. Koedijk, C.J.M. Kool, and F. Palm (2001), "Tail-index estimates in small samples", *Journal of Business and Economic Statistics*, **19**(1), 208–216.

International Monetary Fund (2003), *International Financial Statistics CD-Rom*, International Monetary Fund, Washington, D.C.

International Monetary Fund (2003), "When bubbles burst", in *IMF World Economic Outlook*, International Monetary Fund, Washington, D.C., chapter 2.

Ito, T. and Y. Hashimoto (2002), "High frequency contagion of currency crises in Asia", *NBER Working Paper* 9376, National Bureau of Economic Research, Cambridge, MA.

Kaminsky, G.L., S. Lizondo, and C.M. Reinhart (1998), "Leading indicators of currency crisis", *IMF Staff Papers* 45/1, International Monetary Fund, Washington, D.C.

Kaminsky, G.L. and C.M. Reinhart (1999), "The twin crises: the causes of banking and balance-of-payments problems", *American Economic Review*, **89**(3), 473–500.

Kaminsky, G.L. and S.L. Schmukler (1999), "What triggers market jitters? A chronicle of the Asian crisis", *Journal of International Money and Finance*, **18**(4), 537–560.

Koedijk, K.G., M.M.A. Schafgans and C.G. de Vries (1990), "The tail index of exchange rate returns", *Journal of International Economics*, **29**(1-2), 93–108.

Koedijk, K.G., P.A. Stork and C.G. de Vries (1992), "Differences between foreign exchange rate regimes: the view from the tails", *Journal of International Money and Finance*, **11**(5), 462–473.

Lindgren, C.J., T.J.T. Balino, C. Enoch, A.M. Gulde, M. Quintyn, and L. Teo (1999), "Financial sector crisis and restructuring: lessons from Asia", *IMF Occasional Paper* 188, International Monetary Fund, Washington, D.C.

Longin, F. and B. Solnik (2001), "Extreme correlation of international equity markets", *Journal of Finance*, **56**(2), 649–676.

Martinez-Peria, S.M. (2002), "A regime-switching approach to the study of speculative attacks: a focus on EMS crises", *Empirical Economics*, **27**(2), 299–334.

Mikosch, T., T. Gadrich, C. Kluppelberg, and R.J. Adler (1995), "Parameter estimation for ARMA models with infinite variance innovations", *Annals of Statistics*, **23**(1), 305–326.

Oskooee, M.B. and D.J. Bernstein (1999), "Exchange rate market pressure during the current managed float", *Applied Economics Letters*, **6**(9), 585–588.

Pentecost, E.J., A. van Poeck, and C. van Hooydonk (2001), "Measuring and estimating exchange market pressure in the EU", *Journal of International Money and Finance*, **20**(3), 401–418.

Pontines, V. and R. Siregar (2004), "Exchange market pressure and extreme value theory: incidence of currency crisis in east Asia and Latin America", Mimeo, School of Economics, Unversity of Adelaide.

Pozo, S. and C. Amuedo-Dorantes (2003), "Statistical distributions and the identification of currency crises", *Journal of International Money and Finance*, **22**(4), 591–609.

Resnick, S.I. and C. Stărică (1995), "Consistency of Hill's estimator for dependent data", *Journal of Applied Probability*, **32**(1), 139–167.

Rigobon, R. (2002), *International Financial Contagion: theory and evidence in evolution*, Research Foundation of Association for Investment Management and Research, Virginia.

Weymark, D.N. (1997), "Measuring the degree of market exchange intervention in a small open economy", *Journal of International Money and Finance*, **16**(1), 55–79.

Zhang, Z. (2001), "Speculative attacks in the Asian crisis", *IMF Working Paper* 189, International Monetary Fund, Washington, D.C.