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ECONOMETRIC APPROACH TO EARLY WARNINGS OF VULNERABILITY IN THE BANKING SYSTEM AND CURRENCY MARKETS FOR HONG KONG AND OTHER EMEAP ECONOMIES

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Abstract

This study adopts an econometric approach to develop an early warning system of the vulnerability in the banking system and currency markets for the 11 EMEAP economies over the period from1990 to 2008. We identify a set of leading indicators of banking distress and currency pressure and investigate the causal and contemporaneous linkages between them by using separate panel probit models and a simultaneous probit equation system. Asset-price misalignments, default risk of commercial banks and the non-financial corporate sector, and growth of real credit to the private sector are found to be significant leading indicators for both banking distress and currency pressure. Economic growth, inflation and the ratio of short-term external debt to international reserves are found to be important determinants of banking distress, whereas growth of M2 relative to international reserves, total trade balance over GDP, real effective exchange rate over-valuation and trade integration with China are identified to be crucial indicators of currency pressure. Currency market pressure is shown to have strong leading and contemporaneous impacts on banking distress for the EMEAP economies but not vice versa. These findings imply that the policy measures aimed at sustaining exchange rate stability will have the additional benefit of lowering the likelihood of banking distress in the region. Lastly, China is found to play a stabilising role in the region, i.e. the greater the trade with China, the lower the chance of experiencing currency pressure.

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EXECUTIVE SUMMARY:

- *Amid the wide-spread financial turmoil that originated in the US sub-prime mortgage market in the second half of 2007, early warning systems of financial crises have gained renewed attention to serve as a safeguard to predict and prevent the occurrence of crises.*

- *Employing econometric models on a quarterly panel data set of the 11 EMEAP economies for the period from the second quarter of 1990 to the third quarter of 2008, this study develops an early warning system for banking distress and currency pressure by identifying a set of leading indicators and investigating the contemporaneous and causal linkages between these two types of crises.*

- *Our results suggest that asset-price bubbles in property and stock markets, lending boom and deterioration in the financial health of commercial banks and non-financial corporations are important leading indicators of both banking distress and currency pressure. In addition, slowdown of economic growth, high inflation and large ratio of external liabilities to reserves are useful indicators of banking distress, whereas growth of M2 over foreign reserves, misalignment of the real effective exchange rate, total trade balance as a share of GDP and trade integration with China help to predict currency pressure.*

- *For the EMEAP economies, the economy-specific characteristics contribute to explaining the banking distress but not the currency pressure. Moreover, having currency pressure contemporaneously or previously will increase the probability of having banking distress but not the other way round. This implies that measures introduced to promote exchange-rate stability will also stabilise the banking system in the EMEAP region. Lastly, China is found to play a stabilising role in the region, the greater the merchandised trade with China the lower the chance of experiencing currency pressure.*

- *Our models generate out-sample warning signals for the 11 economies from the last quarter of 2008 to the second quarter of 2009. In respect of banking distress, our model gives a positive signal for Australia in each of the three quarters, a positive signal for Korea in the first two quarters of 2009, and a positive signal for Singapore in the second quarter of 2009. Regarding currency pressure, Australia is the only economy for which a positive signal is raised in the last quarter of 2008.*

I. INTRODUCTION

The current global financial crisis originated in the United States in the second half of 2007 has spread out to many other economies. According to the International Monetary Fund (IMF), several emerging market economies, including Hungary, Ukraine, Latvia and Iceland, have obtained emergency financial assistance to restore stability and confidence in their banking systems and currency markets. The Bank of Korea entered into an US dollar swap agreement with the US Federal Reserve to alleviate the shortage of external funding to its banking system in late 2008. Monitoring and predicting financial crises have therefore become important concerns of the international community and policymakers again.

Banking and currency crises are not new phenomena and they happen from time to time. The Asian financial crisis in the late 1990s was a crisis episode in which several economies in the region suffered from banking and currency crises at about the same time. While financial market integration was not the major cause of the crisis, it did play a role in explaining the joint occurrence of banking distress and currency crises. In face of the US-originated financial turmoil in the second half of 2007 with even more integrated financial markets across the world, the following questions arise naturally and are addressed in this study: "Will the Asian economies suffer again from the twin crises (i.e. joint occurrence of banking and currency crises)?" and "Can the understanding of the previous twin crises helps prevent and predict it in face of current turmoil?"

This study applies an econometric approach to develop an early warning system of the vulnerability in the banking system and currency markets for the 11 EMEAP economies.[2] A similar study was carried out by Wong et al. (2007) on the development of an early warning system of banking distress in these 11 economies. Unlike most previous empirical studies that use static probit models on pooled data, we model the separate and joint occurrence of banking and currency crises for the 11 economies with individual and simultaneous probit models on a set of quarterly (unbalanced) panel data from 1990 Q2 to 2008 Q3. In these models, we examine the predictive power of several macro variables, such as economic growth, real private credit growth, real exchange-rate deviation, asset price gaps, growth of money over international reserves, and a few financial variables, such as commercial bank default probability and non-financial company default probability. In addition, we assess the contemporaneous interrelationship between currency crises and banking distress by estimating a simultaneous probit model system. The use of quarterly data instead of annual data makes the early warning system react in a more timely fashion to the changes of macro and financial conditions.

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[2] The EMEAP (Executives' Meeting of East Asia-Pacific Central Banks) comprises Australia, Mainland China, Hong Kong (of China), Indonesia, Japan, Korea, Malaysia, New Zealand, the Philippines, Singapore and Thailand.

The rest of the paper is organised as follows. Section II briefly reviews the empirical literature on the early warning system of banking and currency crises. Section III describes the probit model methodology and estimation methods. A description of the data set used in this paper and the definition of banking and currency crises are presented in Section IV. Section V delineates the estimation results and discusses the application of the empirical results as early warning signals, including out-sample predictions. Section VI presents some concluding remarks.

II. RELATED LITERATURE

There is ample literature on the theory and empirics of the twin crises since the Asian financial crisis. However, the causal linkage between the two types of crisis can run in both directions. In theory, a currency pressure will induce a severe deterioration in the balance sheets of banks and trigger a banking distress if the banking sector already has high proportion of foreign currency denominated liabilities. On the other hand, a banking distress can lead to speculative attacks of domestic currency if speculators anticipate the trade-off between keeping the exchange rate from devaluation and bailing out the troubled banking system. In addition, some literature does not distinguish between the crises and considers them as driven by underlying common factors such as illiquidity (Chang and Velasco, 1999) and over-borrowing (McKinnon and Pill, 1997 and 1998).

In the empirical literature, there are two main approaches to detect vulnerability in the banking system and currency markets, namely the signal extraction approach and the econometric approach.

