Contagion Effects, Informational Effects, and Economic Fundamentals:

An Analysis of Exchange Rate Dynamics during the Asian Currency Crisis

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Abstract

This paper develops an empirical framework to determine if the Asian currency crisis was contagious, and if so, whether the contagion was warranted or unwarranted. By applying a monetary-portfolio model to monthly data for 1991 — 1998, our results show that short-run variations in exchange rates were largely unexplained by macroeconomic fundamentals. The regime shift in our model suggests that informational effects had a major impact. For example, the collapse of the Thai baht released information for economic agents to reassess the stability of other currencies. Moreover, there were excessive correlations between exchange rates, even after controlling for the influence of fundamentals. All these indicate that the Asian currency crisis was contagious. However, further analysis of the residuals and classification of economies based on cluster analysis together indicate that the Thai baht crisis spread to economies with similar economic conditions. This finding supports the hypothesis of warranted contagion, i.e. the spread of a crisis is not entirely random and dependent on fundamentals.

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1. Introduction

Whether currency crises are largely attributable to economic fundamentals or to contagion has been one of the central issues in international finance and has been hotly debated, notably in the last decade or so, against a backdrop of recurrent currency crises, namely the EMS crisis, the "Tequila" crisis, and more recently, the Asian "flu". There is some evidence pointing to the contagious nature of the Asian currency crisis, (e.g. Baig and Goldfajn, 1999, Corsetti, Pesenti and Roubini, 1998 & 1999, Dekle, Hsiao and Wang, 1999, Furman and Stiglitz, 1998, Radelet and Sachs, 1998, and Tornell, 1999, among many others), but the findings and interpretations of these studies are debatable. One reason for the controversy is lack of a consensus in the contagion concept among economists. For example, Eichengreen, Rose, and Wyplosz (1995, 1996) define contagion as the occurrence of currency crises in (at least) two different countries in any given period. The successful attacks against currencies in the European exchange rate mechanism in September 1992 and the Mexican currency crisis in December 1994 are often cited as examples supporting the contagion hypothesis, as these currency crises were *prima facie* unrelated to the behaviour of fundamentals. This definition of contagion is not universally accepted by other economists, however. In her analysis of the recent Asian crisis, Schwartz (1998) argues that "to show that Thailand spread contagion, however, it would be necessary to demonstrate that otherwise sound economies suffered the Thai fate." Furthermore, even if currency crises are contagious, why contagion spreads to some countries but not to others remains to be explained. For example, in the Mexican crisis, the collapse of the Mexican peso had negative effects on the currencies of Argentina and Brazil, but not on those of Chile and Colombia.

In this study, we define contagion as excessive correlations across economies in asset returns (exchange rate returns in our case). The correlation is said to be excessive if it persists even after economic fundamentals have been taken into account. Moreover, we have adopted the concept of warranted versus unwarranted contagion put forward by Gerlach and Smets (1995), and Kruger, Osakwe and Page (1998). Warranted contagion occurs when a currency crisis spreads to a foreign economy with a similar macroeconomic structure or conditions. In contrast, unwarranted contagion occurs when a currency crisis spreads to another economy (or economies) that otherwise would not have had a speculative attack. The latter case could be attributed to herd-like behaviour or irrational speculation. The distinction between warranted and unwarranted contagion sheds light on how currency crises spread across economies, and why some currencies are immune to contagion while others are not. In case of warranted contagion, contagion and economic fundamentals are not necessarily mutually exclusive.

A concept closely related to contagious currency crises is informational effects or externalities (see, e.g. Drazen, 1999, Eichengreen, Rose, and Wyplosz, 1995 & 1996, and Tavlas, 1996), according to which the collapse of one currency conveys information about the stability of other currencies. Changes in the expectations and behaviour of foreign exchange traders due to the new information could lead to different possible outcomes. Such changes could cause the impact of fundamentals on exchange rates to differ before and after the crisis, and consequently structural changes are observed. Another possible outcome is speculative attacks on currencies of other economies with economic structures or conditions similar to the initial country having a currency crisis. Apparently, warranted contagion takes place in this case. Of course, the possibility of unwarranted contagion cannot be ruled out, as the information could simply trigger another currency crisis unrelated to fundamentals.

