DATING CURRENCY CRISES WITH AD HOC AND EXTREME VALUE-BASED THRESHOLDS: EAST ASIA 1970–2002

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ABSTRACT

Generally a currency crisis is defined to occur if an index of currency pressure exceeds a threshold. This paper compares currency crisis dating methods. For two definitions of currency pressure we contrast 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 1997–1999. Copyright © 2007 John Wiley & Sons, Ltd.

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KEY WORDS: currency crises; crisis episodes; crisis events; crisis dating; exchange rate market pressure; extreme value theory; Asia crisis

NON-TECHNICAL SUMMARY

Recently, several countries experienced large currency depreciations as well as collapses of the financial and productive sector. This triggered many empirical studies on signalling future currency crises as well as studies that look for evidence of the propagation of crises by tracking shifts in correlations and testing contagion channels. Identifying currency crisis episodes plays a crucial role in these empirical studies.

Generally, a currency crisis is defined to occur if an index of currency pressure exceeds a threshold. Eichengreen et al. (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 et al. (1998) followed the concept of Eichengreen et al. fairly closely, but excluded interest rate differentials in their index. The ad hoc threshold is in terms of a number of standard deviations above the mean. The other method, extreme value, exploits the information in the tails of the distribution of the index.

The objective of this paper is to compare these two currency crisis dating methods with respect to the choice of the threshold. We use data on six Asian countries, Indonesia, Malaysia, Philippines, Singapore, South Korea and Thailand, for the period between January 1970 and December 2002. We analyse how many currency crisis episodes are identified and show distributions over time. In general, extreme value theory identifies more or less the same number of crisis episodes as ad hoc thresholds equal to two standard deviations.

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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. 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 1997–1999. On the basis of this assessment, we tend to prefer the exchange market pressure index of Kaminsky, Lizondo and Reinhart with an extreme value-based threshold. This method correctly identified the largest number of crisis episodes, although it also produced the largest number of false signals.

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 signalling 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 et al. (1998) for pre-1997 studies and Abiad (2003) for recent studies; for an assessment of EWS models see Berg et al. (2004). Other studies look for evidence of the propagation of crises by tracking shifts in correlations and testing contagion channels. See Rigobon (2002), Dungey et al. (2003) and Pericoli and Sbracia (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 plays a 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. 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 et al. (1995, 1996), Frankel and Rose (1996) and Aziz et al. (2000). We do not follow this practice in this paper and use the expressions currency crisis and currency crisis episode interchangeably.

Eichengreen et al. (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 et al. (1998), Kaminsky and Reinhart (1999) and Goldstein et al. (2000) followed the concept of Eichengreen et al. fairly closely, but excluded interest rate differentials in their index.¹

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. Pozo and Amuedo-Dorantes (2003) and Haile and Pozo (2003) question the normality assumption and suggest exploiting the information in the tails of the distribution of the index and determine crisis dates from the extreme values.²

The objective of this paper is to compare the currency crisis dating methods of Eichengreen, Rose and Wyplosz and Kaminsky, Lizondo and Reinhart with respect to the choice of the threshold. We use data on six Asian countries, Indonesia, Malaysia, Philippines, Singapore, South Korea and Thailand, for the period between January 1970 and December 2002. We analyse how many currency crisis episodes are identified and show distributions over time. In general, extreme value theory identifies more or less the same number of crisis episodes as ad hoc thresholds equal to two standard deviations. 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 1997–1999.

This paper is organized as follows. Section 2 discusses the currency crises dating methods of Eichengreen et al. (1995) and Kaminsky et al. (1998). 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 choice and the value of the threshold, and their ability to track the official IMF Asia crisis events chronology. Section 7 concludes.