The seminal work by Kaminsky and Reinhart (1999) utilises a signal extraction approach to detect banking and currency crises. The signal extraction approach uses relevant indicators to indicate a signal of crisis or an occurrence of distress if the value of an indicator exceeds a threshold. The threshold value of an indicator is selected to minimise the so-called noise to signal ratio.[3] Their work aims to investigate the causal linkages between crises and to identify the behaviour of macroeconomic fundamentals during a two-year window before the crises. They studied 20 economies in the period from 1970 to 1995, which covered 26 banking crises / distress and 76 currency crises. A set of 16 indicators were selected, measuring the degree of financial openness, balance-of-payment conditions, and real and fiscal sector conditions. It was concluded

[3] Goldstein et al. (2000) enlarged the sample of countries from 20 (used in Kaminsky and Reinhart (1999)) to 25. The analysis was also extended from a univariate analysis of the indicators to a multivariate analysis by constructing a composite index of the indicators, which was introduced in Kaminsky (1998). Crisis or distress contagion across economies was also analysed in Kaminsky and Reinhart (2000).

that when a few indicators exceed certain threshold values, a crisis or an occurrence of a distress is expected in the following twenty-four months.

On the other hand, the econometric approach to analyse financial crisis is based on multivariate probit / logit models. Demiguc-Kunt and Detragiache (1998) adopt a probit model to study the determinants of banking distress using annual data of 65 developed and developing economies for the period from 1980-1994. The dependent variable is a binary variable defined as unity when a crisis occurs and zero otherwise. The explanatory variables considered are classified into four groups: macroeconomic variables, financial variables, institutional variables and past distress variables. The findings are that banking distress is highly related to low economic growth, high inflation, and high real interest rate. Hutchison and McDill (1999), and Domac and Martinez-Peria (2000) essentially follow this approach whereas Hardy and Pazarbasioglu (1998 and 1999) generalise the approach using multi-nominal logit models.

Among the previous research on the twin crises, Rossi (1999) estimates logit models of banking and currency crises for an annual sample of 15 developing countries over the period from 1990 to 1997. He finds that, after controlling for a few qualitative variables, such as capital controls and prudential regulation, a higher probability of a banking distress is related to slow economic growth and rapid bank credit expansion. As to a currency pressure, also after controlling for a few qualitative variables, the chance of the occurrence is highly related to a change in terms of trade, economic growth and the occurrence of banking distress.

Glick and Hutchison (2000) study the joint occurrence of banking and currency crises using the probit approach on a set of annual data of 90 developed and developing economies over 20 years from 1975 to 1997. They first estimate two probit equations, one for each type of crisis, and test empirically the causal link between crises by means of a contemporaneous and a lagged dummy variable. After controlling for the influence of a set of macro variables, they find a significant contemporaneous effect of currency crises in the banking distress equation, and significant contemporaneous and lagged effect of banking crises in the currency pressure equation in the emerging economies sub-sample. As a further step, they estimate a simultaneous probit regression system, and also find a strong and robust contemporaneous correlation between banking and currency crises in the emerging markets sub-sample. However, if developed economies are included, the causal relationship between banking and currency crises disappears.

More recently, Ealcetti and Tudela (2006) study the determinants of twin crises and investigate the direction of causality between banking and currency crises in emerging economies. Unlike others using static probit equations, they model the twin crises as dynamic events and jointly estimate a system of two probit equations using panel data. Their results show that banking and currency crises have become closely intertwined and driven by common fundamentals. Their system estimation also shows strong evidence of unobserved contemporaneous correlation between twin crises and supports the choice of modelling twin crises as a simultaneous system. Furthermore, they find that banking crises are state dependent, i.e. countries having banking crises in the past are more prone to future crises.[4] Lastly, their results reveal no evidence of a significant causal link between banking and currency crises.

This paper differs from the empirical studies reviewed above in three dimensions. First, we adopt a multivariate probit model to reveal the determinants of the two types of crisis that is different from the work by Kaminsky and Reinhart (1999). Secondly, we allow the two-way linkage between banking and currency crises by estimating a simultaneous system of two probit panel equations with individual effects. This, unlike the dynamic models by Ealcetti and Tudela (2006), is able to avoid the spurious dependent result. Thirdly, we use a higher frequency dataset of quarterly data of the 11 EMEAP economies in our empirical analysis, which differs from most previous works that used only annual data such as Glick and Hutchison (2000), as the objective of this paper is to develop an early warning system to detect the vulnerability in the banking system and currency markets.

III. EMPIRICAL SPECIFICATION

In the following section, we discuss the empirical models and estimation strategies applied in this study. The discussion is divided into two parts. In the first part, we review the panel probit model for studying the determinants of each type of crises and discuss some statistics that help evaluate the model. We then discuss the two-equation simultaneous panel probit system. In the simultaneous setting, we assume that the stress of individual financial disturbance feeds back to the other and affects the likelihood of occurrence of the other type of financial disturbance. This modelling strategy follows Glick and Hutchison (2000).

[4] However, some researchers (e.g. Heckman 1981) argue that the state dependency and individual country effects are closely related and Bussiere (2007) remarks that the individual effect model may be preferred to the dynamic model to avoid the spurious dependence result.

3.1 Panel probit for individual financial disturbance

In modelling either banking distress or currency pressure in a probit framework, we assume that there exists a continuous measure of a stress index to the banking sector or foreign exchange market. If the index exceeds a threshold level, then a distress episode is deemed as occurs. We cannot observe the index directly but only the occurrence of the disturbance for individual economy i. We assume that the stress index Y_{it}^* evolves according to the following equation:

$$Y^*_{it} = \alpha_i + X_{it}\beta + \varepsilon_{it}$$

where α_i is a scalar indicating unobserved individual effect for economy i. X_{it} is the observation of economic and financial variables of economy i at time t, including the vector of ones. β is a column vector of parameters with dimension k and is common across economies. ε_{it} is a transitory shock to the stress index in economy i at time t. We further assume that α_i is generated randomly from $N(0, \sigma_\alpha^2)$ and ε_{it} is generated randomly from $N(0, \sigma_\varepsilon^2)$. Moreover, α_i and ε_{it} are independent of each other at all leads and lags. Lastly, Y_{it} is an indicator function of banking distress or currency pressure occurrence in economy i at time t, which is defined as

$$Y_{it} = \begin{cases} 1 & if \quad Y^*_{it} > 0 \\ 0 & otherwise \end{cases}$$

Given the above specification, we can infer the probability of an occurrence of disturbance by making the distributional assumption of ε_{it} as follows:

$$\Pr[Y_{it} = 1] = \Phi(Y^*_{it})$$

and

$$\Pr[Y_{it} = 0] = 1 - \Phi(Y^*_{it})$$

Our specification also allows us to test the significance of unobserved individual effect in explaining the probability of crisis through usual Wald-test, likelihood ratio test or Largrange multiplier test. For each type of disturbances, we test whether the unobserved individual effect α_i plays a role in explaining the observed overall variation of the dependent variable Y_{it}. The test statistics is defined as follows:

$$\rho = \frac{\sigma^2_\alpha}{\sigma^2_\alpha + \sigma^2_e}$$

When ρ is zero, it implies that the panel-level variance does not help explain the observed total variation. In other words, the variation of the unobserved economy-specific characteristics does not help in explaining the outbreak of the financial disturbances.[5]

To measure the goodness-of-fit of our models, a measure called pseudo R^2 is used since conventional R^2 is not defined for a probit model. The pseudo R^2 is defined as unity minus the ratio of the log-likelihood value of the full model over the log-likelihood value of the model including only a constant.[6] As the name suggests, this statistic is an analogy to the R^2 reported in a linear regression model and is bounded between zero and one by definition. In addition, we also use the type I and type II errors to measure the in-sample predicting power of the probit model.

