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A Predictive Model for Financial Crises: An Exploratory Public Policy Tool

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Abstract: This paper aims to establish an early warning system for Malaysia to project future financial crises. We investigate the macroeconomic and financial factors in predicting financial crises using the logit econometric model and monthly data with the sample period from January 1980 to December 2003. Four indicators namely regional crisis dummy, current account balance, M2 growth and real exchange rate show significance and therefore, are incorporated in crisis prediction. The early warning system's predictive power is then examined against various crises periods including the 1997 Asian financial crisis. The empirical results show that the early warning system exhibits forecasting ability. Both in-sample and out-of-sample performance evaluations affirm the system's ability to predict the 1997 Asian financial crisis with at least one early warning signal issued within the 12-month period prior to the actual crisis. The early warning system should be treated as a supplement to policymakers existing forecasting tools in estimating the probability of crisis and assessing a country's vulnerability rather than as an exclusive tool for crisis prediction.

Keywords: financial crisis, economic modelling, policy modelling, monetary policy

JEL classifications: D53, E44, E52, G01, F36

1. Introduction

In response to concerns over repetition of the 1997 Asian financial crisis and the implications on the affected countries, in particular Malaysia, we have established an econometric model to forecast potential financial crises that may hit Malaysia in the foreseeable future. The model aims to alert policymakers on impending financial crises and enable them to take necessary pre-emptive measures to prevent the outbreak of such crises.

2. The 1997 Asian Financial Crisis

To recap, the 1997 Asian financial crisis first erupted in Thailand back in July 1997 when the Thai government announced that the country failed to defend

its depreciating currency despite having depleted almost all its international reserves. Subsequently, fears of collapse in other regional currencies were spread over to Thailand's neighbouring countries, resulting in simultaneous depreciation in regional currencies.

In Malaysia, acute currency speculation activities coupled with mass capital outflows had accelerated the ringgit's depreciation during the crisis period. Tightening monetary and fiscal policies that required huge payoffs in the future did not seem to have stabilized the currency. This left the Malaysian government no choice but to implement an unorthodox policy to regain independence in conducting its monetary policy. On September 1, 1998, Malaysia imposed a capital control and pegged the ringgit at 3.80 to the US dollar. The purpose of these unprecedented measures was to insulate the country from vulnerable external environment, and at the same time curb speculative attacks on its currency, hindering capital flight and undertaking financial system restructuring.

The capital control has in fact gradually restored stability in the foreign exchange market and financial system. Realizing the adverse effects of high funding cost, the government eased interest rates to an accommodative level in order to stimulate investment and consumption on one hand as well as to facilitate restructuring of the financial system on the other hand. At RM3.80 per US dollar, Malaysia has enjoyed uninterrupted trade surpluses since late 1998. The capital control measures were gradually removed in 2003 and the pegged exchange rate regime was eventually scrapped in July 2005.

Relative to other affected countries, Malaysia's macroeconomic fundamentals have been strong with the exception of the large current account deficit prior to the 1997 Asian financial crisis. Real Gross Domestic Product (GDP) grew at a healthy rate of above 9% in most of the 1990s while inflation was well contained in the region of 2.7% to 4.7%. The current account deficit was financed by a combination of capital inflows and foreign borrowings and did not seem to pose a threat to the economy as output was perceived to be sustainable at that point in time. However, excessive credit growth and over-investment in infrastructure and tangible assets raised concerns over an asset bubble, which was exacerbated by continuous capital inflows and financial liberalization.

3. Literature Review – Early Warning System for Financial Crises

Studies and research on financial crises gained momentum after the 1997 Asian financial crisis. The concept of early warning system (EWS) for financial crises was in fact introduced earlier, but only became popular and widely used after the 1997 Asian financial crisis. The objective of EWS is

to "gather" predictive powers of variables to form an integrated system with superior predictive power to forecast future financial crises.

Krugman (1979) developed the first theoretical model of balance-of-payments crisis where he argues that a crisis occurs when continuous deteriorating economic fundamentals become inconsistent with an attempt to fix the exchange rate. In Krugman's model, the crisis is due to soaring domestic credit to finance fiscal deficits or to bailout the banking system.

Similarly, Obstfeld (1984) demonstrated that in addition to the presence of arbitrage opportunities, balance-of-payments crises can also be purely self-fulfilling events. Speculative attacks will be launched on a particular currency when expectations of the eventual abandonment of a fixed exchange rate are inevitably gaining momentum even though the level of foreign exchange reserves is at a comfortable level. Speculation can never occur if market conditions are consistent with the unconditional and indefinite maintenance of the fixed exchange rate. His approach regards currency crises as shifts between different monetary policy equilibriums in response to self-fulfilling speculative attacks. This approach focuses on the contingent nature of government policies which may give rise to multiple equilibria and generate self-fulfilling crisis.

In their literature, Kaminsky, Lizondo and Reinhart (1997) developed a "signalling" early warning system for currency crises which involves monitoring the behaviour of a broad set of indicators as crises are usually preceded by abnormal movements of these indicators. The "signals" issued by the indicators are recorded once they exceed a certain threshold and will be used to estimate the probability of a crisis occurring within the next twenty-four months. Indicators that are proven to be useful in predicting crises are international reserves, real exchange rate, domestic credit, credit to public sector, domestic inflation, trade balance, export performance, money growth, real GDP growth and fiscal deficit.

Abiad (2003) presented a rather sophisticated two-stage Markov switching approach to account for dynamic behaviour of the indicators. The 12-month forecast time horizon model is estimated for five hardest hit Asian countries – Indonesia, Korea, Malaysia, Philippines and Thailand. A total of 22 indicators were classified into three categories and used for estimation. The results show that an indicator may be significant in a particular country model but may not be significant in other countries, largely due to varying economic fundamentals among the affected countries. In the case of Malaysia, six indicators were identified as significant in the country EWS model – real overvaluation, domestic credit growth, real GDP growth, real interest rate, London Inter-bank Overnight Rates (LIBOR) and the ratio of M2 to deposits.

4. Modelling Financial Crises

Generally, there are three methodologies used in modelling financial crises namely signalling method, probit/logit method and cross-country regression. In this paper, we adopted the logit method. This method allows us to unify the predictive powers of various economic variables to form a comprehensive EWS. Note that the logit is a model used for the prediction of the probability of occurrence of an event by fitting data to a logistic curve.

For a more systematic discussion, we divide the methodology of modelling into six basic steps:

a. ***Determine sample period***. In our case, the sample period ranges from January 1980 through December 2003. The monthly data were gathered from International Monetary Fund (IMF), Bank Negara Malaysia (BNM), Bloomberg and Department of Statistics Malaysia (DOSM).

b. ***Determine methodology***. Using the logit method, the probability of a crisis taking place at time t is hypothesized to be a function of a vector of indicators (Gujurati, 1995):

$$\Pr(y=1) = 1 - F(-x'\beta)$$

$$\Pr(y=0) = F(-x'\beta)$$

where F takes a real value and returns a value that lies between 0 and 1, β is a vector of unknown coefficients and $x'\beta$ is the probability distribution function. The estimated parameters are calculated using the method of maximum likelihood:

$$\ell(\beta) = \log L(\beta) = \sum_{i=0}^{n} y_i \log(1 - F(-x_i'\beta)) + (1 - y_i) \log F(-x_i'\beta)$$

which requires estimated parameters to be obtained via iterative solution. The error term distribution for the logit model is as follows:

$$\Pr(y_i = | x_i, \beta) = \frac{1 - e^{-x'\beta}}{1 + e^{-x'\beta}} = \frac{e^{x'\beta}}{1 + e^{x'\beta}}$$

The estimated coefficients from a binary cannot be interpreted as the marginal effect on the dependent variable. That is, the respective estimated coefficients do not imply the increase in the probability of a crisis given one unit increase in the corresponding explanatory variables (indicators). The marginal effect of x_i on the conditional probability is however given by:

$$\frac{\partial E(y|x,\beta)}{\partial x_i} = f(-x'\beta)\beta_i$$

where f is the density function related to F, β_i is weighted by f that depends on all regressors in x. The sign of β_i indicate the direction of the effect of a change in x_i. Positive values of β_i suggest that increasing x_i is poised to accelerate probability of a crisis and negative values of β_i indicates vice versa. Criteria for model evaluations include:

- Log likelihood. The maximized value of the log likelihood is function ℓ.
- Likelihood ratio (LR) statistic test. Tests the joint null hypothesis that all slope coefficients except constant are 0. It is analogous to the F-statistic and tests the overall significance of the model.
- Probability (LR stat). *P*-value of the LR test statistic.
- McFadden R-squared. Analog to normal R^2 in linear regression and always lies between 0 and 1.

c. ***Derive dependent variable***. We derived the dependent variable, Exchange Market Price Index (EMPI) using two economic variables – i) movement in exchange rate and ii) movement in foreign exchange reserves:

$$EMPI_t = \alpha \Delta ER_t + \beta \Delta R_t$$

where ΔER and ΔR are month-on-month change in both nominal exchange rate and foreign exchange reserves for period t while the parameters, α and β equal to inverse of the sample standard deviation of ΔER and ΔR, respectively.

d. ***Define financial crises***. We note that there is no single definition of financial crises. In our EWS, we used Caramazza, Ricci and Salgado's (2004) definition of a financial crisis as weighted average of exchange rate and reserve changes (EMPI) with a threshold of 1.645 times the pooled standard deviation plus the pooled mean. This means the dependent variable or the crisis variable is assigned the value of 1 if a country experiences crisis during a particular period t and 0 otherwise:

$$\begin{aligned} Crisis_t &= 1, \text{if } EMPI_t > \mu_{EMPI} + 1.645\sigma_{EMPI} \\ &= 0, \text{ otherwise} \end{aligned}$$

where μ_{EMPI} and σ_{EMPI} are the pooled mean and standard deviation of EMPI respectively.

We analyzed several definitions of financial crises and found this definition to be statistically acceptable and structurally sensible. As a consequence, only moderate to large changes are deemed crises. Clearly, we adopt the currency definition of crises as opposed to debt crises or banking crises, one reason being the need to warn of another, if any, crisis similar to the one in 1997.

Using this crisis definition, we identified nine financial crises throughout January 1980 to September 2008. Our results are also consistent with findings in Abiad (2003) and the Institute for International Economics (IIE) working paper. Although our model crises periods do not provide a one-on-one match with the other two studies, crises periods overlap and common time threads run through our findings rendering support for the study's results (see Table 1).

Table 1: Crisis identified in Malaysia

Abiad (2003)	IIE (2000)	Our Model
1978M10-1982M6	1995M7	1980M4
1985M1-1986M3	1997M8	1992M9
1992M12 -1994M1		1993M12
1997M7		1994M1
		1997M8-M10, M12
		1998M1

Source: Abiad (2003), IIE (2000). Authors model computed from statistics from BNM (1980-1998).

e. ***Identify and select economic variable***. Based on Kaminsky, Lizondo and Reinhart (1997), Abiad (2003) and subject to data availability, we identified 21 potential economic variables for modelling purpose. The final selection of variables for our model is made by using Abiad's (2003) general-to-specific approach. A bivariate model is thus estimated with a constant term and one independent variable at a time to obtain the sign, z-statistic and p-value for respective coefficients of the indicators.

In order to qualify for inclusion into the EWS, each of these economic variables is required to meet two criteria. Firstly, the estimated coefficients of these variables must posses either positive (+) or negative (-) sign that is in line with expectation. A positive sign implies that as the value of the variables grows, the probability of financial crises outbreak increases and vice versa. On the other hand, a negative sign implies that as the value of the indicator grows, the probability of financial crises outbreak decreases and vice versa. Secondly, the variables must be statistically significant at 5% significance level.

Out of the 21 variables identified, only four variables met the criteria and therefore qualified for inclusion into EWS. As shown in Table 2, the four variables are regional crisis dummy variable, current account balance, real exchange rate and money supply (M2) growth.

Table 2: Estimates of bivariate logit model

Indicator	Expected Sign	Coefficient	z-statistic	p-value
Regional crisis dummy	+	2.33	3.29	0.00
Current account balance	-	-0.00	-1.71	0.09
Current account balance/GDP	-	-7.92	-0.85	0.39
Export, growth	-	3.84	1.33	0.18
Real exchange rate	+	0.33	1.09	0.28
Reserve	-	-0.00	-3.46	0.00
Reserve, growth	-	38.06	4.31	0.00
Bank asset/GDP, growth	+	4.17	2.21	0.03
Domestic credit, growth	+	29.54	2.66	0.01
KLIBOR	+	0.16	1.14	0.25
M2, growth	+	96.97	4.12	0.00
M2/reserve	+	-0.69	-1.39	0.16
M2/reserve, growth	+	-38.21	-4.16	0.00
Real interest rate	+	0.11	1.30	0.19
US$/JPY	+	3.11	9.13	0.34
Fiscal balance	-	0.00	1.66	0.10
LIBOR	+	-0.18	-1.11	0.27
Inflation rate	+	57.32	0.71	0.48
Industrial production, growth	-	-2.18	-0.43	0.67
KLCI, growth	-	-2.23	-0.57	0.57
Real GDP, growth	-	-1.37	-0.28	0.78

Source: Computed from various issues compiled by DOSM (1980-2003) and BNM (1980-2003).

f. ***Performance evaluation***. We evaluate the performance of EWS from two angles – the conventional statistical approach and empirical approach. The conventional statistical approach is used to test the significance of independent variables and the model as a whole while the empirical approach or also known as noise-to-signal ratio is used to gauge the accuracy of the EWS in forecasting financial crises.

As shown in the statistical results in Table 3, it is evident that all the four independent variables are significant at 5% level and thus, explain 52% variation in the dependent variable. The model as a whole is also highly significant as reflected in the significant LR statistic. The coefficient for M2 growth is both large and significant, indicating that money growth has a critical role in explaining an impending crisis. Coefficients for the dummy and real exchange rate are moderately large and also significant indicating that contagion and swings in the exchange rate are important explanatory

Table 3: Estimated logit model

Crises =	-20.89 +	3.20 (RC) –	0.00 (CAB) +	150.49 (M2G) +	2.59 (RER)
	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)

Log likelihood	-19.139	Obs with Dep=0	278
LR statistic	41.757	Obs with Dep=1	9
Probability(LR stat)	0.000	Total obs	287
McFadden R-squared	0.522		

Note: p-values in parentheses.

Table 4: Early warning signals

Crisis Identified	Signals Sent?	Signal Date	No. of Signals Sent	Earliest Signal
1980M4	No	–		–
1992M9	Yes	1991M11	1	10 months before
1993M12	Yes	1993M9, M11	2	3 months before
1994M1	Yes	1993M9, M11, M12	3	4 months before
1997M8-M10, M12	Yes	1996M9-M12, 1997M4, M5, M7	7	11 months before
1998M1	Yes	1997M5, M7-M12	7	8 months before

Source: Computed from statistics compiled by BNM (1980-1998), IMF (1980-1998) and Bloomberg (1980-1998).

variables. While the current account balance has a low-valued coefficient, its significance suggests that its effects should not be ignored.

To evaluate the EWS using the noise-to-signal approach, a cutoff threshold of 3.1%, being the mean of forecast probabilities for the sample period (January 1980 to December 2003) was set for signal issuing purpose (see Table 4). A signal is regarded as a good signal if financial crises occur in the next twelve months while noise or false signals refer to signals that have been issued but financial crises do not ensue in the next twelve months. Our results show that a total of 40 signals were issued, of which 14 signals or 35% are good signals and the remaining 26 or 65% are noise. As such, this translates into a noise-to-signal ratio of 1.86 (see Table 5).

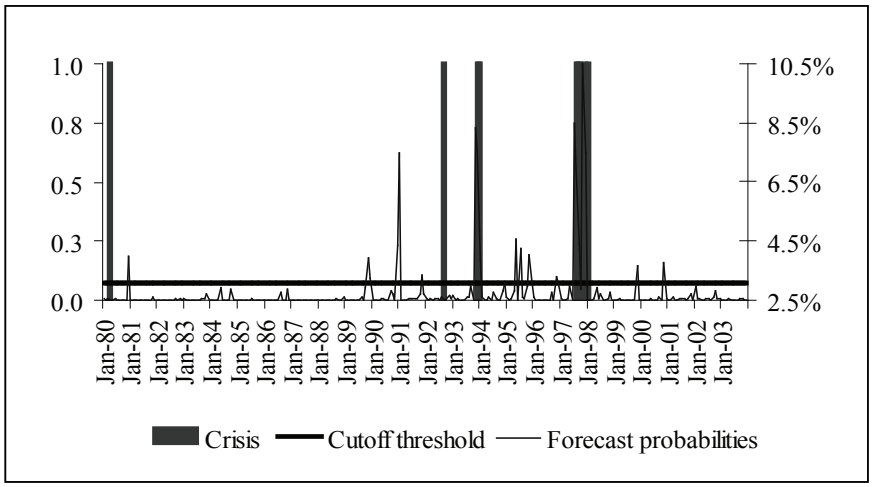
We also performed an out-of-sample test as it is a crucial step in testing the goodness-of-fit of an EWS. To do this, we restricted the sample period from January 1980 through December 1996 (see Figure 1).

Table 5: Noise-to-signal ratio

Cutoff Threshold	Total Early Warning Signal Issued	Signal	Noise	% Signal	% Noise	Noise-to-Signal
0.5%	87	24	63	27.59	72.41	2.63
1.0%	62	20	42	32.26	67.74	2.10
1.5%	52	18	34	34.62	65.38	1.89
2.0%	48	17	31	35.42	64.58	1.82
2.5%	43	15	28	34.88	65.12	1.87
3.0%	40	14	26	35.00	65.00	1.86
3.1%	40	14	26	35.00	65.00	1.86
3.5%	38	14	24	36.84	63.16	1.71
4.0%	34	13	21	38.24	61.76	1.62
4.5%	33	13	20	39.39	60.61	1.54
5.0%	30	12	18	40.00	60.00	1.50
5.5%	28	12	16	42.86	57.14	1.33
6.0%	23	10	13	43.48	56.52	1.30
6.5%	23	10	13	43.48	56.52	1.30
7.0%	22	10	12	45.45	54.55	1.20

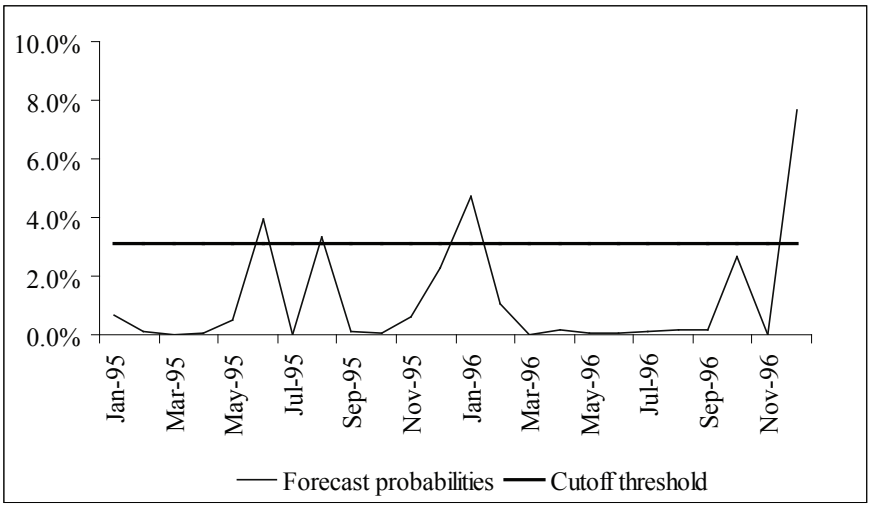
Source: Computed from statistics compiled by BNM (1980-2003), IMF (1980-2003) and Bloomberg (1980-2003).

Figure 1: Crisis, cut-off threshold and forecast probabilities



Source: Compiled from statistics gathered from BNM (1980-2003), IMF (1980-2003) and Bloomberg (1980-2003).

Figure 2: 3.1% cut-off threshold and forecast probabilities (out-of-sample)



Source: Estimated from statistics gathered from BNM (1995-1996), IMF (1995-1996) and Bloomberg (1995-1996).

It is worth noting that prior to the 1997 Asian financial crisis, none of the independent variables are significant at 5% level with the exception of M2 growth. This suggests that, firstly, M2 growth is a consistent variable in predicting financial crises and secondly, the regional crisis dummy variable, current account balance and real exchange rate contributed to the onset of the crisis. The results are intuitively convincing given that contagion effect, deteriorating current account and overvalued exchange rate were deemed the main culprits of the 1997 Asian financial crisis. It should be noted that the model accurately issued a signal in December 1996 for impending financial crises which eventually erupted in August 1997 (see Figure 2).

5. Conclusion

Both theoretical, and to a certain extent empirical studies on various forms of crises are traceable back to the 1970s. Empirical studies on crises and subsequent establishment of EWS to predict crises only gained grounds over the past decade particularly in the post-1997 Asian financial crisis.

The objective of this paper is to develop an early warning system or EWS for Malaysia to predict the 1997 Asian financial crisis and future financial crises. A group of variables were identified and tested for inclusion into the EWS. Variables included in the EWS are statistically significant and possess predictive power and capability to predict financial crises. The purpose of the

EWS is to alert policymakers and enable them to take pre-emptive actions prior to the outbreak of crises. Using EMPI as suggested by Caramazza, Ricci and Salgado (2004), we defined a particular month as a crisis month when EMPI exceeds 1.645 standard deviation of its sample mean. The EMPI is then transformed into a binary dependent variable where crisis months take the value of 1 or 0 for non-crisis or tranquil months.

Using the logit model, the binary dependent variable was initially estimated against 15 correctly signed variables but only four variables, namely regional crisis dummy, current account balance, M2 growth and real exchange rate were found significant in predicting a crisis. A model consisting of these four variables was subsequently formed to forecast the probability of a crisis. Based on the forecast probabilities, the cut-off threshold is pegged at 3.1%. At 3.1% cut-off threshold, the model successfully issued at least one early warning signal prior to eight crisis periods (except April 1980 which falls out of our sample range) in the sample within a 12-month forecast time horizon. A total of forty early warning signals were issued of which 35% and 65% are good and bad signals respectively, associated with a noise-to-signal ratio of 1.86. The out-of-sample performance evaluation was positive in the sense that all crises were correctly called with at least one early warning signal issued within the 12-month forecast time horizon.

Findings from in-sample and out-of-sample performance evaluations convey an important message. The in-sample performance evaluation shows that all the four variables – regional crisis dummy, current account balance, M2 growth and real exchange rate are significant in explaining the 1997 Asian financial crisis. In contrast, the out-of-sample performance evaluation suggests that other than M2 growth, none of the three variables are significant. The results suggest that in addition to excessive M2 growth, the presence of deteriorating current account, spill-over effect from neighbouring countries via trade and financial linkages and overvalued exchange rate have in fact contributed to the 1997 Asian financial crisis.

As pointed out in other literature, EWS is a country-specific model. Variables that are significant in predicting crisis for a country may turn out insignificant for another country. In other words, an EWS that performs well for one country may not even be applicable to other countries. This is true as each country has its uniqueness in economic fundamentals, institutional arrangements, level of integration with world markets and, more subjectively, political climate and authorities' expectations toward macroeconomic policies.

No doubt the performance of EWS can be enhanced by incorporating more variables with predictive powers. However, it is also widely agreed among analysts that no matter how good an EWS is, it will not be able to predict a crisis with a high degree of accuracy. Therefore, EWS should be

treated as a useful supplementary tool to policymakers' existing forecasting tools in projecting financial crises and to assess a country's vulnerability rather than an exclusive tool for crisis prediction. Therefore, EWS should be used together with other predictive models to forecast financial crises.

Finally, crises are likely containable through cooperation among countries via the establishment of international agencies and/or information sharing mechanisms. This study advocates that a regional joint monitoring system is set up to track capital flows which can be incorporated as part of EWS to improve its accuracy in anticipating crisis.

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