2. EXCHANGE MARKET PRESSURE INDEXES AND AD HOC THRESHOLDS


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). 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:

\[
\text{EMPI}_{i,t} = \frac{1}{\sigma_e} \frac{\Delta e_{i,t}}{e_{i,t}} - \frac{1}{\sigma_r} \left( \frac{\Delta r_{m_{i,t}}}{r_{m_{i,t}}} - \frac{\Delta r_{m_{US,t}}}{r_{m_{US,t}}} \right) + \frac{1}{\sigma_i} \Delta (i_{i,t} - i_{US,t})
\]

where \(\text{EMPI}_{i,t}\) 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 \(t\); \(r_{m_{i,t}}\) 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 \(t\); \(\sigma_e\) the standard deviation of the relative change in the exchange rate \(\frac{\Delta e_{i,t}}{e_{i,t}}\); \(\sigma_r\) 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) \(\left(\frac{\Delta r_{m_{i,t}}}{r_{m_{i,t}}} - \frac{\Delta r_{m_{US,t}}}{r_{m_{US,t}}}\right)\); and \(\sigma_i\) 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

\[\text{Crisis} = \begin{cases} 1 & \text{if } \text{EMPI}_{i,t} > \beta \sigma_{\text{EMPI}} + \mu_{\text{EMPI}} \\ 0 & \text{otherwise} \end{cases}\]

where \(\sigma_{\text{EMPI}}\) equals the sample standard deviation of EMPI and \(\mu_{\text{EMPI}}\) 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 \(\beta\) equal to 1.5. Note that Eichengreen et al. (1995) use an exclusion window of 12 months (shortened to 6 months in their 1996 article). As mentioned in the Introduction, we do not follow this practice.

2.2. Kaminsky et al. (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

\[
\text{EMPI}_{it} = \frac{\Delta e_{it} - \sigma_e \Delta r_{it}}{\sigma_r r_{it}}
\]

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

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.

3. EXTREME VALUE THEORY

The dating methods discussed above are based on an 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. A currency crisis is signalled 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 et al. (1990). For a general introduction of extreme value theory see Embrechts et al. (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 \( a \). The tail parameter is an indicator of the tail fatness. With extremal analysis, one can estimate the value for the tail parameter \( (a) \) 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 \( a \) below two and the Student \( t \)-distribution has an \( a \) 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 et al. (1988) suggest to estimate the tail parameter by maximum likelihood estimation (MLE) to distinguish between the different types of distributions, but Koedijk et al. (1992) have shown that the Hill estimator (Hill, 1975) is more efficient and produces smaller standard errors. The Hill estimator works as follows. The series \( \text{EMPI}_1, \ldots, \text{EMPI}_n \) is ordered according to size: \( \text{EMPI}_{(1)} \leq \cdots \leq \text{EMPI}_{(n)} \). Suppose that we want to include \( m \) extreme observations from the right tail. The Hill estimator of the reciprocal of \( a \) is defined by

\[
\frac{1}{a} = \hat{\alpha} = \frac{1}{m} \sum_{i=1}^{m} \left( \ln \text{EMPI}_{(n+1-i)} - \ln \text{EMPI}_{(n-m)} \right)
\]

The optimal choice of \( m \) is not trivial. For finite samples three procedures have been proposed. The first uses Hill plots, where \( 1/\hat{a} \) is plotted for different values of \( m \), and selects the value of \( m \) for which \( 1/\hat{a} \) is stable. For details see Embrechts et al. (1997) and Drees et al. (2000). Alternatives are recursive least squares and Monte Carlo experiments. In recursive least squares \( 1/\hat{a} \) 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 \( 1/\hat{a} \). A stable estimate of \( 1/\hat{a} \) 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 et al. (1990) and Longin and Solnik (2001), can also be employed to find the optimal value of \( m \) without bias and inefficiency. The minimum MSE criterion of \( \hat{\alpha} \) is used to select \( m \) for a given number of observations \( n \) and degrees of freedom.

In this paper, we follow Koedijk et al. (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. We deviate from these authors by prefiltering of the EMPI series. An important prerequisite of the Hill estimator is stationary and serially uncorrelated 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 the 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 et al. (1998) and Kaminsky and Reinhart (1999) in selecting historical data. We expanded their 1970–1995 sample up to and 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 countries’ central banks. We end up with a balanced panel data set of 396 months for six countries, which makes a total of 2376 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 stock 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.