The type I and type II errors are derived from a two-by-two contingency matrix as below:

	A signal is issued	No signal is issued
Disturbance actually occurs	A	B
Disturbance does not occur	C	D

where A, B, C and D represent the numbers of events in throughout our sample that match both criteria in the corresponding entry. Specifically, the type I error is calculated as B/(A+B), which is the proportion that the model fails to issue a signal conditional on disturbances occur., and the type II error is calculated as C/(C+D), which is the proportion that the model issues a false signal conditional on no disturbance occur. The lower type I and type II errors indicate a higher prediction power of the model.

To calculate the likelihoods of type I and type II errors, we need to define a threshold level of crisis occurrence probability. A signal will be issued if the model-predicted probability exceeds the threshold level. However, it should be noted that there exists a trade-off between the type I and type II errors when setting the threshold level. Setting a higher threshold level lowers the probability that a signal will be issued, which makes A and C decrease and B and D increase in the contingency matrix above, resulting in a higher type I error and a lower type II error. In this study, we adopt the

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5 The result based on a likelihood-ratio test is reported in the estimation results tables.

6 The log-likelihood of a perfect probit model is zero.

method proposed in Wong et al (2007) to determine the threshold.[7] The threshold is selected to minimise the weighted sum of the type I and type II errors by grid-search.[8] In addition, the proportion of correct classification, which is defined as (A+D)/(A+B+C+D), is also reported.

3.2 Simultaneous panel probit model

As mentioned above, in addition to investigating the determinants of banking distress and currency pressure, we are also interested in understanding the interplay between these two types of financial disturbances. Following Glick and Hutchison (2000), we specify a simultaneous system of panel probit models to study the impact of including the cross-leading indicators as one determinant of the latent pressure indices. Specifically, we model the banking distress and currency pressure equations as follows:

$$Y_{it}^{B*} = \gamma_B Y_{it}^{C*} + X^B{}_{it}\beta^B + \alpha^B{}_i + \varepsilon_{it}{}^B \quad (1)$$

and

$$Y_{it}^{C*} = \gamma_C Y_{it}^{B*} + X^C{}_{it}\beta^C + \alpha^C{}_i + \varepsilon^C{}_{it} \quad (2)$$

where superscript B and C denote banking distress and currency pressure respectively. In this setting, the interdependence of both disturbances is captured by γ_B and γ_C.

To estimate the parameters in the simultaneous system consistently, we employ the two-stage procedure discussed in Maddala (Ch8. 1977). We first estimate the reduced forms of the above model as follows:

$$Y_{it}^{B*} = X_{it}\overline{\beta}^B + \overline{\alpha}^B{}_i + \tau^B{}_{it} \quad (3)$$

and

$$Y_{it}^{C*} = X_{it}\overline{\beta}^C + \overline{\alpha}^C{}_i + \tau^C{}_{it} \quad (4)$$

where $X = \lfloor X^B X^C \rfloor$ and the variables with upper bar denote the coefficient estimates in the reduced form model. We proceed to the second stage of the estimation by first obtaining the fitted value of $Y^B{}_{it}$ and $Y^C{}_{it}$ from the reduced form equations (3)

7 We also try the method proposed by Kaminsky and Reinhart (1999), which is to minimise the "noise to signal ratio": C/(C+D)/A/(A+B). However, this method mostly resulted in a threshold at very high level and thus gives zero type II error and very high type I error.

8 We calculate the threshold with different weighting schemes on type I and type II errors to reflect different preferences of policymakers. For example, 0.7 for type I error and 0.3 for type II error reflect the fact that policymakers are more concerned about type I error as the ex-post recovery cost of crisis is higher than the ex-ante preventive cost.

and (4), which are denoted as $\hat{Y}^{B}{}_{it}$ and $\hat{Y}^{C}{}_{it}$. After that, we estimate the equations (1) and (2) with $\hat{Y}^{B}{}_{it}$ and $\hat{Y}^{C}{}_{it}$ replacing $Y^{B*}{}_{it}$ and $Y^{C*}{}_{it}$ on the right-hand side of the two equations. Again, we estimate the system of equations on an equation-by-equation basis using random-effect panel probit maximum likelihood procedure. We also employ a log-likelihood test to test for the significance of the unobserved individual effect in each stage.

IV. DATA AND DEFINITION OF BANKING DISTRESS AND CURRENCY PRESSURE

In this section, we describe the details of our dataset and explain how the financial disturbances episodes in our study are defined.

Our dataset covers 11 economies (including Australia, China, Hong Kong SAR, Indonesia, Japan, Korea, Malaysia, New Zealand, the Philippines, Singapore and Thailand) and the period from 1990 Q2 to 2008 Q3. The sample period varies from economy to economy due to the data availability constraints which result in an unbalanced panel data set. Detailed variable definitions and the sample period of each individual economy can be found in Appendix I.

Following Demirguc-Kunt and Detragiache (1998), an episode of banking distress is identified if one or more of the following conditions are satisfied:

(a) the ratio of non-performing loan to total loan in the banking sector exceeds 10%,[9]

(b) the banking system rescue operations cost larger than or equal to 2% of GDP,

(c) a large scale nationalisation of banks takes place as a result of the banking sector problems, and

(d) extensive bank runs occur or emergency measures are enacted in response to the banking distress.

The dependent variable of the banking distress probit equation at a time point takes value of unity if a banking distress occurs in the economy and zero otherwise.

Regarding the identification of a currency pressure, we construct the exchange market pressure index (EMPI) for each economy:[10]

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9 The definition of non-performing loan varies across economies. For Australia and New Zealand, we use the ratio of non-performing assets to total assets in the banking sector. The data are from CEIC and national sources.

10 EMPI is a common measure of exchange-rate pressure in the literature. See Eichengreen, Rose and Wyplosz (1995), Kaminsky, Lizondo and Reinhart (1997) and Lestano, Jacobs and Kuper (2003) among others.

$$EMPI_{i,t} = \frac{\Delta e_{i,t}}{e_{i,t}} - \frac{\sigma_e}{\sigma_r}\frac{\Delta r_{i,t}}{r_{i,t}} + \frac{\sigma_e}{\sigma_i}\Delta i_{i,t}$$

It is a weighted average of the month-on-month depreciation rate of the economy's currency relative to the US dollar, $\Delta e_{i,t} / e_{i,t}$, month-on-month change in foreign reserves, $\Delta r_{i,t} / r_{i,t}$, and month-on-month change in the nominal interest rate, $\Delta i_{i,t}$.[11] The weight of each component is normalised by the sample standard deviation of the month-on-month depreciation rate σ_e and is inversely related to the standard deviation of each component own, i.e. σ_r for the change in foreign reserves and σ_i for the nominal interest rate.

A period is classified to have a currency pressure if the EMPI exceeds the threshold level. The threshold level is defined as three standard deviations from the mean of the EMPI of that economy.[12] The indicator of a currency pressure in a given quarter takes value of one if the EMPI exceeds the threshold in one or more months of that quarter, and zero otherwise. The identified episodes of banking and currency crises are reported in the Appendix II.

The choice of independent variables is based on previous literature on banking and currency crises and is also subject to the data availability. Detailed discussion on the choice of these variables can be found in the literature and we here briefly review the rationale behind.

The set of independent variables that are commonly used in both banking and currency pressure probit models include growth of real private credit (GRPC), property price gap (PPD), stock price gap (SPD), default probabilities of listed commercial banks (PD_Bank), default probabilities of non-financial institutions (Z-score) and short-term external debt to foreign reserves ratio (STDR).

The real private credit is measured as inflation-deflated total credit supplied to the non-government sector by the banking sector. It serves as an important indicator of the vulnerability of the banking system as the excessive private credit growth may bring the banks with an over-extended exposure to private borrowers and lead to higher

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11 IFS lines .rf, 1l.d. and 60l are used.

12 To avoid the EMPI being distorted by the mean and variance of high-inflation episodes, if any, the sample would be split according to whether inflation is higher than 150% in that month and separate indices with different means and standard deviations will be constructed. See Kaminsky, Lizondo and Reinhart (1997). We examine our sample and cannot find an episode in any economy with inflation higher than 150%.

vulnerability of the banking system. Furthermore, the rapid lending growth could also result in excess liquidity which may stimulate speculative attacks on the domestic currency and lead to a currency pressure.

The inclusion of the property price gap and stock price gap is inspired by the results concluded by several studies that asset prices bubbles precede financial crises.[13] Examples include Japan in late 1980's and early 1990's and several Southeast Asian economies in late 1990s.[14] Empirically, Kaminsky and Reinhart (1999) and Lestano et al. (2003) find that there is a positive relationship between asset price bubbles and occurrence of banking distress. We anticipate a crucial role of asset prices in the EMEAP economies due to the substantial direct exposures of their banking sectors to stock and property markets and their heavy reliance on property as collaterals. Also, the theoretical work by Krugman (1998 and 1999) emphasises the significant role played by real asset prices such as land and capital in triggering the Asian financial crisis. The dramatic rise and subsequent burst of the asset prices due to the shift in investor sentiment will undermine the stability of the economy and push it to the edge of speculative attacks on its currency. The property price gap and stock price gap variables are measured as the deviation from their Hodrick-Prescott filter fitted trend.

Motivated by the empirical results in Hardy and Pazarbasioglu (1998 and 1999), we adopt the variables such as PD_Bank and Z-score to make use of the micro-level information to indicate the health of the financial and non-financial sectors. The failure of an individual or a few banks and corporations may threaten the whole banking system through the contagion effect within the banking sector, and between the banking sector and the non-financial corporate sector given the exposure of banks to corporations. Higher default probabilities of banks or non-financial corporations, accompanied with weak economic fundamentals, may also lower the public confidence on the external value of domestic currency, which in turn makes the economy more vulnerable to currency speculation. It should be noted that a lower value of Z-score implies a higher corporate default risk.

The Asian economies in the 1990's were marked by financial liberalisations and large-scale capital inflows. The over-borrowing problem and high level of external liabilities later became a sustainability concern to investors due to the possible sudden reversibility of capital flows. Thus, the ratio of short-term external debt to foreign reserves is added in an attempt to capture capital account imbalances. The ratio is measured as liabilities of domestic residence with maturity up to one year to BIS reporting banks to the total foreign reserve of an economy. According to the IMF (2003), this measure indicates the ability of an economy to meet its scheduled amortisations using its own reserves and would be particularly relevant to the economies that are not fully open to

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[13] These studies include Borio and Low, (2002), and Borio and Drehmann, (2009).

[14] See Allen and Gale (2000).

the international capital market, which is the case of some EMEAP members. A rise in the ratio could reflect a short-term liquidity mismatch and would make the economy more vulnerable to financial crises. As concluded in Zhuang and Dowling (2002), this ratio performs the best among capital account indicators.

In addition to the above indicators used in both the banking and currency probit models, real GDP growth (Growth) and inflation (INF) are added to the banking distress specifications. Real GDP growth is included as the direct measure of the strength of the economy. Weak economic growth which indicates the coming of recession often precedes financial crises. High inflation rate is often related to macroeconomic instability and will adversely affect the banking sector and the economy. These variables are commonly used in banking distress studies.[15]

With respect to currency crises, growth in the ratio of M2 to foreign reserves (GM2R), real effective exchange-rate gap (measured as deviation from the HP-filter fitted trend, REERD), total trade balance (measured as percentage of GDP, TB/GDP) and trade integration index with China (TI) are incorporated into the estimation specifications.

The M2 to foreign reserves captures the extent that the banking sector's liability is backed by international reserves. In the event of a banking distress or currency pressure, the public may lose confidence in the domestic currency and rush to convert the domestic-currency denominated assets to foreign-currency denominated ones. Therefore, the ratio captures the central bank's ability to withstand the pressure of exchanging the domestic currency for foreign currencies by public and to sustain the value of the domestic currency in face of devaluation pressure. An increase in the M2 to foreign reserves implies a decline in the foreign currency-backing of domestic liabilities of the banking system and is expected to increase the probability of banking distress.

Regarding the external side, the real effective exchange rate is added as a measure for assessing currency overvaluation and the external competitiveness of an economy. If the real exchange-rate appreciation is a reflection of upward misalignment of currency value, it will cause more pressure on currency devaluation. It may also lead to a loss of competitiveness in the external market and deterioration in the current account. Total trade balance (as a percentage of GDP) serves to measure the strength of the balance-of-payments position and the ability of an economy to earn foreign currency income through exports. Real exchange-rate appreciation and a decline in total trade balance are expected to increase the likelihood of a currency pressure.

The introduction of the trade integration with China in this study is

[15] In Wong et al. (2007), both variables are significant in the probit model of banking vulnerability in the EMEAP economies.

motivated by the increasingly important role played by China in the regional economy. We attempt to investigate how the economic connections between each individual economy in our sample and China will affect the likelihood that they are subject to occurrence of crises. Since the capital market in China is closed to a large extent, we focus on trade linkages instead of financial linkages. The trade integration with China is measured as the ratio of the bilateral trade value between China and the counterparty economy to the sum of their nominal GDP.[16] Throughout the Asian financial crisis, China put an extensive effort in stabilising the regional economy by maintaining the stability of its currency. Furthermore, the previous and current exchange rate regimes of China enable its currency to avoid big fluctuations. China, therefore, is expected to play a stabilising role in the region. Hence, greater trade integration with China is expected to lower the probability of a currency pressure.

Regarding the frequency and transformation of the data, all indicators, except the Z-score, are observed at quarterly frequency. The quarterly data of Z-score are interpolated from the annual data. Most indicators are transformed to either quarter-to-quarter percentage changes or deviations from a fitted trend to ensure the stationarity. We use the Hodrick-Prescott filter to estimate the trends.

Noting that the macroeconomic indicators in the later periods following a financial disturbance may be affected by the evolution of the disturbance itself or the macro polices enacted in response to the disturbance, we do not include all the banking distress/currency pressure observations in our estimation. Specifically, since banking distress is often found to last for several years, we only include the first four distress observations (i.e. the initial year) in our sample. Since currency crises are relatively short-living (usually not longer than one year), we keep all the distress observations and eliminate the subsequent four observations following the end of a currency pressure.[17]

We employ lagged terms of all the explanatory variables in all estimations based on two considerations. First, it helps to avoid the potential endogeneity problem due to the existence of contemporaneous terms as explanatory variables. Secondly, using lagged terms can also serve as an avenue to study the usefulness of these explanatory variables as leading indicators to predict crises. Previous literature does not provide guidance on choosing the appropriate number of lags for the explanatory variables. We follow Wong et al. (2007) for the convenience of comparison and choose to adopt a four-quarter lag for all variables (with the exception for the real private credit growth, for

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[16] Cheung et al. (2009) propose the use of same index to investigate the trade integration in the Asian region. They find that the region as a whole is becoming more trade-integrated after the Asian financial crisis.

[17] In simultaneous probit model estimations, if the onset of a banking distress is within one year after facing a currency pressure, we will include the observations following the end of the currency pressure and the first four distress observations of the banking distress, and eliminate only the remaining distress observations of the continuing banking distress.

which a lag of eight quarters is used[18]) to investigate the power of these indicators on signalling crises.

V. EMPIRICAL RESULTS

This section presents the estimation results of the multivariate probit models of banking distress and currency pressure on an unbalanced panel data set for the 11 EMEAP economies over the period from 1990 to 2008. In each separate model, we generate the probit estimates with various macroeconomic and financial market factors as well as involving the other type of stress. We also present the estimation of the simultaneous system of two panel probit equations.

Table 1 reports the results where the occurrences of banking distress are explained by a selected set of macro and financial variables as well as the other type of stress. In Model 1a, we find that economic growth and inflation, default probabilities of commercial banks and non-financial corporations, property-price and stock-price gaps, growth of real private credit, and ratio of short-term external debt to foreign reserves statistically lead the onset of banking distress. The sign of these estimates are consistent with the findings in the literature mentioned in section II. Slow economic growth, high inflation, higher default probabilities of commercial banks and non-financial corporations increase the probability of banking distress. The results confirm those obtained in previous studies and are similar to those in Wong et al. (2007) using the same sample. In addition, the ratio of short-term external debt to foreign reserves, which is found to be a useful indicator of currency crises in some studies[19], is also found to be positively related to the risk of banking distress. This suggests that the EMEAP economies which are more susceptible to currency instability are also more likely to experience banking distress. The pseudo R^2 indicates that the estimated probit equation is reasonable, although the type I error is relatively high.

As an additional explanatory variable to the selected macro and financial variables, the currency pressure indicator is significant for the sample. As shown in Models 1b and 1c, the contemporaneous and lagged currency pressure indicators have a significant role in predicting banking distress. However, while all the selected macro and financial variables, except the stock-price gap, are significant along with the contemporaneous currency pressure indicator, only economic growth, inflation and bank default probability remain significant when the lagged currency pressure indicator is added. Both models have pseudo R^2, ranging from 0.44 to 0.60, higher than Model 1a. This means the currency pressure indicator improves the predictability of the probit

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18 This is consistent with the empirical specification used by Demirguc-Kunt and Detragiache (1998).

19 For example, Kaminsky (1998) and Zhuang and Dowling (2002).

equations. Furthermore, Model 1c has the smallest sum of the type I and type II errors. Thus, the performance of Model 1c is the best among all three models.

We estimate three similar probit models for the currency pressure and the estimates are shown in Table 2. In Model 2a, in the absence of banking distress variable, the occurrence of currency pressure can be explained by the growth of M2 relative to foreign reserves, default probability of banks, Z-score, property-price gap, stock-price gap, growth of real credit to the private sector, real exchange-rate deviation and the China factor (measured as the bilateral trade integration between China and other EMEAP economies). On the other hand, the short-term external debt to foreign reserves is not significant. The significant variables are similar to the results in many previous currency pressure studies. An increase in the ratio of M2 relative to foreign reserves resulting from rapid growth of money supply and/or decline in foreign reserves is generally observed prior to the onset of currency crises. A large appreciation of real effective exchange rate indicates the loss of competitiveness of an economy in the international market and will increase the probability of a currency pressure. Asset-price bubbles increase the vulnerability of the currencies of the sample economies. Interestingly, the China factor is negatively significant. In other words, if an EMEAP economy is having more merchandised trade with China, the chance of having a currency pressure will be less. Such stabilising effect on the currencies in the region may be attributed to the stable economic growth in China and the stable renminbi exchange rate in the past decades. The strong and persistent economic growth in China and the stable currency value of the renminbi brings larger volume of bilateral trade with the economies in the region. This, in turn, greatly helps to stabilise and improve the external sector of the economies in the region, most of which are export-oriented, and as a result, provides stabilizing effect on their currencies. The individual effect is not significant in the model as the p-value of the test statistic, ρ, is large. This means that statistically the individual differences between the EMEAP economies are not important in determining the occurrence of currency crises. In the Asian financial crisis, some of the EMEAP economies experienced tremendous pressures and attacks on their currencies around the same time partly due to the contagion effect and partly due to their external-oriented economic structure.

Models 2b and 2c reflect the fact that in our sample very few banking distresses happened before currency crises. As most currency crises happened either simultaneously or before banking distresses, the contemporaneous banking distress indicator is significant at the 5% level whereas the lagged banking distress indicator is not significant at all. In Model 2b, with the contemporaneous banking distress indicator, all variables except the Z-score remain significant at either 5% or 10% level. In Model 2c, where the lagged banking distress indicator is present, most variables still remain significant except the ratio of short-term external debt to foreign reserves. The pseudo R^2, type I error and type II error of the three models are very similar, indicating that the addition of banking distress variable does not improve the model's in-sample fit and predictive power materially.