With all these related concepts in mind, this empirical study attempts to disentangle the effects of contagion, information, and economic fundamentals on exchange rate dynamics using the Asian crisis as a case study. It addresses the following issues: (1) was the Asia crisis contagious? (2) If so, was contagion warranted or unwarranted? Put differently, do currency crises spread across economies in a purely random fashion or can the spread be largely explained by fundamentals? (3) Are there informational effects? Our main objective is to fill the gap in the literature by developing an empirical framework to distinguish between warranted and unwarranted contagion, and also provide empirical evidence with reference to the Asian currency crisis.

In this paper we first apply SUR (seemingly unrelated regression) techniques to a system of exchange rates with economic fundamentals as explanatory variables. Then we test for structural changes due to informational effects, and the SUR residuals for the pre-crisis and post-crisis periods are compared to examine the existence of contagion. Finally, to determine whether contagion is warranted or unwarranted, we apply cluster analysis by classifying the economies into groups with similar economic conditions according to a set of economic variables. While cluster analysis has a long history of applications to other behavioural and social sciences, such as psychology and sociology, recently there has been a growing usage in economics. Examples include Artis and Zhang (1997, 1998), who examine similarities and dissimilarities in the economic structures of industrial countries to determine which countries are good candidates for monetary union with Germany, Chu (1999), who tests a signalling hypothesis in free banking, and Crowley and Nedialkov (1999), who examine whether the Canadian provinces form a stable currency union. Cluster analysis can provide insightful, interesting and meaningful interpretations for empirical results that may not be attainable by the traditional linear regression framework commonly used by economists.

Our empirical results suggest the contagious nature of the Asian currency crisis, as the exchange rates of many Asian economies showed excessive correlations, even after controlling for the effects of fundamentals, following the onset of the crisis in July 1997. This is notably ture in the cases of Thailand, Malaysia and the Philippines. However, these three countries are classified as economies of a similar economic structure based on our cluster analysis results. Hence, our findings provide some evidence in favour of warranted contagion.

The rest of the paper proceeds as follows: in the next section, we present the data description and the methodology; and in Section 3, we report and discuss the empirical results. The paper ends with a summary of the findings and some concluding remarks.

2. Data and Methodology

2.1 The Data

For the purpose of distinguishing between warranted and unwarranted contagion, the sample economies included in our study should be as comprehensive as possible and not be limited to those economies affected by the Asian currency crisis. Therefore, we include all major East Asian economies — namely Hong Kong, Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, Taiwan, and Thailand.[1] These economies represent extensive diversity in economic profiles, government policies and exchange rate policies.

1 Because of data availability problems, we are not able to include Burma, the Mainland China, Laos, Macau and Vietnam in our study.

We have collected from the CEIC, the IFS Database and the National Statistics of Taiwan (http://www.stat.gov.tw) a set of macroeconomic variables that potentially exert effects on balance-of-payments positions or provide revisions on market expectations on exchange rate changes. We have selected the macroeconomic variables that are complied and reported on a monthly basis.[2] There are a couple of reasons to justify our choice of using monthly data. First, given the relatively short duration of the post-crisis period and high volatility in exchange rate movements, monthly data are preferred to quarterly and annual data if we aim at obtaining more reliable regression results and meaningful economic interpretations. More important, the use of low frequency data is highly unlikely to capture the expected-to-be short-lived contagion effects due to currency crises. High frequency data on a daily or weekly basis are more likely to encompass contagion effects, but the effects of economic fundamentals are more difficult to identify because it may take some time before the fundamentals exert their impact on exchange rates. Our choice of monthly data is thus a compromise.

Based on our chosen theoretical model, which will be elaborated in detail in Section 2.2 below, the economic fundamental variables selected include exports, imports, foreign debt, industrial production, interest rate, money supply (M2) and foreign exchange reserves. In order to place the exchange rate changes in synchrony with the reporting frequency of the economic variables, we have obtained from the IFS the monthly exchange rates (period averages) of nine Asian economies, each defined in terms of units of the local currency per US dollar.

