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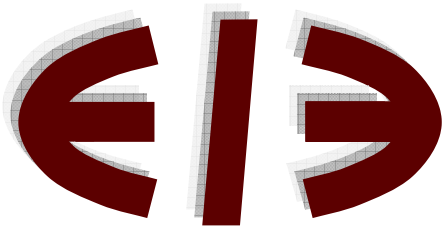

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1 Introduction

The Asian financial crisis broke out in Thailand in July 1997, and rapidly spread throughout the neighboring countries. The crisis severely affected several Asian countries, like Thailand, Indonesia, Malaysia and South Korea which not only had a sharp depreciation of their currencies but also had a negative economic growth in 1998 (see Table 1. Even Japan, having maintained stable growth since World War II, suffered from negative 2.9 percent growth in GDP in 1998. As for Taiwan, the economic growth rate dropped from 6.8 percent in 1997 to 4.8 percent in 1998.

The Asian financial crisis has attracted a great deal of attention of economists. Corsetti, Pesenti and Roubini (1999), Flood and Marion (1998), Krugman (1998), Kaminsky and Reinhart (1997), Radelet and Sachs (1998), Sachs, Tornell and Velasco (1996) all analyze the causes and impact of the crisis. Cambridge Journal of Economics devoted an entire recent issue (vol 22, no 6) to Asian financial crisis where various papers examine the entire South Asia region and all the countries in trouble. Hu, Lin, Shea and Wu (1999) focused on the case of Taiwan.

An important question then arises? Is it possible to predict next financial crisis? If yes, then what are the predictors? The answer lies in combined usage of economic theory and econometric methods. By using the economic theory, one can locate possible potential crisis predictors whereas appropriate econometric models can pinpoint effective ones.

As was pointed out by Kaminsky, Lizondo and Reinhart (1997), there are basically four approaches to formulate an empirical crisis early warning model. The first approach provides only a qualitative discussion of the causes and developments for financial crisis but give no formal tests. For example, see Kuo and Liu (1998). The second one analyzes the stylized facts before and after the crisis and then use parametric or nonparametric tests to compare the cases with and without crises. The third approach employs the probit/logit model where binary variable of crisis indicator is regressed against predictors as explanatory variables. Blanco and Garber (1986) as well as Sachs, Tornell and Velasco (1997) are two examples. The final approach is the signaling approach. Deviation of explanatory variables from normal value over a predetermined threshold before the crisis are taken as a signal for a crisis. Then the performance of each individual crisis indicator or combined indicators to predict crisis can be evaluated by using the 2x2 tables and other statistics. Kaminsky and Reinhart (1996) belongs to this category.

Most of these models rely on conventional t-statistics to decide which variables to include in the early warning model. However, it is well known that the correlation among the candidate explanatory variables makes the final selection result sensitive to the orders that each variable enters the equation. Some others use criterion like AIC, C_p and BIC to select sub-models. The computation burden could be prohibitive when number of candidate variables is large. To solve the difficulty, the backward or forward selection procedures have been introduced. It is not uncommon

to find out that these two procedures suggest different models.

By proposing the fifth approach, we suggest using the Stochastic Search Variable Selection (OSES) developed by George and McCulloch (1993) to identify the crisis predictors. As is suggested by the name, SSVS stochastically searches for practically significant variables. Each variable coefficient is assumed to come from a mixture of two normal variates with respectively large and small variances. For the former case, this variable is considered as insignificant and should be excluded from the model whereas for the latter, this variable is significant and should be included in the model. By using Gibbs sampler to simulate a correlated sample and 'best model' is identified as the one with highest frequency in the sample.

SSVS is not affected by the ordering of the candidate variables and is particularly effective when the sample size is much smaller than the number of all possible models. It has been successfully applied to the case with huge number of predictors. George and McCulloch (1996) compares various hierarchical mixture prior formulations of variable selection uncertainty in normal linear regression model. George, McCulloch and Tsay (1996) extended SSVS to generalized linear model like probit model and allowed individual observation to choose different model.

The rest of the paper is organized as follows. Section 2 examines the possible predictors of financial crisis from the viewpoint of economic theory. Section 3 introduces the econometric methods for variable selection used in this model. Empirical results are analyzed in section 4 and section 5 concludes.

2 Economic Aspects of the Financial Crisis

As discussed in Merton (1998), the current Asian financial crisis is a combination of three interrelated crises: the currency crisis, the interest rate crisis and the credit risk crisis. According to Flood and Marion (1999), the literature concerning financial crisis can be distinguished into two generations of models. Models of the first generation emphasize the deviation of government policy from the objectives that it tries to pursue. For example, in a fixed exchange change rate regime, the government adopts a policy that contributes to current account deficit and depletion of foreign exchange reserves. Second-generation models stress the self-fulfilling expectations that arise from the weakness in economic fundamentals. The Asian financial crisis can be explained partially by the first-generation models and partially by the second-generation models. These countries pegged or linked closely their currencies to the U.S. dollar. While they had high savings rates, the governments maintained expansionary economic policies that led to excess investment and consistent current account deficits. From 1990-1997, the current account deficits as a percentage of GDP were on average of 1.36% for Korea, 2.58% for Indonesia, 5.514% for Malaysia, 4.3% for Philip-

pines and 6.5% for Thailand respectively. The economics were helped initially by the depreciation of the U.S. dollar against the Japanese Yen from 1990 until 1994. But in 1994 when the Chinese Renminbi devalued against the U.S. dollar and the value of the U.S. dollar began to rise against the Japanese Yen, the competitiveness of these countries began to fall, and the current account deficits were no longer sustainable. When doubts were raised about the governments' ability to maintain currency value, speculators began to attack the currencies and expectations became self-fulfilling. Thailand was the first to fall victim to speculative attacks, and soon Malaysia, Indonesia and South Korea followed. Weak financial structures also reduced the governments' abilities to respond to the crisis. As noted in Fischer (1998), the markets treated countries in better shape more kindly than those in worse shape.

There is a long list of potential variables causing the Asian financial crisis, especially when those factors concerning self-fulfilling and contagious effects are taken into account. However, some variables are not directly observable and using poor proxy variables could introduce significant measurement error and cause serious problem for econometric analysis. Thus, our analysis focus on analysis of market fundamentals. Existing literature on financial crisis often enlist many possible factors but fail to identify the key ones. For example, from Tables 2 to 6, it can be seen that there have been existing current account deficit since 1990 in those countries severely affected in the crisis. Thus, some economists consider prolonged current account deficit in an important cause of financial crisis. In addition, insufficient foreign exchange reserve and government budget deficit are also considered as possible causes of financial crisis.

The variables considered in this paper are inflation rate, ratio of government budget deficit to GDP, growth rate of money supply as measure by M_2, ratio of foreign reserve to GDP and ratio of current account to GDP.

In view of increasing sample size and efficiency of analysis, we use the quarterly data. By so doing we pay the price of missing some potential variables, such as ratio of interest payment to GDP, and short-term debt to GDP since they are only available in annual frequency.

3 Econometric methodology

3.1 Indicators of financial crisis

The index of crisis can be defined either as a continuous variable or as a binary one. For the former, it is often formulated in terms of variability of exchange rate and foreign exchange reserve. As for the latter, binary index is set to be one if some key variable exceeds the predetermined threshold and zero otherwise.

In this paper, we analyze three crisis indicators. The first two indicators are market pressure

index defined in term of nominal and real exchange rates respectively.

$$\begin{aligned} I_1 &= \Delta e_t/\sigma_{\Delta e_t} - \Delta r_t/\sigma_{\Delta r_t} \\ I_2 &= \Delta e_t^r/\sigma_{\Delta e_t^r} - \Delta r_t/\sigma_{\Delta r_t} \end{aligned}$$

where e_t, e_t^r, r_t are respectively the nominal exchange rate, real exchange rate and foreign exchange reserve and σ stands for standard deviation. The third indicator is defined to be one if deviation of I_1 exceeds 1.5 standard deviation of I_1 computed over the whole sample.

$$I_3 = \{ \begin{array}{ll} 1 & \text{if } I_1 > 1.5\sigma \\ 0 & \text{if } I_1 \leq 1.5\sigma \end{array}$$

It is worth noting that even when e_t and r_t have been standardized respectively by their standard deviations, number of components included in the crisis index will affect its scale. Thus, the threshold value of the index still needs to be further standardized.

While abrupt changes of exchange rate signals the outbreak of financial crisis, preventive measures exhausting foreign reserves to protect exchange rate can often result in serious effects on the economy. This justifies including foreign reserve as a component of crisis index while sometimes interest rates is also included. See Eichengreen, Rose and Wyplosz (1995) and Kaminsky, Lizondo and Reinhart (1997) for further details.

3.2 Stochastic Search Variable Selection

Consider the standard linear regression model

$$Y_t \sim N(X_t'\beta, \sigma^2) \tag{1}$$

where X_t, β are two kx1 vectors, Y_t the explained variable, and σ^2 variance of the Y_t. The SSVS puts a hierarchical mixture prior on the regression coefficients for model selection. Each component β_i of β is modeled as realization from a scale mixture of two normal distributions:

$$\beta_i|\gamma_j \sim (1-\gamma_j)N(0,\tau_j^2) + \gamma_j N(0, c_j^2\tau_j^2) \tag{2}$$

$$P[\gamma_j = 1] = 1 - P[\gamma_j = 0] = w_j \tag{3}$$

(β_j, γ_j) are usually assumed to be independent of each other though more general case is possible.

To close the model, one needs to specify the prior for σ^2

$$\sigma^2|\gamma \sim IG(v_r/2, v_\gamma\lambda_\gamma/2) \tag{4}$$

or equivalently,

$$v_\gamma \lambda_\gamma / \sigma^2 \sim \chi^2_{v_\gamma} \tag{5}$$

where IG is inverse Gamma and $\chi^2_{v_r}$ chi-square with degree of freedom v_r. $\gamma_i' s$ is assumed to be independent with marginal distribution

$$f(\gamma) = \Pi p_i^{\gamma_i} (1 - p_i)^{(1-\gamma_i)} \tag{6}$$

The hyper parameters τ_j and c_j are respecified to be small and large respectively so that when $\gamma_j = 0, \beta_j \sim N(0, \tau_j^2), \beta_j$ is so small and it would suffice to exclude x_j from the model. When $\gamma_j = 1, \beta_j \sim N(0, c_j^2 \tau_j^2)$, has high probability to be large and is better to leave x_j in the model.

SSVS uses the Gibbs Sampler to compute the joint posterior by drawing sequentially from the following sets of conditionals:

$$\beta | \gamma, \sigma, y; \sigma | \beta, y; \gamma_j | \gamma_{(-j)}, \beta \tag{7}$$

where $\gamma_{(-j)} = (\gamma_1, \cdots, \gamma_{j-1}, \gamma_{j+1}, \cdots, \gamma_p)$.

3.3 Computation procedures

The computation procedure is as follows.

1. Compute OLS for full model and the variance of estimated residual to initialize the iteration process.

2. Update $\sigma^2 (X'X + \sigma^2 D_r^{-2}) X'Y$ to draw

   $$P(\beta | \sigma^2, \gamma, Y) = N((X'X + \sigma^2 D_\gamma^{-2} X'Y, \sigma^2 (X'X + \sigma^2 D_\gamma^{-2})^{-1})$$

   where D_γ is a diagonal matrix of $(1 - \gamma_i)\tau_i + \gamma_i c_i \tau_i$. Cholesky decomposition is needed in this step.

3. Generate multivariate normal random variate

   $$B_n \sim N[(X'X + \sigma^2 D_r^{-2}) X'y, \sigma^2 (X'X + \sigma^2 D_r^{-2})]$$

4. Update σ^2

   $$P(\sigma^{-2} | \beta, Y) = Ga(\frac{n + \nu}{2}, \frac{|Y - X'\beta|^2 + \nu\lambda}{2})$$

5. Update γ from Bernoulli distribution

$$P(\gamma_i|\beta, \gamma_{-i}) = \frac{1}{a+b}$$

where

$$\begin{aligned} a &= P(\beta|\gamma_{-i}, \gamma_i = 1)P(\gamma_{-i}, \gamma_i = 1) \\ b &= P(\beta|\gamma_{-i}, \gamma_i = 0)P(\gamma_{-i}, \gamma_i = 0) \end{aligned}$$

Repeat steps 3 to 5 until it converges.

4 Empirical results

All data are quarterly data from the first quarter of 1987 to the fourth quarter of 1997 taken from International Financial Statistics. Indonesia has only annual GDP and has no quarterly GDP. We use linear extrapolation to compute quarterly data. This is a simple way, not satisfactory but is the best we can do. Our experience shows that including quarterly GDP as possible explanatory variable would lead to no convergence as number of repetitions increases. However, when quarterly GDP is only used to compute various ratios, convergence is achieved.

Thailand, Malaysia, Indonesia, Philippines, South Korea and Taiwan are included in the model selection analysis. All these Asian countries are affected by the financial crisis at varying degree. The model selection results are reported in Table 7. The three highest frequency of the selected models are put at the second column of each panel. Consider the fact that for 6 variables as in our case, the number of total possible sub-models is 64. Thus the fact that all our top models have selected frequency more than 3% seems to support the use of SSVS.

From the table, we observe that using all three crisis index indicators leads to identical result by selecting the same two crisis predictors, annual growth rate of M_2, and ratio of government debt to GDP. It is worth noting that while the ratio of total foreign debt to GDP and the ratio of current account to GDP have sometimes been considered as important variables, they are not selected by SSVS. The ratio of short term debt to total foreign debt might be relevant but is not considered here due to lack of quarterly data.

While our empirical results appears puzzling at first glance, it provides an insight on financial crisis from different perspective. The M_2 growth rate and ratio of government debt to GDP can be viewed as indicators of monetary and fiscal policies respectively. The implementation of monetary and fiscal policies will affect aggregate demand and then prices. In turn, change in prices result in

change of term of trade, trade surplus or deficit, and exchange rate. This explains why the growth rate of M_2 and ratio of government debt to GDP are more fundamental than other variables and are selected by SSVS. Furthermore, it is worth noting that different governments can adopt different means to implement the monetary and fiscal policies and the resulting effects could vary. This is an important topic but is not pursued here due to limitation of data availability.

Our empirical findings seem to provide a supporting evidence for Krugman (1979), who argues that it is the continuous deterioration of macroeconomic fundamentals that causes the financial crisis. Our empirical analysis also indicates that inappropriate monetary and fiscal policies should be held responsible for financial crisis. However, it is worth mentioning that we do not take into account the self-fulfilling and contagious effects as pointed out in Calvo and Vegh (1999), Sachs, Tornell and Velasco (1996) and Drazen (1996). Thus, the effect of non-macroeconomic fundamentals cannot be excluded.

5 Conclusions

Economists have proposed different aspects on the causes of the financial crisis and this paper concentrates on market fundamentals. By employing SSVS method, we conclude that annual growth rate of money supply, M_2, and the ratio of government debt to GDP are promising predictors for financial crisis. It is worth mentioning that the frequently mentioned factors, such as ratio of total foreign reserve to GDP and the ratio of current deficit to GDP are not selected by our analysis. Our empirical analysis implies that monetary and fiscal policy play a crucial role in exploring the Asian financial crisis.

While there are few Bayesian analysis on financial crisis, our analysis is by no means complete. We have not yet considered contagion effect which is an important aspect of financial crisis. Also, the out-sample forecasting performance of selected crisis predictor have yet to be studied.

A detailed comparison of our predictors with those in the literature would be interesting and deserve further investigation. In addition, it would be interesting to apply the same analysis to more countries and to higher frequency data, such as monthly data.

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Table 1: Exchange rates

	Thailand	Malaysia	Indonesia	Philippines	S. Korea
1990	25.58	2.70	1842.81	24.31	707.76
1991	25.51	2.75	1950.32	27.48	733.35
1992	25.40	2.55	2029.92	25.51	780.65
1993	25.32	2.57	2087.10	27.12	802.67
1994	25.15	2.62	2160.75	26.42	803.45
1995	24.91	2.50	2248.61	25.71	771.27
1996	25.34	2.52	2342.30	26.22	804.45
1997	31.36	2.81	2909.38	29.47	951.29
1998*	43.35	3.96	9929.47	40.28	1471.66
	China	Hong Kong	Singapore	Taiwan	Japan
1990	4.78	7.79	1.81	26.89	144.79
1991	5.32	7.77	1.73	26.81	134.71
1992	5.52	7.74	1.63	25.16	126.65
1993	5.76	7.74	1.62	26.39	111.20
1994	8.62	7.73	1.53	26.46	102.21
1995	8.35	7.74	1.42	26.48	94.06
1996	8.31	7.73	1.41	27.46	108.78
1997	8.29	7.74	1.48	28.70	120.99
1998*	8.28	7.75	1.69	33.64	133.16

* Up to July, 1998

Source: IMF, International Financial Statistics

Table 2 :Indonesia

Year	EDT/GNP	INT/GNP	RES/EDT	STD/EDT	DCPI	DM2	BP/GDP	BD/GDP	DGDP
1987	73.0	4.1	13.5	12.1	9.2	22.5	-2.8	0.4	12.0
1988	63.9	3.9	11.7	12.4	8.0	23.9	-1.7	1.6	11.5
1989	61.3	4.0	11.3	13.4	6.5	39.8	-1.2	0.2	6.2
1990	64.0	3.6	12.4	15.9	7.8	44.2	-2.8	-0.7	9.0
1991	64.9	3.8	13.0	18.0	9.4	17.0	-3.7	-0.9	8.3
1992	66.2	3.4	13.0	20.5	7.6	20.2	-2.0	-0.3	5.1
1993	58.7	3.3	14.0	20.2	9.6	22.0	-1.2	0.1	5.8
1994	63.3	3.1	12.4	18.0	8.5	20.2	-1.6	0.6	8.6
1995	64.6	3.2	12.0	20.9	9.5	27.6	-3.2	0.5	8.9
1996	58.3	3.0	15.0	25.0	7.9	29.6	-3.4	0.0	7.1
1997	65.3	3.2	12.8	26.4	6.6	27.7	-2.7	-0.5	5.5

Source: World Debt Table, External Financing for Developing Countries, World Bank, 1996, 1999

Table 3 : S.Korea

Year	EDT/GNP	INT/GNP	RES/EDT	STD/EDT	DCPI	DM2	BP/GDP	BD/GDP	DGDP
1987	29.8	2.4	9.4	23.3	3	19.1	7.5	-4.9	4.9
1988	19.9	1.6	34.9	27.4	7.2	21.5	8.1	-7	5.8
1989	14.9	1.3	46.8	29.9	5.6	19.8	2.4	-5.6	7.5
1990	18.7	1	31.8	48.5	8.6	17.2	-0.9	-5	7.4
1991	18.4	0.9	25.8	46.8	9.3	21.9	-3	-4.4	6.4
1992	18.8	0.9	30	43.9	6.2	14.9	-1.3	-0.4	7.2
1993	19	0.9	32.4	44.3	4.8	16.6	-0.3	-0.4	7.3
1994	24.9	1	27.4	42.7	6.2	18.7	-1	1	7.5
1995	25.4	1.5	28.5	51.3	4.5	15.6	-1.8	0.4	8.2
1996	27.4	1.5	25.9	49.9	4.9	15.8	-4.8	0.8	8
1997	32.8	1.6	14.3	37.5	4.5	14.7	-2	-0.2	4.6

Source: World Debt Table, External Financing for Developing Countries, World Bank, 1996, 1999

Table 4: Malaysia

Year	EDT/GNP	INT/GNP	RES/EDT	STD/EDT	DCPI	DM2	BP/GDP	BD/GDP	DGDP
1987	77.1	5.6	37.5	10.3	2	11.2	8.3	-8.9	5.4
1988	56.7	5	40.3	8.6	2	6.7	5.2	-4.3	8.9
1989	45.6	3.7	53.7	14	2.8	16.2	-0.6	-5.2	8.7
1990	37.5	2.9	69.5	12.4	2.7	12.8	-2.1	-4.8	9.8
1991	38.3	2.4	68.6	12.1	4.4	14.5	-8.9	-4.7	8.6
1992	36.3	2	90	18.2	4.7	19.1	-3.7	-0.8	7.8
1993	42.9	2.2	107.8	26.6	3.6	22.1	-4.7	0.2	8.3
1994	44	2.1	86.8	20.4	3.7	14.7	-6.2	2.3	9.2
1995	41.3	1.9	71.9	21.2	3.4	24	-8.4	0.9	9.5
1996	42	2.2	70.3	27.9	3.5	20.9	-5	0.7	8.6
1997	50.5	3	45.5	31.6	4	18.5	-5.3	1.8	7.5

Source: World Debt Table, External Financing for Developing Countries, World Bank, 1996, 1999

Table 5: Philippines

Year	EDT/GNP	INT/GNP	RES/EDT	STD/EDT	DCPI	DM2	BP/GDP	BD/GDP	DGDP
1987	91.3	5.5	7.8	12.7	3.8	13.5	-1.3	-3.7	4.8
1988	77.3	5.3	7.5	13.3	8.8	23.7	-1	-3.8	6.3
1989	68.3	5.1	8.3	13.8	10.6	28.2	-3.4	-1.7	6.1
1990	69.4	4	6.7	14.5	14.2	15.3	-6.1	-3.9	2.4
1991	71.1	3.6	13.7	15.2	18.7	15.7	-2.3	-2.6	-1
1992	61.2	2.8	16.2	15.9	8.9	11	-1.6	-1.2	0.3
1993	64.9	3.9	16.5	14	7.6	24.6	-5.5	-1.5	2.1
1994	59.9	3.2	18.1	14.5	9	26.8	-4.6	1	4.4
1995	49.6	3	20.5	14	8.1	25.2	-4.4	0.6	4.8
1996	46.5	2.5	29.3	19.9	8.4	15.8	-4.7	0.3	5.7
1997	53	2.6	19.2	26	5.1	20.5	-5.2	0.1	5.1

Source: World Debt Table, External Financing for Developing Countries, World Bank, 1996, 1999

Table 6: Thailand

Year	EDT/GNP	INT/GNP	RES/EDT	STD/EDT	DCPI	DM2	BP/GDP	BD/GDP	DGDP
1987	40.9	2.7	25.6	13.1	2.6	20.2	-0.8	-0.7	9.5
1988	35.7	2.5	32.8	22.1	3.8	18.2	-2.8	2.4	13.2
1989	32.9	2.3	44.8	26.1	5.4	26.2	-3.6	3.7	12
1990	33.4	2.4	50.6	29.5	5.9	26.7	-8.5	5.2	10
1991	39	2.7	48.7	33.1	5.7	19.8	-7.7	6.4	7.5
1992	38.4	2.5	50.6	35.2	4.1	15.6	-5.7	2.8	8.1
1993	42.9	1.8	48.3	42.9	3.3	18.4	-5.1	2.1	8.7
1994	46.4	1.9	46.2	44.5	5.2	12.9	-5.4	2.7	8.6
1995	50.5	2.5	44.5	49.5	5.8	17	-7.9	3	8.8
1996	51.3	3	42.6	41.5	5.9	12.6	-7.9	0.9	5.5
1997	62.6	3.7	28.8	37.3	5.6	16.4	-4	-0.9	-0.4

Source: World Debt Table, External Financing for Developing Countries, World Bank, 1996, 1999

Table 7: SSVS Model selection results

Index 1		Index 2		Index 3	
Model variables	Selection percentage	Model variables	Selection percentage	Model variables	Selection percentage
3,4	0.0341	3,4	0.0343	3,4	0.0344
2,4,5,6	0.0338	5	0.0340	5	0.0340
3	0.0328	2,4,5	0.0340	2,4,5	0.0340

Selection percentage for any specific model is measured as the ratio of number of replications such that the underlying model is chosen to total number of replications.

X_1: Constant

X_2: CPI(Rate)

X_3: M_2(Rate)

X_4: Debt/GDP

X_5: Balance/GDP

X_6: Reserve/GDP