The above single equation probit models show contemporaneous correlation between the banking and currency crises. Table 3 shows the model estimates based on the simultaneous system estimations of both the banking distress and currency pressure equations.[20] After controlling for the simultaneous bias, bank default probability still has predictability on banking distress whereas the ratio of M2 to foreign reserves, real effective exchange rate misalignment and property price gap help to predict currency crises. However, in both simultaneous probit equations, the panel factor becomes insignificant as indicated by the p-value of the ρ statistics. Both equations have pseudo R^2 around 0.3 to 0.4, which are lower than those in the single equations. The type I and type II errors are also similar to those in the single equations, albeit a little larger.

As indicated in Table 3, the currency pressure has a contemporaneous effect on banking distress whereas there is no evidence of having contemporaneous banking distress effect on currency pressure in the simultaneous equation system, which are contrary to the results from the single equation estimation. As mentioned in Section III, the two-stage estimation procedure of the simultaneous equation system requires the use of the fitted values of ${Y^B}_{it}$ and ${Y^C}_{it}$ obtained from the first stage as explanatory variables, instead of using the binary indicators directly. In this way, we are able to control for the simultaneous bias between the banking distress and currency pressure, and access the role of banking distress (currency pressure) in determining the currency pressure (banking distress) more accurately than the treatment in the single equation models. However, we should be cautious about this finding. Since our sample contains very few episodes where banking distresses preceded currency pressures, it might cause the insignificance of banking distress in inducing currency pressure.

We use the estimated single equation models to produce out-sample warning signals of both banking distress and currency pressure in each EMEAP economies. The reason why we adopt separate single probit equations for out-sample predictions is because they outperform the simultaneous probit system in terms of in-sample goodness-of-fit as well as the prediction power. Since the currency pressure variable can improve the in-sample predictions in Model 1b and Model 3a, we use the same specifications for out-sample forecasts of banking distress. However, we have to use either the fitted values from the reduced-form equation or the EMPI as a leading proxy. The EMPI is commonly regarded as a more reliable measure of currency pressure as it is directly calculated from market data in contrast to the fitted values from a reduced-form model which may be suffered from model misspecifications. Therefore, we select it as the

[20] Our simultaneous equation methodology follows Maddala (1983, pp 246-7).

proxy of the currency pressure variable in our prediction equation. Table 4 shows the parameter estimates of the prediction equation. In addition to the significance of the EMPI, most other determinant variables in Model 2b remain significant except the stock -price gap.

The out-sample warning signals of banking distress from the last quarter of 2008 to the second quarter in 2009 are presented in the first column of Table 5. Our model gives a positive signal for Australia in each of the three out-sample periods, a positive signal for Korea in the first two quarters of 2009, and a positive signal for Singapore in the second quarter of 2009. These signals are broadly consistent with the idea that the current turmoil may have lagging impacts on emerging economies as it takes time for the shrinking import demand and foreign investment demand from the US and advanced economies in Europe to have an influence on the banking sectors of those emerging economies.

Regarding the out-sample predictions of vulnerability in currency markets, we use Model 2a since the fitted value of the banking distress variable is insignificant in the currency pressure probit Model 3b. The out-sample predictions of currency pressure from the last quarter of 2008 to the second quarter in 2009 are shown in the second column of Table 5. We only have one alarm signal and it is for the Australian currency in the last quarter of 2008.

Finally, we turn our focus to the predictions for Hong Kong for the period from 2008 Q4 to 2009 Q3 since we have the required input data for 2009 Q3 in the single probit models. Our models have not generated any signals for either banking distress or currency pressure during this period. This is consistent with what we have observed generally. According to our model the strong economic growth in 2007 contributed directly to stabilising the banking sector in late 2008 and early 2009 as well as indirectly to supporting the currency market through lowering the non-financial corporation default probability in the same quarters. Moreover, as shown above, maintaining the stability of the Hong Kong dollar provides a positive feedback effect to stabilising the banking sector. Our models also predict no substantial risk of banking distress and currency pressure for Hong Kong in the second and third quarters in 2009, mainly because of the continued positive economic growth until the third quarter of 2008. The weakening economy brought prices in the property and stock markets closer to their medium-term trends and also moderated inflation pressure in the same quarters. In our empirical models, these factors also contribute to stabilising the banking sector and currency market in the two quarters.

VI. CONCLUDING REMARKS

This paper investigates the use of the probit models to detect the vulnerability in both the banking system and currency markets in the EMEAP economies over the period from 1990 to 2008. During the sample period, many EMEAP economies experienced both types of crises particularly in the Asian financial crisis. The determinant variables found significant in the separate probit models are similar to those in the previous literature. As to banking distress, we find economic growth, inflation, default probabilities of the banking and non-financial corporate sectors, asset price gaps, growth of real credit to private sector and short-term external debt over foreign reserves help predict the probability of banking distress. With regard to currency pressure, the determinant variables are M2 over foreign reserves, default probabilities of the banking and non-financial corporate sectors, asset price gaps, growth of real credit to the private sector, trade integration with China, real exchange rate misalignment, total trade balance as percentage of GDP and short-term external debt over foreign reserves. These variables reflect the external-oriented nature of most EMEAP economies. In particular, the larger volume of bilateral trade with China helps to stabilise their external sector as persistent economic growth in China and stable value of the renminbi increases the demand of goods from those economies and therefore, provides a stabilizing effect on the currencies value of those economies

The unobserved individual effect is significant in the banking distress equation. This may reflect the difference in the institutional settings of the banking systems in these economies. On the other hand, the unobserved individual effect is found to be insignificant in the currency pressure equation. This finding echoes with the finding in other previous studies on currency crises, such as Gerlach and Smets (1995), Eichengreen et al. (1996) and Caramazza et al. (2000), who show that currency crises are a regional phenomenon due to strong contagion effects and economy-specific effects are relative weaker.

This paper also investigates the twin-crises phenomenon in the EMEAP group in the sample period. Contrary to some studies on twin crises in emerging markets, we only find a feedback effect from currency pressure to banking distress but not the other way round. Thus, measures to promote exchange-rate stability in the EMEAP group appear to be effective in fostering broader stability in the banking sector. Although our empirical results do not show evidence of a direct feedback from banking distress to currency pressure, measures to limit the short-term external liabilities of the economy, including the banking sector, may reduce the currency instability due to sudden capital outflows as the growth of M2 over foreign reserves is a significant determinant variable in the currency pressure equation.

To predict currency pressure, we use Model 2a since banking distress has no leading information of the possibility of future foreign exchange instability. Abiad (2003) and Peltonen (2006) remark that, although the probit model is able to signal currency crises reasonably well in-sample, developing a stable model that can accurately predict currency crises remains a challenging task. Alternative approaches include regime-switching models and artificial neural network models. We leave the investigation of the usefulness of these models in predicting currency instability for the EMEAP group to future research.

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Table 1: Probit regression estimates for banking distress (1)

Model	1a	1b	1c
Banking distress t	**Coefficient**	**Coefficient**	**Coefficient**
Constant	**-2.5588****	**-2.7136****	**-2.5548****
	(0)	*(0)*	*(0)*
Currency pressure t		**1.9356****	
		(0)	
Currency pressure t-1			**3.0157****
			(0)
Growth t-4	**-0.371****	**-0.3744****	**-0.2619***
	(0.001)	*(0.002)*	*(0.06)*
INF t-4	**0.2348****	**0.3424****	**0.3274****
	(0.04)	*(0.005)*	*(0.006)*
PD_Bank t-4	**0.0408****	**0.0403****	**0.0181**
	(0)	*(0)*	*(0.145)*
Z-Score t-4	**-1.2106****	**-1.3491****	**-0.7783***
	(0)	*(0.001)*	*(0.053)*
PPD t-4	**0.0548****	**0.0369***	**0.0129**
	(0.003)	*(0.058)*	*(0.635)*
SPD t-4	**0.0162****	**0.0087**	**0.0021**
	(0.046)	*(0.345)*	*(0.841)*
GRPC t-8	**0.0712****	**0.069****	**0.0422**
	(0.003)	*(0.007)*	*(0.163)*
STDR t-4	**0.4718****	**0.4234****	**0.2082**
	(0.007)	*(0.024)*	*(0.361)*
Rho	**0.5958****	**0.6165****	**0.3875****
	(0)	*(0)*	*(0.026)*
Pseudo R^2	0.3566	0.4378	0.6021
Type I error	0.8889	0.5625	0.5000
Type II error	0.0143	0.1706	0.0349
Proportion of correct classification	0.9498	0.8151	0.9525

Notes:
1. P-values in parentheses (the P-value for Rho is that of the likelihood test of Rho=0).
2. ** significant at 5% level; * significant at 10% level.
3. In calculating the type I and type II errors, the weighting scheme of the two is 0.5 to 0.5.

Table 2: Probit regression estimates for currency pressure

Model	**2a**	**2b**	**2c**
Currency pressure t	**Coefficient**	**Coefficient**	**Coefficient**
Constant	**-3.9024****	**-5.0977****	**-3.977****
	(0)	*(0)*	*(0)*
Banking distress t		**1.5041****	
		(0.016)	
Banking distress t-1			**0.1271**
			(0.825)
GM2R t-4	**0.0322****	**0.0386****	**0.0322****
	(0.027)	*(0.015)*	*(0.027)*
PD_Bank t-4	**0.0221****	**0.0193***	**0.0219****
	(0.014)	*(0.053)*	*(0.016)*
Z-Score t-4	**-0.9259****	**-0.5385**	**-0.8777***
	(0.022)	*(0.257)*	*(0.056)*
PPD t-4	**0.156****	**0.1548****	**0.1548****
	(0)	*(0)*	*(0)*
SPD t-4	**0.0342****	**0.0321****	**0.0337****
	(0.01)	*(0.03)*	*(0.013)*
GRPCt-8	**0.0744****	**0.0855****	**0.0745****
	(0.026)	*(0.023)*	*(0.027)*
TI t-4	**-0.3175****	**-0.3025****	**-0.315****
	(0.022)	*(0.026)*	*(0.022)*
REERD t-4	**0.1867****	**0.1601****	**0.1837****
	(0)	*(0)*	*(0)*
TB/GDP t-4	**-0.3141****	**-0.3998****	**-0.3179****
	(0.001)	*(0)*	*(0.001)*
STDR t-4	**0.3216**	**0.5472***	**0.3412**
	(0.226)	*(0.06)*	*(0.221)*
Rho	**0.0243**	**0.0213**	**0.024**
	(0.35)	*(0.294)*	*(0.344)*
Pesudo R^2	0.6127	0.6516	0.613
Type I error	0	0	0
Type II error	0.0801	0.0250	0.0835
Proportion of correct classification	0.9223	0.9757	0.9191

Notes:
1. P-values in parentheses (the P-value for Rho is that of the likelihood test of Rho=0).
2. ** significant at 5% level; * significant at 10% level.
3. In calculating the type I and type II errors, the weighting scheme of the two is 0.5 to 0.5.

Table 3: Simultaneous probit regression estimates

Model	3a		3b
Banking Distress t	**Coefficient**	**Currency Pressure t**	**Coefficient**
Constant	**-0.2533**	**Constant**	**-2.1737****
	(0.7702)		*(0)*
Currency pressure t	**0.6299****	**Banking distress t**	**0.107**
	(0.0108)		*(0.2922)*
Growth t-4	**-0.2058**	**GM2R t-4**	**0.0291****
	(0.3512)		*(0.0265)*
Z-Score t-4	**-0.4137**	**REERD t-4**	**0.1146****
	(0.1098)		*(0.0001)*
PD_Bank t-4	**0.0344****	**PPD t-4**	**0.0687****
	(0.0069)		*(0.0004)*
Rho	**0.4397**	**Rho**	**0.0315**
	(0.3406)		*(0.9037)*
Pseudo R^2	0.3163	**Pseudo R^2**	0.3586
Type I error	0.2500	**Type I error**	0.0526
Type II error	0.2009	**Type II error**	0.1099
Proportion of correct classification	0.7954	**Proportion of correct classification**	0.8924

Notes:
1. P-values in parentheses (the P-value for Rho is that of the likelihood test of Rho=0).
2. ** significant at 5% level; * significant at 10% level.
3. In calculating the type I and type II errors, the weighting scheme of the two is 0.5 to 0.5.

Table 4: Probit regression estimates for banking distress (2)

Model	**4**
Banking distress t	**Coefficient**
Constant	**-2.6161****
	(0)
EMPI t-3	**0.1401****
	(0.001)
Growth t-4	**-0.3743****
	(0.001)
INF t-4	**0.2862****
	(0.034)
PD_Bank t-4	**0.0419****
	(0)
Z_Score t-4	**-1.0526****
	(0.003)
PPD t-4	**0.0496****
	(0.012)
SPD t-4	**0.0124**
	(0.164)
GRPC t-8	**0.0634****
	(0.011)
STDR t-4	**0.4391****
	(0.016)
Rho	**0.6056****
	(0)
Pseudo R^2	0.4123
Type I error	0.2500
Type II error	0.2394
Proportion of correct classification	0.7599

Notes:
1. P-values in parentheses (the P-value for Rho is that of the likelihood test of Rho=0).
2. ** significant at 5% level; * significant at 10% level.
3. In calculating the type I and type II errors, the weighting scheme of the two is 0.5 to 0.5.

Table 5: Out-sample predictions of Banking Distress and Currency Pressure

Banking Distress			Currency Pressure		
Economy	**Date**	**Signal**	**Economy**	**Date**	**Signal**
Hong Kong	2008 Q4	0	**Hong Kong**	2008 Q4	0
	2009 Q1	0		2009 Q1	0
	2009 Q2	0		2009 Q2	0
	2009 Q3*	0		2009 Q3*	0
China	2008 Q4	0	**China**	2008 Q4	0
	2009 Q1	0		2009 Q1	0
	2009 Q2	0		2009 Q2	0
Indonesia	2008 Q4	0	**Indonesia**	2008 Q4	0
	2009 Q1	0		2009 Q1	0
	2009 Q2	0		2009 Q2	0
Japan	2008 Q4	0	**Japan**	2008 Q4	0
	2009 Q1	0		2009 Q1	0
	2009 Q2	0		2009 Q2	0
Korea	2008 Q4	0	**Korea**	2008 Q4	0
	2009 Q1	1		2009 Q1	0
	2009 Q2	1		2009 Q2	0
Malaysia	2008 Q4	0	**Malaysia**	2008 Q4	0
	2009 Q1	0		2009 Q1	0
	2009 Q2	0		2009 Q2	0
Philippines	2008 Q4	0	**Philippines**	2008 Q4	0
	2009 Q1	0		2009 Q1	0
	2009 Q2	0		2009 Q2	0
Thailand	2008 Q4	0	**Thailand**	2008 Q4	0
	2009 Q1	0		2009 Q1	0
	2009 Q2	0		2009 Q2	0
Singapore	2008 Q4	0	**Singapore**	2008 Q4	0
	2009 Q1	0		2009 Q1	0
	2009 Q2	1		2009 Q2	0
Australia	2008 Q4	1	**Australia**	2008 Q4	1
	2009 Q1	1		2009 Q1	0
	2009 Q2	1		2009 Q2	0
New Zealand	2008 Q4	0	**New Zealand**	2008 Q4	0
	2009 Q1	0		2009 Q1	0
	2009 Q2	0		2009 Q2	0

Notes:

1. The predictions for banking distress are based on the specifications in Table 4. The predictions for currency crises are based on the specifications of Model 2a in Table 2. Equal weights for the type I and type II errors are used to calculate the threshold level.

* As the required data are available for the predictions for Hong Kong in 2009 Q3, we are able to generate warning signals for the banking distress and currency pressure for Hong Kong in that quarter.

APPENDIX I

Sample periods for	Banking distress	Currency crises	Simultaneous system of banking and currency crises
Economy			
Hong Kong	1993 Q1 – 2008 Q3	1993 Q1 – 2008 Q3	1993 Q1 – 2008 Q3
China	1994 Q2 – 2008 Q3	1994 Q4 – 2008 Q3	1994 Q2 – 2008 Q3
Indonesia	1996 Q1 – 2008 Q3	1996 Q1 – 2008 Q3	1996 Q1 – 2008 Q3
Japan	2000 Q2 – 2008 Q3	2000 Q2 – 2008 Q3	1991 Q1 – 2008 Q3
Korea	1992 Q4 – 2008 Q3	1992 Q4 – 2008 Q3	1992 Q4 – 2008 Q3
Malaysia	1992 Q2 – 2008 Q3	1992 Q1 – 2008 Q3	1992 Q2 – 2008 Q3
Philippines	1993 Q4 – 2008 Q3	1993 Q4 – 2008 Q3	1993 Q4 – 2008 Q3
Thailand	1994 Q2 – 2008 Q3	1994 Q1 – 2008 Q3	1994 Q2 – 2008 Q3
Singapore	1991 Q4 – 2008 Q3	1991 Q4 – 2008 Q3	1991 Q4 – 2008 Q3
Australia	1993 Q3 – 2008 Q3	1993 Q3 – 2008 Q3	1993 Q3 – 2008 Q3
New Zealand	1993 Q1 – 2008 Q3	1993 Q1 – 2008 Q3	1993 Q1 – 2008 Q3

Data Descriptions and Sources

Variable Name		Definition	Data Source	
M2 over international reserves	Quarterly change rate, in percentage	Money and quasi-money divided by total foreign exchange reserves	IFS: lines 34 plus 35 (converted to U.S. dollars) divided by line 1D.D	
Real GDP growth	Quarterly change rate, in percentage	GDP in constant prices, in domestic currency[21]	CEIC and national sources	
Default probability of listed commercial banks	In level	Country average of the default probability of listed commercial banks[22]	Bloomberg and staff estimates	
Real effective exchange rate deviation	Deviation from trend, in percentage	Percentage of deviation of real effective exchange rate from the trend component computed by HP-filter	JPMorgan Real Broad Effective Exchange Rate Index from Bloomberg	
Real domestic private credit growth	Quarterly change rate, in percentage	Growth rate of claims on private sector minus GDP-deflator inflation	IFS: 32D, CEIC and national sources	
Z-Score	In level	The 10th percentile of the Altman Z-scores of listed non-financial companies	Thomson Reuters and staff estimates	Annual series; Cubic spine interpolation
Trade Integration with China	In level	Bilateral trade value between China and the counterpart divided by sum of their GDP	Direction of Trade, IFS and CEIC	
Real property price gap	Deviation from trend, in percentage	Percentage of deviation of property price index (deflated by GDP deflator) from the trend component computed by HP-filter	CEIC, DTZ website, national sources and staff estimates	

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21 The base year differs across countries depending on the data source.

22 See Merton (1974) "On the Pricing of Corporate Debt: The Risk Structure of Interest Rate?" Journal of Finance, 29(2) for details.

Real equity price gap	Deviation from trend, in percentage	Percentage of deviation of equity price index (deflated by GDP deflator) from the trend component computed by HP-filter	Bloomberg, CEIC, national sources and staff estimates
Inflation	Quarterly change rate, in percentage	Annual change rate of GDP-deflator	CEIC and national sources
Trade Balance over GDP	In level	Export value minus import value divided by GDP	IFS: line 70, 71 and CEIC
Short-term external debt over foreign reserves	In level	Liabilities to BIS banks (consolidated) with maturity up to 1 year divided by foreign reserve	Joint External Debt Hub (JEDH) and IFS line 1D.D

APPENDIX II

Chronology of Crises

Economy	Banking distress	Currency crises	Sources
Hong Kong	1998 Q4 – 1999 Q4	1998 Q3	Publications of central banks, Kaminsky and Reinhart (1999), Laeven and Valencia (2008), Caprio and Klingebiel (2003),and Lestano et al. (2003)
China	1994 Q2 – 2003 Q4	1993 Q2 – Q3	
Indonesia	1992 Q4 – 1995 Q4, 1997 Q4 – 2005 Q1	1997 Q3 – 1998 Q2	
Japan	1992 Q2 – 2005 Q2	1990 Q2 and 1991 Q4	
Korea	1997 Q4 – 2003 Q2	1997 Q4 – 1998 Q1	
Malaysia	1997 Q3 – 2002 Q4	1997 Q3 – 1998 Q1	
Philippines	1998 Q3 – 2005 Q2	1997 Q3 – 1998 Q1	
Thailand	1997 Q1 – 2005 Q2	1997 Q3 – 1998 Q1	
Singapore	1998 Q3 – 2000 Q3	1997 Q4 – 1998 Q1	
Australia		2008 Q3	