Figures 1 and 2 show the EMPIs of ERW and KLR. 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.

4.2. Time series properties of EMPIs

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 and KLR EMPI series for our sample. Comparing Figure 1 to Figure 2 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, the standard deviation of the KLR index (12.21) suggests 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 null hypothesis of normality is rejected in all cases. So, we conclude that the statistical basis for the choice of the threshold values in the dating methods of ERW, KLR and modified KLR is weak, again no surprise if we look at Figures 1 and 2.

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 two exceptions—the no-trend specifications of the KLR EMPIs of Indonesia (0.50) and Singapore
The outcomes of the KPSS test in Table 2 support the null hypothesis that these series are stationary.

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

Figure 1. Eichengreen, Rose and Wyplosz.

(0.66)—the outcomes of the KPSS test in Table 2 support the null hypothesis that these series are stationary.

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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 Stărică (1995) and Mikosch et al. (1995) we estimate AR($p$) and GARCH($p, q$) models and apply the Hill estimator to the estimated residuals. Resnick and Stărică (1995) confirm that this method produces more stable Hill estimates of the tail estimator $1/\alpha$ than using unfiltered data.

**5. EXTREME VALUES**

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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 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.

### Table 1. Descriptive statistics of EMPIs, 1970–2002

<table>
<thead>
<tr>
<th>EMPI</th>
<th>Mean</th>
<th>Median</th>
<th>Standard deviation</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Jarque-Bera</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indonesia</td>
<td>0.06</td>
<td>0.08</td>
<td>1.40</td>
<td>1.13</td>
<td>12.88</td>
<td>1,694.42</td>
</tr>
<tr>
<td>Malaysia</td>
<td>0.02</td>
<td>0.00</td>
<td>1.72</td>
<td>-1.18</td>
<td>13.61</td>
<td>1,946.98</td>
</tr>
<tr>
<td>Philippines</td>
<td>0.10</td>
<td>0.04</td>
<td>1.75</td>
<td>1.30</td>
<td>12.01</td>
<td>1,450.20</td>
</tr>
<tr>
<td>Singapore</td>
<td>-0.13</td>
<td>-0.10</td>
<td>1.65</td>
<td>-0.48</td>
<td>8.66</td>
<td>543.32</td>
</tr>
<tr>
<td>South Korea</td>
<td>0.03</td>
<td>0.02</td>
<td>1.61</td>
<td>0.62</td>
<td>24.17</td>
<td>7,422.46</td>
</tr>
<tr>
<td>Thailand</td>
<td>0.07</td>
<td>-0.03</td>
<td>1.63</td>
<td>1.23</td>
<td>14.51</td>
<td>2,284.17</td>
</tr>
<tr>
<td>KLR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indonesia</td>
<td>-0.32</td>
<td>-0.12</td>
<td>12.21</td>
<td>1.83</td>
<td>28.24</td>
<td>10,731.62</td>
</tr>
<tr>
<td>Malaysia</td>
<td>-0.44</td>
<td>-0.45</td>
<td>3.50</td>
<td>0.04</td>
<td>9.79</td>
<td>760.24</td>
</tr>
<tr>
<td>Philippines</td>
<td>0.15</td>
<td>-0.16</td>
<td>5.57</td>
<td>0.97</td>
<td>16.56</td>
<td>3,094.47</td>
</tr>
<tr>
<td>Singapore</td>
<td>-0.98</td>
<td>-1.02</td>
<td>3.02</td>
<td>-0.47</td>
<td>8.81</td>
<td>571.84</td>
</tr>
<tr>
<td>South Korea</td>
<td>-0.32</td>
<td>-0.47</td>
<td>5.17</td>
<td>2.97</td>
<td>34.47</td>
<td>16,927.94</td>
</tr>
<tr>
<td>Thailand</td>
<td>-0.34</td>
<td>-0.36</td>
<td>3.70</td>
<td>1.21</td>
<td>15.76</td>
<td>2,781.65</td>
</tr>
</tbody>
</table>

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

### Table 2. Augmented Dickey–Fuller and KPSS tests of EMPIs, 1970–2002

<table>
<thead>
<tr>
<th>EMPI</th>
<th>Augmented DF statistics</th>
<th>KPSS statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No trend (Lag(s))</td>
<td>Trend (Lag(s))</td>
</tr>
<tr>
<td>ERW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indonesia</td>
<td>-7.70</td>
<td>(2)</td>
</tr>
<tr>
<td>Malaysia</td>
<td>-10.53</td>
<td>(1)</td>
</tr>
<tr>
<td>Philippines</td>
<td>-18.48</td>
<td>(0)</td>
</tr>
<tr>
<td>Singapore</td>
<td>-18.40</td>
<td>(0)</td>
</tr>
<tr>
<td>South Korea</td>
<td>-17.11</td>
<td>(0)</td>
</tr>
<tr>
<td>Thailand</td>
<td>-16.28</td>
<td>(0)</td>
</tr>
<tr>
<td>KLR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indonesia</td>
<td>-5.45</td>
<td>(5)</td>
</tr>
<tr>
<td>Malaysia</td>
<td>-17.58</td>
<td>(0)</td>
</tr>
<tr>
<td>Philippines</td>
<td>-19.84</td>
<td>(5)</td>
</tr>
<tr>
<td>Singapore</td>
<td>-18.15</td>
<td>(5)</td>
</tr>
<tr>
<td>South Korea</td>
<td>-10.74</td>
<td>(5)</td>
</tr>
<tr>
<td>Thailand</td>
<td>-15.65</td>
<td>(5)</td>
</tr>
</tbody>
</table>

Note: The number of lags for the unit root tests is based on Schwarz information criterion. At the 5% 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% level are 0.46 and 0.15 for no trend and trend specifications, respectively.
We select the optimal number of extreme observations with recursive least squares, successively dropping observations from the regression of $1/z$ on a constant and trend. The derived recursive residuals are plotted in Figure 3 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 boundaries. For example, the recursive residuals of the ERW index for Indonesia passes the confidence boundary at the tenth largest observation.
Table 5 lists optimal values of $m$ and accompanying values of $\tilde{z}$. Currency crises are then identified by the corresponding EMPI observations. We observe that the KLR EMPIs pick up much more number of extreme observations than the ERW index, except for Singapore and Thailand. In the next section we will

Figure 3. Recursive residuals of filtered EMPI’s ERW and KLR. Note: Vertical axis: recursive residuals (bold lines) and ± two standard errors (solid lines). Horizontal axis: 100 minus the number of extreme observations $m$. 

analyse these outcomes in more detail. In all cases, the values obtained for $\bar{z}$ are larger than two, which suggests Student-$t$ distributions for both EMPIs.

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 currency crises totals for different values of the threshold for all indexes, including the thresholds of the original articles, i.e. two standard deviations above the mean for ERW and three for KLR.

We observe that as expected the higher the value of the threshold, the lower the number of crises. 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 close to the KLR ones. The number of crisis episodes obtained with the extreme value (EV) threshold corresponds to outcomes found with an ad hoc threshold of two standard deviations above the mean. However, in five out of 12 cases the extreme value yields even more crisis episodes than an ad hoc threshold of 1.5 standard deviations above the mean.

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 4 shows the currency crisis distribution of four dating methods: ERW and KLR with the ad hoc thresholds of the original articles, and extreme value theory applied to the filtered indexes. The crisis episodes are not randomly distributed. The figure shows a clustering of crises around 1997–1999: 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 September 1986 devaluation in Indonesia, the February 1970 devaluation and a major revision of the exchange rate regime in 1983–1984 in the Philippines, a major abolishment of all exchange controls in December 1979 and the July 1975 devaluation in Singapore, the January 1974 and January 1980 devaluations in South Korea, and a number of currency control abolishments and liquidity crunches at the end of 1979 and the July 1981 devaluation in Thailand are identified by three or more methods.

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. Therefore, we confront the crisis observations of the methods of Figure 4 to the official IMF chronology of the 1997–1999 Asia crisis, see Lindgren et al. (1999).

As Table 7 illustrates, the IMF identified 48 crisis events between March 1997 and July 1999, 11 of which correspond to currency crisis episodes (the bold entries in the second column) and 27 to bank crisis episodes (italic). We observe that the dating methods work reasonably well in picking up currency crisis episodes in the Asia crisis. All methods except KLR with the ad hoc threshold, pick up five of the 11 currency crisis episodes.
episodes. Some events, like the pressure on the Ringgit in Malaysia and the Thailand Baht float in July 1997 are picked up by all methods, others are found by at least three methods. The first signal of the Asia crisis in Thailand in March 1997, the widening of the Rupiah band in Indonesia in July 1997, the further depreciating of the Indonesian Rupiah in February 1998, and all currency crisis episodes after June 1998 are not identified at all except one.

The number of crisis events found with the ERW index is not very sensitive to the choice of the threshold. The \textit{ad hoc} threshold of two standard deviations above the mean produces one extra crisis event compared to the extreme value threshold. The KLR index is more sensitive to the threshold. The least number of events is found by the method of KLR with the \textit{ad hoc} threshold of three standard deviations; most events, 19, by extreme values applied to KLR. However, the latter method also generates the highest number of wrong signals by identifying 30 crisis episodes in total.

7. CONCLUSION

Identifying and observing financial crises lie at the heart of much international research. This paper analysed two currency crisis dating methods, both defining a currency crisis when an exchange market pressure index exceeds some threshold. We investigated the sensitivity of currency crisis dates to the choice of the threshold, \textit{ad hoc} or extreme value based, for six Asian countries over the period 1970–2002. Crisis chronologies differed between methods and choice of threshold. To judge the quality of a method, we
investigated whether the crisis events of the 1997–1999 Asia crisis as documented by the IMF were picked up. On the basis of this assessment, we tend to prefer the exchange market pressure index of Kaminsky, Lizondo and Reinhart with an extreme value-based threshold. This method correctly identified the largest number of crisis episodes, although it also produced the largest number of false signals.

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<table>
<thead>
<tr>
<th>Date</th>
<th>Country</th>
<th>Event</th>
<th>ERW</th>
<th>KLR</th>
<th>Extreme observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 1997</td>
<td>Thailand</td>
<td>First official announcement of problems in two unnamed finance companies, and a recapitalization programme. Sixty-six finance companies secretly receive substantial liquidity support from the Bank of Thailand. Significant capital outflows</td>
<td></td>
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<tr>
<td>April 1997</td>
<td>Malaysia</td>
<td>Bank Negara Malaysia imposes limits on bank lending to the property sector and for the purchase of stocks</td>
<td></td>
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<tr>
<td>June 1997</td>
<td>Thailand</td>
<td>Operations of 16 finance companies suspended and a guarantee of depositors’ and creditors’ funds in remaining finance companies announced</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July 1997</td>
<td>Indonesia</td>
<td>Pressure on the rupiah develops. Widening of the rupiah’s band. Currency meltdown—severe pressure on rupiah</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Malaysia</td>
<td>Bank Negara Malaysia intervenes aggressively to defend the ringgit; efforts to support the ringgit are abandoned; ringgit is allowed to float. Currency meltdown—severe pressure on ringgit</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Philippines</td>
<td>Peso is allowed more flexibility. Currency meltdown—severe pressure on peso</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>South Korea</td>
<td>Several Korean banks are placed on negative credit outlook by rating agencies</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Thailand</td>
<td>Baht is floated and depreciates by 15–20%. Currency meltdown—severe pressure on baht</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>August 1997</td>
<td>Indonesia</td>
<td>Authorities abolish band for rupiah, which plunges immediately</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>South Korea</td>
<td>Government guarantees banks’ external liabilities; withdrawal of credit lines continues</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Thailand</td>
<td>Measures adopted to strengthen financial sector. Operations of 42 finance companies suspended. Three-year Stand-By Arrangement with IMF approved</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>October 1997</td>
<td>Indonesia</td>
<td>Bank resolution package announced; 16 commercial banks closed; limited deposit insurance for depositors in other banks; other bank closures to follow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thailand</td>
<td>Financial sector restructuring strategy announced; Financial Sector Restructuring Agency and asset management company established; blanket guarantee strengthened; new powers to intervene in banks. Emergency decrees to facilitate financial sector restructuring</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>November 1997</td>
<td>Indonesia</td>
<td>Three-year Stand-By Arrangement with IMF approved</td>
<td></td>
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<tr>
<td></td>
<td>South Korea</td>
<td>Exchange rate band widened. Won falls sharply. Korea Asset Management Corporation’s (KAMCO) non-performing asset fund is established</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
December 1997

Thailand  Change in government. Significant strengthening of economic reform programme

Indonesia  Deposit runs on banks, accounting for half of banking system assets

South Korea  IMF approves three-year Stand-By Arrangement but rollover of short-term debt continues to decline. New government is elected; commitment to programme is strengthened. Foreign private bank creditors agree to maintain exposure temporarily. Legislation passed strengthening independence for Bank of Korea and creating Financial Supervision Commission. Fourteen merchant banks are suspended and two large commercial banks taken over by the government

January 1998

Thailand  Fifty-six suspended finance companies are permanently closed

Indonesia  Second IMF-supported programme announced. Indonesian Bank Restructuring Agency (IBRA) established and blanket guarantee announced

Malaysia  Measures announced to strengthen prudential regulations. Bank Negara Malaysia announces blanket guarantee for all depositors

South Korea  Agreement with external private creditors on rescheduling of short-term debt. Ten of the 14 suspended merchant banks closed; 20 remaining merchant banks are required to submit rehabilitation plans

Thailand  Bank of Thailand intervenes in two commercial banks; shareholders eliminated

February 1998

Indonesia  President Suharto reelected. Doubts about future of financial sector programme grow stronger amid political uncertainty. Rupiah depreciates further and currency board is debated

South Korea  New president and government take office

March 1998

South Korea  Programme to consolidate finance companies and to recapitalize commercial banks is announced

Malaysia  Three-year Stand-By Arrangement agreed with IMF

Philippines  Three-year Stand-By Arrangement agreed with IMF

Thailand  One commercial bank purchased by foreign strategic investor. New loan classification and loss provisioning rules introduced

April 1998

Indonesia  IBRA closes seven banks and takes over seven others

South Korea  Four of the 20 merchant banks’ rehabilitation plans rejected; banks are closed

May 1998

Indonesia  Widespread riots. Rupiah depreciates, deposit runs intensify, and Bank Indonesia must provide liquidity. President Suharto steps down. A major private bank taken over by IBRA

Thailand  Bank of Thailand intervention in seven finance companies; shareholders eliminated

June 1998

Indonesia  International lenders and Indonesian companies agree on corporate debt rescheduling

Malaysia  Danaharta, an asset management company, is established
For the first time, government closes commercial banks (five small ones). Two merchant banks are closed and two merged with commercial banks. New loan classification and loss provisioning rules introduced.

Authorities allow market-determined interest rates on Bank Indonesia bills.

Dynamodal (bank restructuring and recapitalization agency) is established.

Comprehensive financial sector restructuring plan announced, including facilities for public support of bank recapitalization. Intervention in two banks and five finance companies; shareholders’ stakes eliminated. Majority ownership in one medium-sized commercial bank by foreign strategic investor.

Indonesia’s bilateral external debt to official creditors refinanced. Bank Mandiri created through merger of four largest state-owned banks. Plans announced for joint government–private sector recapitalization of private banks.

Capital controls introduced, exchange rate pegged, disclosure requirements relaxed, and measures to stimulate bank lending adopted.

Amended Banking Law passed, which included strengthening of IBRA.

Capital controls replaced with declining exit levies.

Government closes 38 banks and IBRA takes over seven others. Eligibility of nine banks for joint recapitalization with government announced.

Closure of one joint-venture bank. Government announces a plan to recapitalize the three other state banks (all insolvent).

Eight private banks recapitalized jointly through public and private funds.

Government announces plan for resolution of IBRA banks. Legal merger of component banks of Bank Mandiri.

One small private bank intervened and put up for sale; one major bank announces establishment of an asset management company.

Correctly (total) identified crisis episodes

<table>
<thead>
<tr>
<th>Date</th>
<th>Country</th>
<th>Event</th>
<th>ERW</th>
<th>KLR</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 1998</td>
<td>Indonesia</td>
<td>For the first time, government closes commercial banks (five small ones). Two merchant banks are closed and two merged with commercial banks. New loan classification and loss provisioning rules introduced</td>
<td></td>
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</tr>
<tr>
<td>August 1998</td>
<td>Malaysia</td>
<td>Authorities allow market-determined interest rates on Bank Indonesia bills</td>
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<tr>
<td>September 1998</td>
<td>Indonesia</td>
<td>Danamodal (bank restructuring and recapitalization agency) is established</td>
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<tr>
<td>September 1998</td>
<td>Thailand</td>
<td>Comprehensive financial sector restructuring plan announced, including facilities for public support of bank recapitalization. Intervention in two banks and five finance companies; shareholders’ stakes eliminated. Majority ownership in one medium-sized commercial bank by foreign strategic investor</td>
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<tr>
<td>September 1998</td>
<td>Indonesia</td>
<td>Indonesia’s bilateral external debt to official creditors refinanced. Bank Mandiri created through merger of four largest state-owned banks. Plans announced for joint government–private sector recapitalization of private banks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>October 1998</td>
<td>Indonesia</td>
<td>Amended Banking Law passed, which included strengthening of IBRA</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>February 1999</td>
<td>Malaysia</td>
<td>Capital controls replaced with declining exit levies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>March 1999</td>
<td>Indonesia</td>
<td>Government closes 38 banks and IBRA takes over seven others. Eligibility of nine banks for joint recapitalization with government announced</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April 1999</td>
<td>Indonesia</td>
<td>Closure of one joint-venture bank. Government announces a plan to recapitalize the three other state banks (all insolvent)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 1999</td>
<td>Indonesia</td>
<td>Eight private banks recapitalized jointly through public and private funds</td>
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<td></td>
</tr>
<tr>
<td>July 1999</td>
<td>Indonesia</td>
<td>Government announces plan for resolution of IBRA banks. Legal merger of component banks of Bank Mandiri</td>
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<td></td>
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<tr>
<td>July 1999</td>
<td>Thailand</td>
<td>One small private bank intervened and put up for sale; one major bank announces establishment of an asset management company</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Correctly (total) identified crisis episodes

| Correctly (total) identified crisis episodes | 13 (18) | 10 (13) | 12 (18) | 19 (30) |

Note: Bold (italics) denote currency (bank) crisis events.
We already noted that our final judgment of the dating methods on the basis of a chronology of the Asia crisis is suboptimal. Researchers and policymakers 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, 2003a, b). Extension of this work to other financial markets and a broader range of economies, including developing markets, would be of immense assistance for economic researchers and policymakers alike.

ACKNOWLEDGEMENTS

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NOTES

1. Lestano and Jacobs (2004), the working paper companion of this paper, evaluate two additional EMPI definitions. 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.

2. 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 et al. (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.

3. Note we use base money instead of M1.

4. Pontines and Siregar (2004), following Huisman et al. (2001), estimate this equation by GLS to take into account heteroscedasticity. In our sample, GLS outcomes are similar to OLS outcomes.

REFERENCES