Constrained by data availability, our sample covers the period from January 1991 to December 1998. The Asian currency crisis started to spread to other Asian economies when Thailand officially devalued the baht on July 2, 1997, although some of the East Asian currencies, most notably the Thai baht and the Korean won, had already been under heavy speculative attack a few months before the collapse of the Thai baht.[3] In our empirical study, we divide our sample into a pre-crisis or tranquil period (January 1991 — June 1997) and a post-crisis period (July 1997 — December 1998). Because of missing data, we have 76 observations in the pre-crisis period and 14 observations in the post-crisis period.

2.2 Methodology[4]

2.2.1 Economic Fundamentals and Regression Models

The basic premise of our study is as follows: we have hypothesized that the exchange rate dynamics in the East Asian economies are simultaneously driven by economic fundamentals and other factors not explicitly specified, including contagion effects. As shall be seen in our model specification below, the set of economic fundamentals includes changes in money supply (M2), interest rate, industrial production,

2 Under this criterion, we exclude gross domestic product and unemployment rates which are reported on a quarterly basis.

3 For example, the Central Banks of Thailand and Singapore jointly intervened in the currency markets when the Thai baht was under heavy speculative attack in mid-May 1997.

4 All the computer codes, which are written in SAS, are available from the third author (efcysin@cityu.edu.hk) upon request.

foreign reserves,[5] foreign debt [6] and exports and imports, which should be comprehensive enough to capture the possible impact of economic fundamentals on exchange rates.[7] However, we expect the impact of each fundamental variable on the exchange rate to differ across the economies, reflecting divergences in economic structures and policies. We have further assumed that the set of fundamentals will remain valid determinants for exchange rate movements over the entire sample period, although we have allowed for the possibility of their impacts to change after the onset of the Asian currency crisis.

For the purpose of this study, it suffices that we have specified a model that can capture as far as possible the potential impact of fundamentals on exchange rates based on economic theories. Given that the "true" model for the Asian currency crisis is unknown, structural estimation based on one particular theoretical model can potentially lead to inconsistent estimates and invalid statistical inferences. Therefore, we have adopted an eclectic approach by specifying a general model that incorporates both the monetary and portfolio approaches to exchange rate determination, and we have allowed the data to speak for itself regarding which exchange rate theory (or theories) is more applicable in explaining the exchange rate movements of a particular economy. Our model here can be regarded as an extended and modified version of the general monetary-asset model as discussed in Gandolfo (1995, pp. 397-400). Four classes of model, namely the flexible-price monetary model of Frenkel (1976) and Bilson (1978), the sticky-price monetary model of Dornbusch (1976) and Frankel (1979), the sticky-price asset model of Hooper and Morton (1982) and their model with risk, can be derived as special cases of this general model, depending on the values and signs of the parameters. Mathematically, for an economy, the model is specified as follows:

$$e_t = a_0 + a_1 e_{t-1} + a_2(m-m_{us})_t + a_3(y-y_{us})_t + a_4(i-i_{us})_t + a_5 TB_t + a_6 K_t + \mu_t \quad \textbf{(1)}$$

where the subscript US denotes the variables for the US economy, *t* is time, and

e = logarithm of the spot exchange rate,
m = logarithm of the money supply,
y = logarithm of real income,
i = short-term interest rate,
TB = cumulated trade balance,
K = cumulated capital movement balance, and
μ = a random disturbance term.

5 Foreign reserves are taken as the total foreign exchange minus gold. Statistics on the foreign reserves for Hong Kong on a monthly basis are not available for part of the sample period.

6 Among our sample economies, Hong Kong does not have any official monthly data on foreign debt for part of the sample period.

7 For example, Baig and Goldfajn (1999) include only the US stock index and Yen/US Dollar exchange rate as fundamentals.

Note that, besides the set of fundamental variables, we also include the lagged dependent variable on the right-hand side of equation (1) because Somanath (1986) has found that the inclusion of the lagged dependent variable improves substantially the performance of the monetary models. On the other hand, this specification also encompasses the hypothesis that exchange rates follow a random walk (Meese and Rogoff, 1983). This would be the case when the lagged dependent variable is the only significant determinant in the regression results.

If exchange rate movements are influenced by the underlying chosen economic fundamentals, we expect that when exchange rate changes are regressed on changes in the relevant economic variables, the signs of the regression coefficients will be consistent with the directions as predicted by economic theories. The first fundamental variable in equation (1) is the differential between money supply growth in the *i*th economy and its counterpart in the United States. We use M2 as a proxy for the money supply. All the four theoretical models predict the sign to be positive, i.e. an increase in the domestic money supply relative to the US is expected to be associated with a weaker currency.

The second fundamental variable is the differential in income or output growth. As our study is based on a monthly basis, we use the industrial production index as a proxy for output. All the four theoretical models predict that an increase in the domestic income is expected to result in a stronger local currency.

However, the four theories have different views regarding the impact of interest rate differentials on exchange rates. Strictly speaking, both short-term and long-term interest rate differentials should be included in equation (1). In our study, we have included only the short-term interest rate differentials because all these Asian economies, except Japan, do not have well-established and sophisticated markets for long-term financial instruments. The Frenkel-Bilson flexible price monetary model predicts that the short-term interest rate differential is positively related to the domestic currency. On the contrary, the other three theories predict a negative relationship.

The remaining fundamental variables in equation (1) reflect the portfolio approach model by Hooper and Morton, as they do not appear in both the Frenkel-Bilson flexible price monetary model and the Dornbusch-Frankel sticky price monetary model. In other words, the parameter estimates of these variables should be statistically not different from zero if the monetary models are correct. In contrast, the Hooper-Morton model predicts that the parameter estimate for the cumulated trade balance be negative: a persistent domestic trade-balance surplus leads to an appreciation of the domestic currency. In our study, the trade-balance effect is proxied by export and import growth of the domestic economy, with the expected signs for exports and imports being negative and positive, respectively.[8]

8 We have also tried using net trade figures instead of exports and imports in our regression analysis. However, the statistical significance of the trade variable is weaker than when we model the separate effects of exports and imports. Specifically, we find that the coefficient of exports is consistently significant for some countries. This result is consistent with the notion that these economies are export-led and hence their export performance is expected to have an important influence on their exchange rates.

The last fundamental variable reflects the effect of cumulated capital movements balance on the exchange rate. According to the Hooper-Morton model with risk, the predicted sign is positive, reflecting a risk premium in a world of imperfect asset substitutability. To proxy for the effect of cumulated capital movements balance, we include changes in international debt outstanding and changes in foreign exchange reserves in our model. An increase in international debt outstanding is expected to be associated with a weaker local currency, whereas an increase in the level of foreign exchange reserves is expected to have just the opposite effect.

In our actual estimation, we modify the above model in the following two ways. First, we use one-period lagged macroeconomic variables in our regression instead of contemporaneous variables. A major reason for imposing this assumption is that contemporaneous regression results can be very difficult to interpret because the effects of economic fundamentals on exchange rates can be mixed with the effects of exchange rates on economic fundamentals. This is particularly the case when the exchange rate is under a "dirty float", that is when a central bank changes its monetary policy stance in response to developments in the exchange rate. The main advantage of using lagged economic fundamentals rather than contemporaneous variables is to isolate the former effect from the latter, thus making analysis and interpretation of empirical results more tractable and meaningful.

Second, we have considered the return rate of the exchange rate because we are interested in changes in exchange rates more than in their levels. Modified upon equation (1), the model we have adopted is specified as follows:

$$\Delta e_t = b_0 + b_1\Delta e_{t-1} + b_2\Delta(m-m_{us})_{t-1} + b_3\Delta(y-y_{us})_{t-1} + b_4\Delta(i-i_{us})_{t-1} + b_5\Delta exp_{t-1} + b_6\Delta imp_{t-1} + b_7\Delta res_{t-1} + b_8\Delta fd_{t-1} + \in_t. \quad \textbf{(2)}$$

where *exp*, *imp*, *res* and *fd* denote the logarithms of exports, imports, foreign reserves and foreign debt respectively; $\in$ is a random disturbance term; and all other variables are the same as defined in equation (1).

As a quick reference, Table 1 provides a summary of the signs of the regression coefficients for the macroeconomic fundamentals as predicted by our modified and extended model based on the four theories of exchange-rate determination.

In the above specification, we have assumed that the structure of the set of fundamental variables will hold over the entire sample period, but the impact of such factors may change under different economic regimes. We seek to analyze whether the pattern of economic fundamentals is maintained after the onset of the currency crisis, and whether the influence of economic fundamentals is strengthened or weakened subsequently. Put differently, the parameters in equation (2) are allowed to differ in value before and after the currency crisis. We will discuss this issue in more detail in the next section.

2.2.2 Informational Effects and Tests for Structural Changes

According to the informational effects hypothesis, the collapse of currency *i* conveys information about the impending collapse of currency *j*. The existence of such informational effects could be reflected in at

least two ways.[9] First, informational effects are consistent with a structural change in the equation for *i* due to the currency crisis, followed by an almost immediate structural change in the equation for currency *j*, as currency traders revise their expectations and change their portfolio decisions accordingly based on the information revealed by the currency crisis.[10] These are expected to be reflected in changes in both the parameter estimates immediately after the onset of the currency crisis. Second, it should be noted that informational effects and contagion effects can co-exist — for example, speculative attacks on currency *i* provide information about the instability and unwillingness of the monetary authorities to defend currency *j* and prompt traders to attack currency *j*. In this case, these two effects would be reflected in post-crisis changes in the correlation coefficients between currencies *i* and *j* in the cross correlation matrix of the residuals. We will explain how to use the cross correlation matrix to identify contagion effects in the next section.

To detect the existence of informational effects, or more correctly structural changes due to the currency crisis, we have performed a Chow test as well as a likelihood ratio test for each economy. If the test results indicate structural changes, we will compare the regression results for the pre-crisis sub-sample with those for the post-crisis sub-sample period. The pre-crisis period represents a controlled experiment to be used as a benchmark for comparing the effects of the currency crisis. The pre-crisis regression provides an analysis of the relevant set of economic variables in a "normal" or tranquil period. Based on the regression results, we checked whether the effects of the economic variables strengthened or weakened as a result of the currency crisis. Furthermore, we also used the cross-correlation matrix to examine the impact, the existence as well as the nature of contagion due to the currency crisis, which is the subject we now turn to.

2.2.3 Warranted or Unwarranted Contagion and Cluster Analysis

When exchange rate movements in the East Asian economies are interrelated or currency crises are contagious, the traditional ordinary least square regression becomes inefficient since covariances of the disturbance terms are neglected. To account for the potential interrelationship of currency movements among the sample economies, we applied Zellner's (1962) SUR to the system of nine equations specified in equation (2). The empirical framework has an advantage of allowing us to examine at the same time the impact of fundamentals on exchange rates before and after a currency crisis, the subsequent informational effects, and contagion effects, if any.[11]

By our definition, contagion exists when there are excessive correlations in the currencies after controlling for the effects of the fundamentals. We followed the basic idea contained in the studies of King and Wadhwani (1990) and Lee and Kim (1993), who used changes in the correlation between stock market returns around the time of the 1987 stock market crash as a measure of the transmission of international

9 They are some of the implications of informational effects.

10 As monthly rather than weekly or daily data are used in our empirical study, we expect to observe *simultaneous* structural changes in both equations *i* and *j* immediately after the onset of the currency crisis if informational effects exist.

11 Different approaches have been adopted to empirically study currency crises. For a review of the literature, see, for example, Kaminsky, Lizondo and Reinhart (1998).

shocks. The cross correlation matrix of the error terms captures the interrelationship of contemporaneous disturbances across different economies, including contagion effects, after controlling for the effects of the economic fundamentals on exchange rates. When economies *i* and *j* have strong contemporaneous interdependence, we expect the cross correlation term for *i* and *j* to be substantially different from zero. Assuming that the factors affecting the correlation in the pre-crisis period continue to hold in the post-crisis period, the off-diagonal elements in this correlation matrix, particularly those measuring the correlation between the currencies having crises, can serve as proxies to measure the extent of contagion effects of the currency crisis. In the presence of contagion among the economies as a result of the currency crisis, the correlation coefficients for the post-crisis period are expected to be substantially positive and significantly higher in value than their counterparts for the pre-crisis period.

To further determine whether contagion is warranted or not, we first applied cluster analysis to classify the nine Asian economies into similar economic *structures* according to certain economic criteria. We briefly outline our cluster analysis here. Technical details can be found in Everitt (1993). (See also Section II in Artis and Zhang, 1998.) In essence, we have nine Asian economies ("objects" in the literature of cluster analysis) and five economic variables.[12] First denote the *l-th variable (l=1,2,...,5)* of the *i-th economy (i=1,2,...,9)* as x_{il}. In this paper, we use the *centroid clustering method*. A cluster w_k, once formed is represented by its centroid $cx(w_k)$, which, together with its coordinates $cx_l(w_k)$ *(l=1,2,...,5)*, maybe expressed as:

$$cx(w_k) = (cx_1(w_k), cx_2(w_k), ..., cx_5(w_k)),$$

and

$$cx_l(w_k) = \frac{1}{|w_k|} \sum_{i \in w_k} x_{il} \quad for\ l = 1,2,...,5. \qquad \textbf{(3)}$$

where $|w_k|$ is the number of economies in the cluster.

In our cluster analysis, changes in domestic interest rates and inflation rates as well as percentage changes in exports, imports, and the money supply on a monthly basis over the post-crisis period are used as the variables or features to classify the nine economies into different groups of "similar" economic structures, or more accurately similar economic circumstances or conditions. Our choice of these variables as the criteria is suggestive rather than definitive.[13] For the sake of convenience and consistency, we chose a set of economic variables similar to those used in our regressions as the criteria in the cluster analysis. Put differently, we have tried to determine if the SUR residuals are related to the economic fundamentals in a systematic way that is not captured by the traditional linear regression model framework. Here we assume that the collapse of the Thai baht prompted traders to reassess the economic performance of the other eight economies based on changes in the above economic fundamentals in

12 Out of the seven economic variables discussed in Sub-section 2.2.1, foreign reserves and foreign debt are excluded in the cluster analysis because of the data availability for Hong Kong. See Footnotes 4 and 5.

13 Apparently, there is a large number of admissible criteria as long as "economic structure" is not explicitly and precisely defined. For instance, one can use per capita GDP, trade pattern, etc, as criteria for classification in the cluster analysis.

the post-crisis period. Two economies are said to be similar in economic conditions if they have similar changes in inflation rates, trade balances, money supply growth, etc.[14] To a certain extent, such changes also reflect the economic policies pursued by their governments. For instance, two countries having approximately the same high money supply growth rates can be viewed as having similar expansionary monetary policies. In the case of warranted contagion the currency crisis of an economy spills over to another economy of similar conditions, causing a corresponding depreciation in the exchange rate of the latter's currency after controlling for the influence of economic fundamentals. Meanwhile, the exchange rates of economies of different economic conditions should be less affected. In other words, economies similar to Thailand in economic conditions are expected to be vulnerable to speculative attacks and crises. The more similar the economic conditions, the more vulnerable is the currency.[15]

In the actual empirical study, we have examined whether the resultant classifications from the cluster analysis and the SUR residuals are related in a systematic way. The SUR residuals for two similar economies for the post-crisis period should be positively and highly correlated with each other. In contrast, the SUR residuals are expected to become more positively and highly correlated across the board after the crisis in the case of unwarranted contagion. This is because contagion spreads out to other economies irrespective of the degree of similarity or dissimilarity in their economic conditions. The irrational and herd behaviour is a dominant force in foreign exchange markets, making economic fundamentals less substantial, if not immaterial, in explaining post-crisis exchange rate movements.

3. Empirical Results

The exchange rates of the nine economies were relatively stable before the Asian financial crisis but responded quite differently to the Thai baht crisis, as can be seen in Figure 1, in which the exchange rates are normalized to 100 as of January 1996 for the purpose of comparison. The dramatic change in exchange rate volatility due to the crisis is reflected by the summary statistics reported in Table 2. In general, exchange rates have become not only more volatile but also closely correlated in the post-crisis period, as can be seen in Tables 3 and 4, which show the correlation coefficients between changes in two currency movements for the pre-crisis period and for the post-crisis period respectively. On the surface, the prominently higher values of the correlation coefficients for the post-crisis period seem to suggest contagion. Further investigation, however, is needed because these are the correlation coefficients before controlling for the impact of economic fundamentals.[16]

The OLS and SUR regression results for each of the economies for the pre-crisis period are reported in Tables 5 and 6, respectively. