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Causes of the 1997 Asian Financial Crisis: What Can an Early Warning System Model Tell Us?

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Juzhong Zhuang is a Senior Economist with the Regional Economic Monitoring Unit, Asian Development Bank, and J. Malcolm Dowling is a Senior Fellow at the Department of Economics, Melbourne University. Views expressed in the paper do not necessary reflect those of the authors' affiliated organizations.

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Foreword

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Abstract

Using an early warning system (EWS) model, this paper provides more empirical evidence on the causes of the 1997 Asian financial crisis, with a view to discriminating between the two hypotheses of "weak fundamentals" and "investors' panic." The results show that there are strong warning signals of heightened financial vulnerability in each of the five most affected countries from the EWS model prior to the crisis, suggesting that weaknesses in economic and financial fundamentals in these countries played an important role in triggering the crisis. The warning signals point to fundamental weaknesses including real appreciations of domestic currencies, deteriorations in current account positions, excessive external borrowings by banks and currency mismatches in their balance sheets, excessive growth of domestic credit, economic slowdown, and the burst of asset price bubbles.

Contents

I. INTRODUCTION

In the last few years there has been considerable discussion of the causes of the 1997 Asian financial crisis. Two main views have emerged. The first attributes the initial financial turmoil in some Asian countries in 1997 and its propagation over time mainly to sudden shifts in market expectations and confidence followed by regional contagion (Radelet and Sachs 1998; Marshall 1998; and Chang and Velasco 1999). While admitting the worsening of the macroeconomic performance of some affected countries in the mid-1990s, this view suggests that the extent and depth of the crisis should not be attributed to deterioration in fundamentals, but rather to panic on the part of domestic and international investors.

The second argues that the crisis occurred primarily as a result of structural and policy distortions (Corsetti, Pesenti, and Roubini 1998; Dooley 1999). According to this view, fundamental imbalances triggered the currency and financial crisis in 1997 even as after the crisis started, market overreaction and herding caused the plunge in exchange rates, assets prices, and economic activity to be more severe than warranted by the initial weak economic and financial conditions.

It is important to establish which of these hypotheses is more plausible. If the Asian crisis was caused more by weak fundamentals, policy and institutional reforms should be designed mainly to address these weaknesses; while if the crisis was caused more by investor panic, policy reform should perhaps focus more on ways to prevent and contain investor panic. Therefore, discriminating between the two hypotheses could have important policy implications.

A number of studies have attempted to provide empirical evidence of economic and financial fragility in the affected Asian countries prior to the 1997 crisis. Some studies have compared indicators of fragility in the affected countries at the onset of the crisis with those in nonaffected or less-affected emerging economies, using cross-sectional regression (for example Corsetti, Pesenti, and Roubini 2000). Results from these studies, in general, show that the affected countries were on average more fragile than others, although a few nonaffected countries were also found to be vulnerable according to the indicators used. These types of study, however, cannot discriminate between the two hypotheses described above. To do this requires testing not only whether there was fragility in the affected countries, but also whether such fragility had reached some "crisis-triggering level."

Other works have attempted to show whether early warning system (EWS) models could have predicted the 1997 Asian crisis. The most notable examples are Kaminsky (2000); Berg and Patillo (1999a, b); Goldstein, Kaminsky, and Reinhart (2000); and Edison (2000). Two approaches

have been widely used in constructing EWS models in this literature. The first is the so-called signaling approach pioneered by Kaminsky and Reinhart (Kaminsky, Lizondo, and Reinhart 1998). It involves monitoring a set of high-frequency leading indicators that tend to behave differently prior to a crisis and examining whether they individually or collectively have reached "threshold" values that are historically associated with the onset of a financial crisis. The second approach uses probit/logit models (see for example Berg and Patillo 1999b). Probit/logit EWS models are multivariate and allow testing of statistical significance of explanatory variables. But these models usually require large samples to estimate, and can only accommodate a limited number of explanatory variables to avoid multicolinearity. In contrast, the signaling approach-based EWS models are univariate, and do not allow testing of statistical significance, as they are nonparametric. But such models can work with small samples and impose no restriction on the number of explanatory variables.

An EWS approach could be useful in discriminating between the two hypotheses and help to determine what actually happened in Asia in 1997. This is because EWS models involve estimating "crisis-triggering" threshold values for economic and financial indicators from historical data. If, in cases of the affected Asian countries, there were strong warning signals of a heightened probability of a financial crisis prior to the 1997 crisis from such models, then there are good reasons to suggest that the crisis was caused more by weak fundamentals than by market overreaction and investor panic.

However, most existing EWS studies are oriented toward demonstrating whether financial crises are predictable rather than discriminating between the two hypotheses of "investor panic" and "weak fundamentals." Using an EWS model, this paper provides more empirical evidence on economic and financial fragility in the affected Asian countries prior to the crisis, with a view to discriminating between the two hypotheses. In order to examine a variety of indicators of economic and financial fragility, we follow the signaling approach in constructing the EWS model.

The EWS model in this paper differs from existing studies in a number of ways. First, to cut down on the problem of heterogeneity we focus only on a small number of countries that were at the center of the 1997 Asian crisis. Second, to enable better discrimination between the two hypotheses, we do not consider unsuccessful speculative attacks in defining the left-hand side variable. Third, among explanatory variables, we include the ratio of foreign liabilities to foreign assets of the banking sector, as a measure of currency mismatch, and the real exchange rate of the Japanese yen against the US dollar. These variables have not been used by other studies, and could be relevant for East Asian countries.

The EWS model is constructed using monthly data from 1970 to 1995 for Indonesia, Republic of Korea (Korea), Malaysia, Philippines, Singapore, and Thailand. Most of these countries, with the exception of Singapore, have been known as the "countries worst hit by the crisis", with Thailand being the origin of the crisis. The model is then applied to data from 1996 to 1997 to test whether there were warning signals in each of the six countries prior to the 1997 financial crisis.

The rest of this paper is organized as follows. Section II describes methodology. Section III discusses empirical results. Section IV concludes.

II. METHODOLOGY

The signaling approach to constructing EWS models involves the following steps: identifying historical crisis episodes, selecting leading indicators as predictors of crisis episodes, setting threshold values of the selected leading indicators, constructing composite leading indices, and predicting crises. Goldstein, Kaminsky, and Reinhart (2000) provide technical details of these steps.

A. Identifying Historical Crisis Episodes

The first step is to determine what constitutes a crisis. This paper focuses only on currency crises and a crisis episode is considered to occur in a particular month if the month-over-month percentage change in a bilateral nominal exchange rate (e.g., local currency/US dollar) exceeds its sample mean by two standard deviations.[1] In practice, it is often the case that a large movement in an exchange rate is followed closely by another or several large movements, some of which may still be part of the crisis associated with the first instance of depreciation. Therefore, it is assumed that only a depreciation episode that takes place 12 months or more after the previous one is a separate crisis.

B. Selecting Leading Indicators

Leading indicators as predictors of currency crises are often chosen based on economic rationales as well as the availability of data. Kaminsky, Lizondo, and Reinhart (1998) made a comprehensive survey of various types of indicators used in empirical studies of EWS models. Table 1 provides a list of leading indicators used in constructing the EWS model in this paper and their economic rationales. Most indicators are observed at monthly intervals. But some are available only on a quarterly or annual basis. For these indicators, monthly observations were interpolated from annual/quarterly data.

Some leading indicators need to be transformed to ensure that they are stationary and free from seasonal effects. For each indicator in this paper, three forms of specifications are considered: level, change (or percentage change) over 12 months, and deviation from its trend. The level form is adopted as long as an indicator is nontrending and has no discernible seasonality. In addition, either change (or percentage change) over 12 months or deviation from the trend is used as the second specification, depending on relative performance of the two in predicting crises, and as long as the second specification improves the predictability of the EWS model. To estimate trends and deviations from trends, we used the Hodrick-Prescott (HP) filter (Enders 1995).

[1] Most existing studies use a weighted average of month-over-month percentage changes in a bilateral nominal exchange rate and foreign reserves (Eichengreen, Rose, and Wyplosz 1994) to identify historical currency crisis episodes. Including foreign reserves enables the capture of so-called unsuccessful speculative attacks. In this paper, the foreign reserves variable is not used in identifying crisis episodes as we do not consider unsuccessful attacks.

Table 1. **List of Leading Indicators**

Leading Indicator	Rationale
Current Account Real exchange rate Exports Imports Trade balance/gross domestic product (GDP) Current account balance/gross domestic investment (GDI)	Weak exports, excessive import growth, and currency overvaluation could lead to deteriorations in the current account, and historically have often been associated with currency crises in many countries. External weaknesses and currency overvaluation could also add to the vulnerability of the banking sector since a loss of competitiveness and the external market might lead to a recession, business failures, and a decline in the quality of loans. Banking crises could also lead to currency crises.
Capital Account Foreign reserves M2/foreign reserves Short-term debt/foreign reserves Foreign liabilities/foreign assets Deposits in BIS banks/foreign reserves	With increasing globalization and financial integration, capital account problems could make a country highly vulnerable to shocks. Manifestations of capital account problems could include declining foreign reserves, excessive short-term foreign debt, debt maturity and currency mismatches, and capital flight.
Financial Sector M2 multiplier (M2/M0) Domestic credit/GDP Excess real M1 balances Central bank credit to the public sector/GDP Domestic real interest rate Lending–deposit rate spread Real commercial bank deposits	Currency and banking crises have been linked to rapid growth in credit fueled by excessive monetary expansion in many countries, while contractions in bank deposits, high domestic real interest rates, and large lending-deposit rate spreads often reflect distress and problems in the banking sector.
Real Sector Industrial production Stock prices	Recessions and a bust in asset price bubbles often precede banking and currency crises.
Global Economy US real interest rate US GDP growth World oil prices Dollar/yen real exchange rate	Foreign recessions could spill over to domestic economies and lead to domestic recessions. High world oil prices pose a danger to the current account position, and also could lead to domestic recessions. High world interest rates often induce capital outflows. For many East Asian countries, the depreciation of the Japanese yen against the US dollar could put other regional currencies under pressure.
Fiscal Sector Fiscal balance/GDP Government consumption/GDP	Large fiscal deficits could lead to a worsening in the current account position, which could in turn put pressure on the exchange rate.

C. Setting Leading Indicators' Thresholds

For each leading indicator, a threshold divides its distribution into a region that is considered normal and a region that is considered abnormal and associated with a heightened probability of crises. For each month, if the observed outcome of an indicator falls into the abnormal region, that indicator is said to be sending a warning signal. A warning signal could be true if a crisis follows within 24 months (denoted as *A*), or false if no crisis follows within 24 months (denoted as *B*).[3] The latter is usually referred to as Type-II error. Similarly, when the observed outcome of an indicator stays in the normal region and hence issues no warning signals, this could be false, if a crisis follows within 24 months (denoted as *C*); or true, if no crisis follows within 24 months (denoted as *D*). The former is referred to as Type-I error (see Table 2.)

Table 2. **True and False Warning Signals**

	A crisis follows within 24 months	No crisis follows within 24 months
Signal	A	B
No signal	C	D

There is a tradeoff between the Type-I and Type-II errors. Widening the abnormal region will increase the number of false signals (*B*) but reduce the number of missed crises (*C*). On the other hand, narrowing the abnormal region will increase the number of missed crises but reduce the number of false signals. Kaminsky, Lizodon, and Reinhart (1998) proposed the setting of the optimal threshold for an abnormal region so as to minimize the so-called noise-to-signal ratio, *NSR*, which is defined as the ratio of the probability of an indicator signaling during noncrisis or tranquil times, to the probability of the indicator signaling during crisis times, that is,

$$NSR = [B/(B+D)]/[A/(A+C)] \quad (1)$$

where *A, B, C,* and *D* are defined in Table 2. Empirically, the minimum *NSR* and the associated threshold of each indicator are estimated using a grid search procedure. This involves calculating *NSR*s assuming different thresholds and finding the minimum one. The grid search is usually limited to a region between the 10th and 20th percentile of an indicator's frequency distribution: at the upper tail if the indicator is positively correlated with the crisis probability, and lower tail

[3] An EWS model should issue warning signals well in advance of the onset of a crisis. This lead time could vary by indicators, and differ among crisis episodes and across countries. But in order to classify warning signals into true or false ones, a maximum lead time, termed the crisis window, has to be set. In the literature, this crisis window has commonly been set at 24 months and we follow this practice.

if the two are negatively correlated. In the grid search, the frequency distribution is assumed to be country-specific for each indicator—control for country-specific effects that may not be related to financial vulnerability but nevertheless influence an indicator's absolute value—but the same percentile is applied to all the six countries at each iteration. Therefore, in the model, each indicator's threshold in percentile terms is uniform across the six countries, but that in actual value is country-specific.

With threshold values, actual observations of leading indicators can be converted into zero (if the actual value does not cross the threshold value) or one (if the actual value crosses the threshold value) signals. On the basis of the historical crisis episodes, these signals can be classified into true or false as shown in Table 2. The minimum *NSR,* calculated by pooling all the countries together, provides a measure of the predictive power of each leading indicator. The lower this ratio, the more powerful is a leading indicator in predicting crises. A second but closely related performance measure is the conditional probability, which is defined as

$$NSR = [B/(B+D)]/[A/(A+C)] \tag{2}$$

$P(C|S)$ is the probability of a crisis occurring within 24 months conditional on a warning signal from a leading indicator. The higher the conditional probability, the greater is the predictive power. A third performance measure is the proportion of crises accurately predicted by a leading indicator during the sample period, defined as

$$P(C\backslash S) = A/(A+B) \tag{3}$$

The higher the *PC,* the greater is the indicator's predictive power.

D. Constructing Composite Leading Indices

Based on the assumption that the greater the number of leading indicators signaling a crisis, the higher the probability that such a crisis would actually occur, Kaminsky (2000) proposed a number of composite leading indices. One such composite index, I_t, is a weighted average of zero/one signals by individual leading indicators, S_{it}, with weights being inverses of their respective minimum *NSR*s, defined as

$$I_t = \sum \frac{S_{it}}{\varepsilon_i} \tag{4}$$

where ε_i is the minimum *NSR* of the leading indicator i. Therefore, this composite index gives more weights to better performing (with smaller minimum *NSR*s) indicators. In this paper, six sector-specific and an overall composite leading indices are constructed. A sector-specific composite

leading index is a weighted average of one/zero signals of individual leading indicators in a particular sector, with weights being inverses of their respective minimum *NSRs*. The six sectors are current account, capital account, fiscal account, financial sector, real sector, and global economy. Sector-specific composite leading indices, which have not been used by other studies, allow the identification of sources of economic and financial weaknesses. The overall composite index is a weighted average of the six sector composite indices, with weights being inverses of minimum *NSRs* of the sector composite indices.[4]

E. Predicting Crises

As composite leading indices contain more information and are in general more reliable than single indicators, they are used for predicting crisis probabilities. One approach is to estimate composite leading indices' thresholds, minimum *NSR*s, and conditional probabilities following the same grid search procedure as applied to individual indicators. A composite leading index will issue a warning signal, with a conditional probability attached, if its observed outcome in a particular month exceeds its threshold.

It is also possible to assign a particular level of crisis probability to any value of a composite leading index by dividing the entire sample into several groups, each corresponding to a particular range of the composite index, and calculating the proportion of months associated with crises for each group, using the following formula,

$$P(C \mid I^{l} < I_{t} < I^{u}) = \frac{no.\ of\ months\ \ with\ \ I^{l} < I_{t} < I^{u}\ \ and\ \ a\ crisis\ \ following\ \ in\ 24\ months}{no.\ of\ \ months\ \ with\ \ I^{l} < I_{t} < I^{u}} \qquad (5)$$

where I_t is the value of the composite index at time t, I^l is the lower bound of a particular range of the composite index, I^u is the upper bound of the range, and $P\,(C \mid I^l < I_t < I^u)$ is the probability of a crisis occurring within 24 months conditional on I_t lying in the range between I^l and I^u. In

[4] The selection of individual indicators for composite indices has an important bearing on their performance in predicting crises. Some indicators may be good at predicting crises individually, but may make no contribution to the performance of composite indices if crises they capture have been captured by indicators already included. In fact, because adding additional indicators changes the existing weighting structure of a composite index, such indicators could "crowd out" good indicators, leading to poorer performance of the composite index. One way to deal with this problem is to use the so-called quadratic probability score, *QPS,* in selecting indicators. *QPS* is defined as

$$QPS = \frac{1}{T}\sum 2(P-R)^2$$

where T is the number of sample observations, P is the predicted probability of a crisis estimated from a composite index, and R is the observed realization (equal to one if a crisis occurs and zero otherwise). A reduction in *QPS* indicates an improvement in the predicative power of the composite index.

empirical model estimation, we divided the entire sample, ranked by the value of the composite leading index, into eight groups. The first group contains all observations with the composite leading index equal to zero. The next seven groups contain all the observations with the composite leading index greater than zero, and are classified in percentile as follows: 0-30, 30-50, 50-70, 70-80, 80-90, 90-95, and 95-100.

III. RESULTS

The EWS model was estimated using monthly data of Indonesia, Korea, Malaysia, Philippines, Singapore, and Thailand from 1970 to 1995. The model was then applied to data from 1996 to 1997 to test, out-of-sample, whether there were warning signals in the six countries prior to the onset of the 1997 financial crisis. The data appendix provides details of variable definitions and data sources.

A. Crisis Episodes and Crisis Probabilities: 1970-1997

In Figures 1-6 we plot the crisis episodes in the six countries during 1970-1997, identified using the technical definition of currency crises; and the time series of crisis probabilities for the corresponding period, estimated on the basis of the outcomes of the overall composite index and equation (5). Crisis probabilities before 1996 are in-sample estimates and those in 1996-1997 are out-of-sample predictions.

The estimated cut-off level of depreciation for a crisis episode estimated using sample data from 1970 to 1995 is 8.8 percent for Indonesia, 4 percent for Korea, 3 percent for Malaysia, 7.8 percent for the Philippines, 2.7 percent for Singapore, and 2.5 percent for Thailand.[5] These suggest that, on average, exchange rates were more volatile in Indonesia, Korea, Philippines, and Thailand than in Malaysia and Singapore. Based on these cut-off levels, during 1970-1997, Indonesia had six crisis episodes, Korea had four, Malaysia eight, Philippines six, Thailand three, and Singapore seven. Many depreciation instances in Singapore and Malaysia would not have been classified as crisis episodes judged by absolute cut-off levels for the first four countries. Further, different episodes might have different implications depending on the context. Some might have very significant impacts on the real sector and the whole economy, especially if they were accompanied by banking crises, such as the 1997 Asian financial crisis. These were "true crises" in a more conventional sense. On the other hand, some episodes even if involving the same extent of depreciation as "true crises" might have only limited impacts, and may not have been considered crises at the time they occurred.

In Thailand, since the crisis episode in November 1984, the crisis probability remained low, fluctuating around 20 percent in most of the period. But from early 1996, the crisis probability started to climb, reaching over 70 percent in late 1996, remaining above this level until July 1997

[5] These cut-off levels were estimated in terms of domestic currency per US dollar.

Figure 1. **Indonesia: Currency Crisis and Probability of Currency Crisis 1970-1995 (in-sample), 1996-1997 (out-of-sample)**

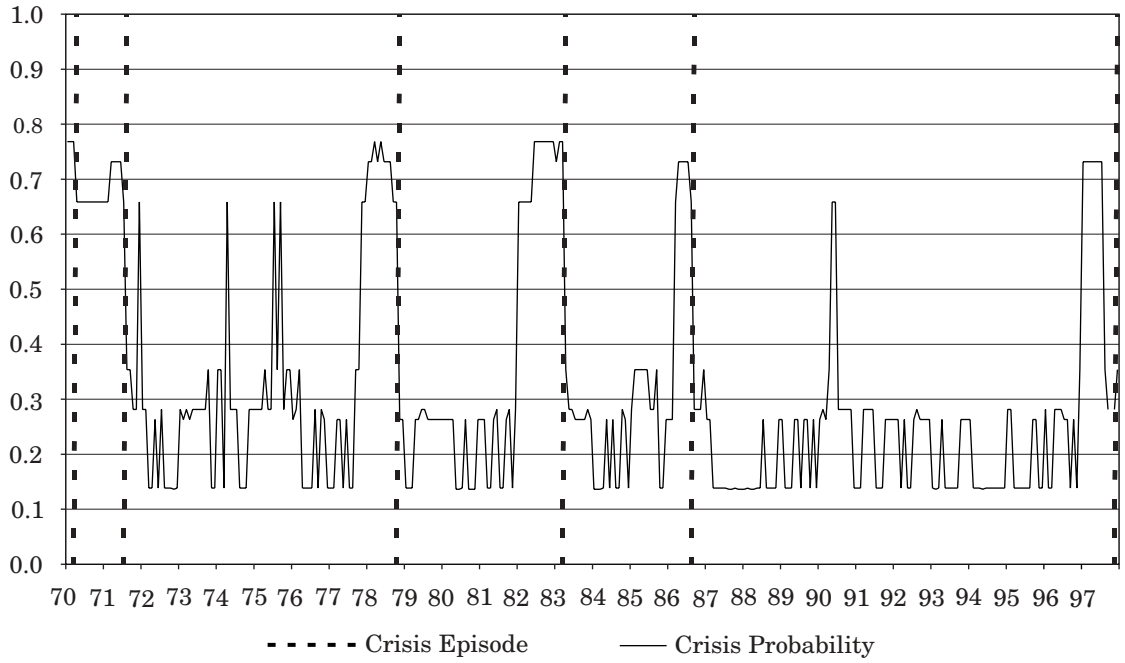


Figure 2. **Korea: Currency Crisis and Probability of Currency Crisis 1970-1995 (in-sample), 1996-1997 (out-of-sample)**

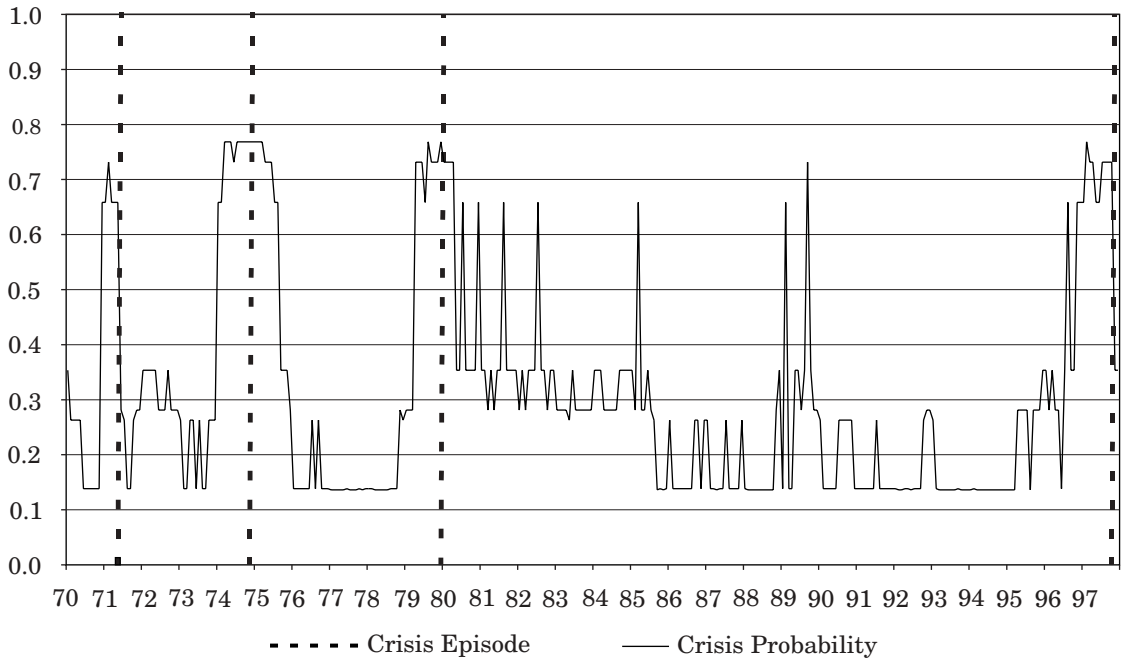


Figure 3. **Malaysia: Currency Crisis and Probability of Currency Crisis 1970-1995 (in-sample), 1996-1997 (out-of-sample)**

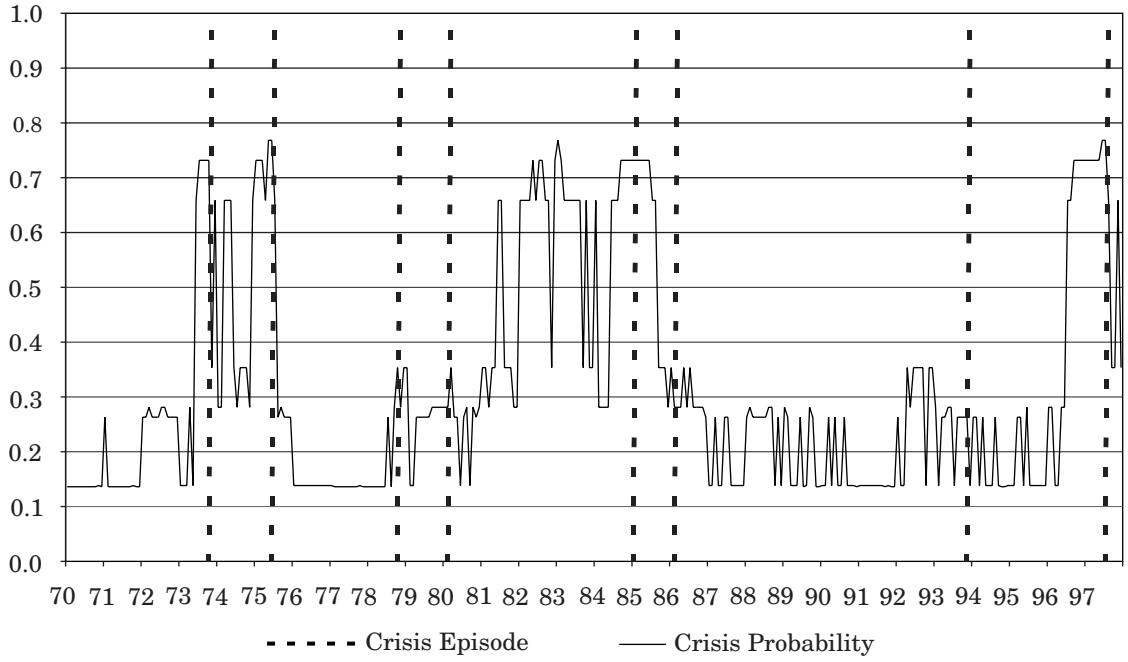


Figure 4. **Philippines: Currency Crisis and Probability of Currency Crisis 1970-1995 (in-sample), 1996-1997 (out-of-sample)**

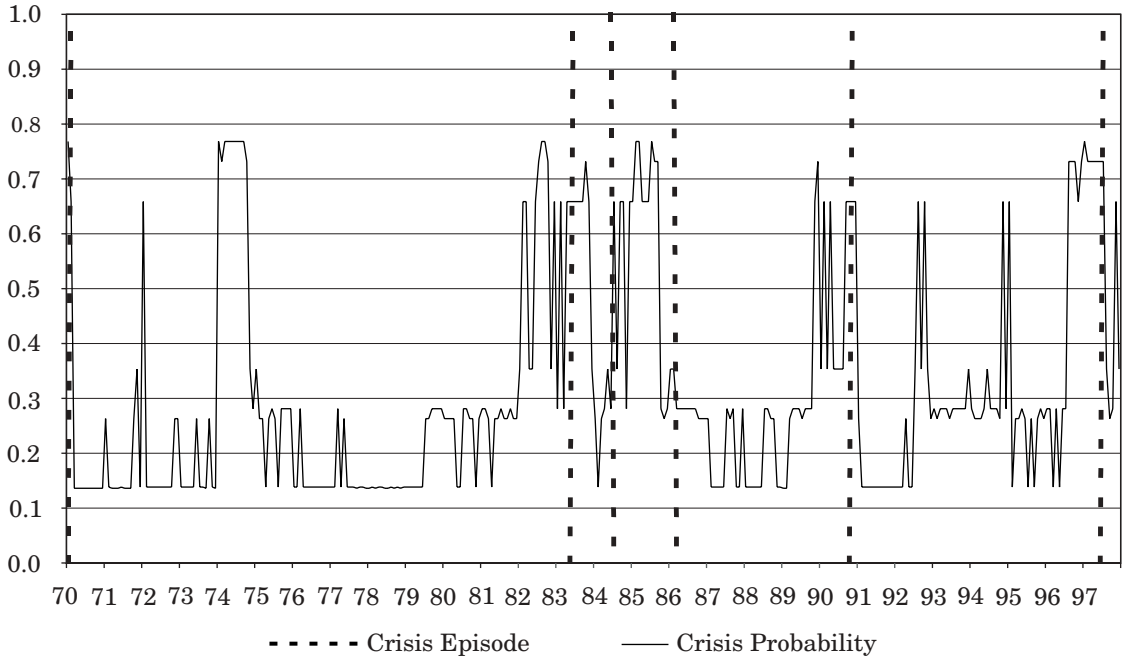


Figure 3. **Thailand: Currency Crisis and Probability of Currency Crisis 1970-1995 (in-sample), 1996-1997 (out-of-sample)**

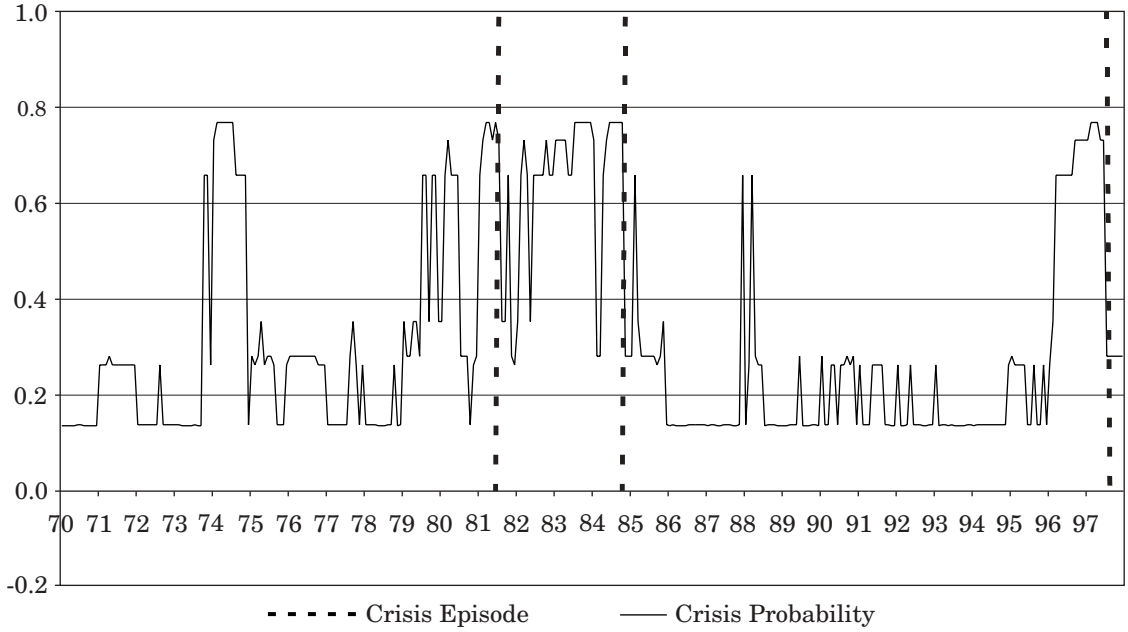
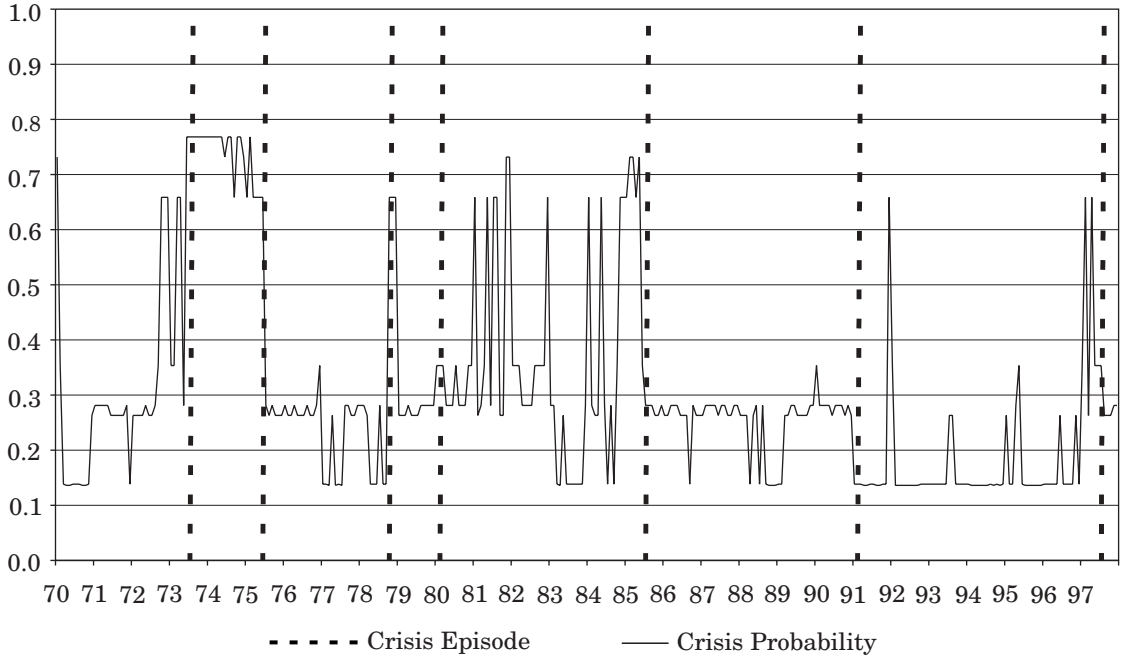


Figure 4. **Singapore: Currency Crisis and Probability of Currency Crisis 1970-1995 (in-sample), 1996-1997 (out-of-sample)**



when the Thai baht depreciated by 19.6 percent. In the case of Korea, the crisis probability remained below 20 percent for most months during 1990-1995. It started to climb in early 1996, and continued to increase, staying high at more than 70 percent until November 1997 when the Korean won depreciated by 17 percent. In Malaysia, the crisis probability also increased dramatically from mid-1996 and reached more than 70 percent late that year and stayed above this level until the Malaysian ringgit depreciated by 11.1 percent in August 1997. The Philippines was less affected by the 1997 crisis. However, the model also shows some financial vulnerability in this country from mid-1996. The crisis probability increased dramatically from mid-1996 and stayed high at more than 70 percent until July 1997, when the peso depreciated by about 9 percent. In Indonesia, the crisis probability also remained low during most of the period 1987-1996. But it started to climb from early 1997, and remained at more than 70 percent for seven consecutive months before the Indonesian rupiah depreciated by 21.5 percent in December 1997. It is worth mentioning that earlier studies failed to predict the 1997 crisis in Indonesia (Goldstein, Kaminsky, and Reinhart 2000). Last, the model does not work sufficiently well in the case of Singapore. The crisis probability increased prior to the Singapore dollar's depreciation, by 3.7 percent, in August 1997. But compared with those for other countries, the increase came later and was less pronounced.

In sum, our results show that in all the five affected countries the crisis probability heightened significantly prior to the 1997 Asian crisis. But in Singapore, although there was a sign of heightening of the crisis probability, the heightening was much less pronounced.

B. Warning Signals during the 24 Months prior to the 1997 Crisis

On the basis of a composite leading index's optimal threshold (where the noise-to-signal ratio is at the minimum), we can estimate the number of warning signals issued during the 24 months prior to the 1997 Asian financial crisis. Table 3 reports the optimal thresholds of and warning signals issued by the overall as well as the six sector-specific composite leading indices. Figures in parentheses are months of lead time of their first warning signals. Before discussing these results, it is important to assess how reliable these warning signals are, by looking at the composite leading indices' three performance measures: the minimum noise-to-signal ratio, conditional crisis probability, and share of crises predicted, also reported in Table 3. The overall composite leading index has an optimal threshold at the 88th percentile of its frequency distribution. At this threshold, it has a minimum *NSR* of 0.137, meaning that, in the sample, the likelihood of the overall composite leading index signaling during tranquil times is only a little over one tenth of the likelihood of its signaling during crisis times. The corresponding conditional probability is 77 percent, meaning that, once this index signals, the probability of a crisis following within 24 months is 77 percent. Further, with this threshold and an abnormal region lying above it,[6] the overall composite leading

[6] If the threshold is at the upper tail of an indicator's frequency distribution, the region above the threshold is defined as the abnormal region; while if the threshold is at the lower tail of the frequency distribution, the region below the threshold is defined as the abnormal region.

Table 3. **Composite Leading Indices: Optimal Thresholds, Warning Signals during the 24 Months prior to the 1997 Asian Financial Crisis, Months of Lead Time, and Performance Measures**

	Optimal Threshold (percentile)	Number of Warning Signals and Months of Lead Time (in parenthesis)						Noise-to-Signal Ratio	Conditional Crisis Probability (%)	Share of Crisis Predicted (%)
		Indonesia	Korea	Malaysia	Philippines	Thailand	Singapore			
Overall Composite Index	88	7 (11)	9 (10)	13 (13)	10 (11)	10 (10)	0 (0)	0.137	77	83
Current Account	90	7 (11)	11 (16)	13 (13)	11 (11)	16 (16)	0 (0)	0.136	77	83
Capital Account	90	1 (23)	0 (0)	2 (3)	0 (0)	0 (0)	0 (0)	0.288	62	63
Financial Sector	90	0 (0)	0 (0)	2 (2)	0 (0)	0 (0)	0 (0)	0.313	60	67
Real Sector	90	2 (2)	9 (14)	0 (0)	2 (10)	4 (13)	0 (0)	0.322	53	31
Global Economy	80	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.540	46	75
Fiscal Sector	87	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.540	46	46

Source: Authors' estimation.

index predicts 83 percent of the crisis episodes in the sample. These measures suggest that the overall composite leading index has significant predictive power.

Among the sector-specific composite indices, the current account composite index is the best performing. In fact, it has more or less the same level of reliability as the overall composite leading. The performance of the capital account composite index is also good: it has a minimum *NSR* of 0.288, a conditional probability at 62 percent, and a proportion of crises called at 62.5 percent. In comparison, the financial sector composite index, real sector composite index, fiscal account composite index, and global economy composite index are less reliable: they have higher minimum *NSR* ratios, lower conditional probabilities, and lower shares of crises predicted.

The overall composite leading index issued seven warning signals in Indonesia during 24 months prior to the 1997 crisis, with a lead time of 11 months. The number of signals is nine in Korea, with a lead time of 10 months; 13 in Malaysia, with a lead time of 13 months; 10 in the Philippines, with a lead time of 11 months; and 10 in Thailand, with a lead time of 10. But there is no warning signal in the case of Singapore.

The fact that there were strong and persistently early warning signals in not just Thailand, the origin of the crisis, but all the five countries most affected by the 1997 crisis appears not to square well with the "investor panic, market overreaction and regional contagion" postulate. Rather, the evidence lends support to the "weak fundamentals" hypothesis. In the case of Singapore, however, the evidence suggests that the depreciation of the Singapore dollar was more a result of regional contagion than weak fundamentals. This appears consistent with the fact that Singapore was less affected by the 1997 financial crisis.

Among sector-specific composite indices, the current account composite index issued more or less the same number of warning signals and had the longer or same lead time as the overall composite index in most cases. Among other sector indices, the capital account composite index signaled once in Indonesia, with a lead time of 23 months, and twice in Malaysia, with a lead time of three months. It issued no warning signals in other countries. The financial sector composite index only issued twice in Malaysia, with a lead time of two months. It issued no warning signals in the other countries. The real sector composite index signaled twice in Indonesia, with a lead time of two months; nine times in Korea, with a lead time of 14 months; twice in the Philippines, with a lead time of 10 months; and four times in Thailand, with a lead time of 13 months. However, the global and fiscal composite indices issued no warning signals in any of the countries.

To take the analysis of weak fundamentals a bit further, Table 4 reports warning signals issued by individual leading indicators during 24 months prior to the 1997 crisis. To assess how reliable these individual leading indicators are, we also report the three performance measures.

Table 4 shows that seven out of the 38 leading indicators of the model have a conditional probability greater than 50 percent. These are, in order of probability value, the deviation of the real exchange rate against the US dollar from its trend (78 percent), the deviation of the real effective exchange rate from its trend (72 percent), the short-term debt/foreign reserves ratio (65 percent), the residents' deposits in Bank for International Settlements (BIS) banks/foreign reserves ratio (57 percent), the M2/foreign reserves ratio (54 percent), the foreign liabilities/foreign assets

ratio (52 percent), and the current account balance/GDI ratio (51 percent). The conditional probability for the rest of the individual indicators ranges from 30 to 49 percent. Across the six indicator categories, on average, the current account has the highest conditional probability, which is followed by the capital account, the global economy, the financial sector, the real sector, and the fiscal sector. These suggest that the current account and capital account indicators are on average more reliable than other types of indicators in assessing vulnerability to crises.

During the 24 months prior to the 1997 crisis, almost half of the 38 leading indicators of the model issued at least one warning signal in each of the five countries most affected by the crisis, with the total number of signals ranging from 108 for Indonesia to 151 for Thailand. In the case of Singapore, the number of signaling indicators and total number of warning signals are much less, only 12 and 57, respectively. Across the six indicator categories, although there were signals from every category in every country, most of them were issued by the current account, capital account, financial sector, and real sector indicators.

The real exchange rate against the US dollar and real effective exchange rate against the basket of currencies of major trading partners,[7] both measured in deviations from their trends, issued warning signals in all the six countries, suggesting that there were real appreciations in currencies of all these countries prior to the 1997 crisis. The number of signals indicates that the real appreciation was more persistent and pronounced for the Thai baht, Malaysian ringgit, Korean won, and Philippine peso than for the Singaporean dollar and Indonesian rupiah. Real currency appreciation was accompanied by a worsening of trade and current account positions in these countries, as indicated by warning signals from the trade balance/GDP ratio, the current account balance/GDI ratio, and/or export growth. These results suggest that in all the five affected countries, not only were there apparent deteriorations in current account positions prior to the 1997 crisis, but the deteriotations also reached critical levels that historically had often been associated with the onset of currency crises. Even in Singapore, where no composite leading indices issued warning signals, there were signals from individual current account indicators.

There were also warning signals from the capital account indicators in all the six countries. The ratio of foreign liabilities to foreign assets of the banking sector, a measure of currency mismatch, issued persistent signals in Thailand (23), Indonesia (19), and Malaysia (8) prior to the 1997 crisis. In Korea and the Philippines, although this ratio itself did not signal, its deviation from its trend signaled. These results suggest that banks in all these countries were borrowing heavily from abroad prior to the 1997 crisis, leading to serious currency mismatches. Notably, however, there were no warning signals from this measure—either the ratio itself or its deviation from its trend—in the case of Singapore.

The ratio of M2 to foreign reserves measures a country's ability to withstand the pressure of substituting local currency for foreign currency by investors. This ratio issued signals in Indonesia and Malaysia, and its deviation from its trend signaled in Korea and Thailand. The ratio of short-term debt to foreign reserves, a measure of liquidity mismatch, is the best performing among the

[7] We use the JP Morgan estimates.

Table 4. **Individual Leading Indicators: Optimal Thresholds, Warning Signals during the 24 Months prior to the 1997 Asian Financial Crisis, and Performance Measures**

Leading Indicators	Optimal Threshold (percentile)	Number of Warning Signals						Noise-to-Signal Ratio	Conditional Crisis Probability (%)	Share of Crisis Predicted %)
		Indonesia	Korea	Malaysia	Philippines	Thailand	Singapore			
Current Account										
Real exchange rate, deviation from trend ($/local currency)	90	7	21	13	11	17	4	0.132	77.8	83.3
Real effective exchange rate, deviation from trend (JP Morgan)	89	9	7	15	11	10	2	0.176	72.4	79.2
Current account balance/GDI	17	0	0	0	0	0	0	0.447	50.5	55.6
Imports, 12-month % change	90	0	0	0	1	0	0	0.551	45.5	58.3
Trade balance/GDP, 12-month change	10	0	1	1	4	1	0	0.655	41.2	792
Trade balance/GDP	20	7	0	11	23	10	0	0.765	37.7	75.0
Exports, 12-month % change	11	0	7	0	0	6	4	0.779	37.1	54.3
Current account balance/GDI, 12-month change	12	0	0	0	0	0	12	0.869	34.1	29.4
Capital Account										
Short-term debt/foreign reserves	88	1	0	2	0	0	0	0.222	64.6	50.0
Deposits in BIS banks/foreign reserves	90	0	0	0	0	0	0	0.324	56.7	23.1
M2/foreign reserves	90	10	0	1	0	0	0	0.391	54.2	45.8
Foreign liabilities/foreign assets	90	19	0	8	0	23	0	0.434	51.6	37.5
M2/foreign reserves, deviation from trend	90	1	1	4	0	2	0	0.479	49.1	62.5
Short-term debt/foreign reserves, deviation from trend	90	1	0	5	0	0	0	0.493	45.1	61.1
Foreign liabilities/foreign assets, deviation from trend	90	9	1	8	7	9	0	0.573	44.7	70.8
Deposits in BIS banks/foreign reserves, 12-month change	81	0	10	0	6	0	7	0.590	38.9	54.5
Foreign reserves, 12-month % change	20	0	5	8	0	4	6	0.823	35.8	70.8

Table 4. *(cont'd.)*

Leading Indicators	Optimal Threshold (percentile)	Number of Warning Signals						Noise-to-Signal Ratio	Conditional Crisis Probability (%)	Share of Crisis Predicted %)
		Indonesia	Korea	Malaysia	Philippines	Thailand	Singapore			
Financial Sector										
Central bank credit to the public sector/GDP	90	0	0	0	0	0	0	0.413	49.5	16.7
Real commercial bank deposits, 12-month % change	10	0	0	0	0	0	0	0.494	48.2	45.8
Lending-deposit rate spread, 12-month change	90	0	0	0	0	1	0	0.531	44.3	69.2
Real interest rate, deviation from trend	86	20	0	2	0	0	0	0.532	41.1	85.7
Lending–deposit rate spread	90	0	0	0	1	0	0	0.612	38.8	33.3
Ratio of real M1 to trend	90	4	3	10	1	5	2	0.631	42.3	79.2
Central bank credit to the public sector/GDP, 12-month change	83	0	10	12	0	6	0	0.646	37.9	61.1
Real interest rate	89	4	0	0	0	0	0	0.668	35.7	42.9
M2 multiplier, 12-month % change	81	2	16	0	7	0	1	0.975	32.0	79.2
Domestic credit/GDP, 12-month % change	83	0	13	6	23	5	0	1.119	29.1	54.2
Real Sector										
Industrial production index, 12-month % change	10	2	1	0	3	4	0	0.771	37.4	58.3
Stock price index, 12-month % change (US$)	14	4	10	0	2	13	3	0.784	32.0	58.3
Stock price index ,12-month % change (local currency)	20	1	10	0	8	17	3	0.945	28.1	66.7
Global Economy										
World oil price, 12-month % change	90	0	0	0	0	0	0	0.517	47.0	37.5
US real interest rate	89	0	0	0	0	0	0	0.558	45.3	41.7
Real dollar/yen exchange rate, deviation from trend	10	6	6	6	6	6	6	0.569	44.8	50.0
US annual GDP, 12-month % change	10	0	0	0	0	0	0	0.643	41.7	29.2
Fiscal Sector										
Fiscal balance/GDP	20	0	0	0	0	0	0	0.761	37.8	58.3
Government consumption/GDP	80	0	0	0	23	0	0	0.794	36.8	45.8
Government consumption/GDP, deviation from trend	87	1	0	0	6	0	0	0.811	36.3	50.0
Fiscal balance/GDP, 12-month change	10	0	10	0	0	12	7	0.890	34.0	25.0

Source: Authors' estimation.

capital account indicators according to our estimation. This ratio and its deviation from its trend issued warning signals in Indonesia and Malaysia. The ratio of residents' deposits in BIS banks to foreign reserves measures the extent of capital flight. The fact that this measure (in terms of its deviations from its trend) issued warning signals in Korea, Philippines, and Singapore suggests there was capital flight in these countries prior to the 1997 crisis. Finally, the foreign reserves position deteriorated in Korea, Malaysia, Thailand, and Singapore prior to the 1997 crisis, as indicated by warning signals from the foreign reserves growth.

Financial sector indicators in Table 4 can be divided into two groups: macroeconomic indicators and aggregated microprudential indicators. Macroeconomic indicators, including the M2 money multiplier (which is the ratio of M2 to M0), the ratio of domestic credit to GDP, the ratio of the real M1 balance to its trend, and the ratio of central bank credit to the public sector to GDP, measure domestic credit growth. Warning signals by some of these indicators in Table 4 suggest evidence of excessive growth of domestic credit prior to the 1997 crisis, particularly in Korea, Malaysia, Philippines, and Thailand. Aggregated microprudential indicators, including growth of real commercial bank deposits, the lending-deposit rate spread, and the real interest rate, measure the health of financial institutions. Table 4 shows that warning signals from these indicators are far fewer than those from indicators of credit growth. Nevertheless, the real interest rate issued warning signals in Indonesia and Malaysia and the lending–deposit rate spread issued signals in the Philippines and Thailand. A major reason why there are very few warning signals from indicators of the health of financial institutions could be that we have not used more direct indicators of financial health, such as NPL ratios, capital adequacy ratios, and bank lending portfolios, due to data constraints.

Table 4 also suggests deteriorations in the real sector in most countries under consideration prior to the 1997 crisis, with the exception of Malaysia and Singapore. Growth of industrial production issued warning signals in Indonesia, Korea, Philippines, and Thailand, suggesting economic slowdown in these countries in certain months before the crisis. Stock prices also fell, reflecting perhaps bursts in asset prices bubbles, particularly in Korea and Thailand, where stock price indices in both US dollars and local currency issued warning signals persistently.

Although the ratio of fiscal balance to GDP issued no warning signals, the 12-month change in this ratio signaled in Korea, Singapore, and Thailand. In the case of the Philippines, the ratio of government consumption to GDP issued persistent warning signals.

Finally, among the four global economy indicators, the real US dollar/Japanese yen exchange rate issued six warning signals during 24 months prior to the 1997 crisis. This suggests that the yen's real depreciation against the US dollar contributed to some extent to the stress in many economies in East Asia.

IV. CONCLUSIONS

Using a signaling approach-based EWS model, this paper has attempted to provide more empirical evidence on the causes of the 1997 Asian financial crisis, with a view to discriminating between the two hypotheses of "weak fundamentals" and "investors' panic." The results show that the overall composite leading index of the EWS model issued persistent warning signals prior to the 1997 crisis in not just a few, but all of the five countries most affected by the crisis. This finding appears not to square well with the "investor panic, market overreaction and regional contagion" postulate. Instead, it lends support to the hypothesis that weaknesses in economic and financial fundamentals in these countries triggered the crisis. In the case of Singapore, however, there were no signals from the overall composite leading index, suggesting that the depreciation of the Singaporean dollar was more a result of regional contagion than weak fundamentals.

The results also show that almost half of the 38 individual leading indicators of the EWS model issued warning signals in every affected country during the 24 months prior to the 1997 crisis. These warning signals point to the sources of fundamental weaknesses. First, in most countries under consideration, there were appreciations in the real exchange rate against both the US dollar and the basket currencies of their major trading partners. The real appreciations appeared to have contributed to the deteriorations in these countries' trade and current account positions. Second, there were apparent problems in the capital account, as indicated by persistent warning signals by the ratio of M2 to foreign reserves in the case of Indonesia, and the ratio of foreign liabilities to foreign assets of the banking sector in Indonesia, Malaysia, and Thailand. Third, there was strong evidence of excessive growth of domestic credit, particularly in Korea, Malaysia, Philippines, and Thailand. Last, there was also evidence of deteriorations in the real sector in most countries, and the burst of asset price bubbles, especially in Korea and Thailand. The fact that all these individual leading indicators issued warning signals prior to the 1997 Asian crisis indicates that they had reached the critical levels that historically had often triggered currency crises, lending further support to the "weak fundamentals" hypothesis.

Data Appendix

Indicator	Source and Definition
Real exchange rate	Nominal exchange rate (IFS line 00ae) adjusted for relative consumer prices (IFS line 64)
Real effective exchange rate	JP Morgan web site
Exports	Exports in dollars (IFS line 70d)
Imports	Imports in dollars (IFS line 71d)
Current account balance/GDI	Current account (IFS line 78ald) divided by GDI (IFS lines 93e plus 93I) converted into dollars using IFS line 00af
Trade balance/GDP	Trade balance (IFS lines 70d less 71d) divided by gross domestic product (IFS line 99b) converted into dollars using IFS line 00ae
Foreign reserves	Gross international reserves less gold (IFS line 1L.d)
M2/foreign reserves	M2 (IFS lines 34 plus 35) converted into dollars using IFS line 00ae divided by foreign reserves (IFS line 1L.d)
Short-term debt/foreign reserves	Foreign debt with maturity of less than 1 year (data from World Bank Global Development Finance Statistics) divided by foreign reserves (IFS line 1L.d)
Deposits in BIS banks/foreign reserves	Deposits in BIS banks (IIF data) divided by foreign reserves (IFS line 1L.d)
Foreign liabilities/foreign assets	Foreign liabilities (IFS line 26c) divided by foreign assets (IFS line 21)
M2 multiplier	M2 (IFS lines 34 plus 35) divided by base money (IFS line 14)
Domestic credit/GDP	Domestic credit (IFS line 32) divided by GDP (IFS line 99b)
Excess real M1 balances	Real M1 (IFS line 34 divided by IFS line 64) divided by its trend derived using HPF
Domestic real interest rate	Nominal interest rate (IFS line 60p) less inflation rate (IFS line 64x)
Lending–deposit rate spread	Lending rate (IFS line 60p) less deposit rate (IFS line 60l)
Real commercial bank deposits	Commercial bank deposits (IFS lines 24 plus 25) divided by consumer prices (IFS line 64)
Central bank credit to the public sector/GDP	Central bank credit to the public sector (IFS lines 12A to 12C) divided by GDP (IFS line 99b)
Industrial production	Index of industrial production (IFS line 66c)
Equity prices	Stock price index (Bloomberg data)
US real interest rate	Nominal interest rate (IFS line 60p) less inflation rate (IFS line 64x)
US GDP	GDP (IFS line 99b)
World oil price	Spot oil price (IFS line 00176aaz)
Real yen/dollar exchange rate	Nominal yen/dollar exchange rate (IFS line 00ae) adjusted for relative consumer prices (IFS line 64)
Fiscal balance/GDP	Fiscal balance (IFS line 80) divided by GDP (IFS line 99b)
Government consumption/GDP	Government consumption (IFS line 91f) divided by GDP (IFS line 99b)

Source: Primary data source is the International Financial Statistics (IFS). Other sources noted by indicator.

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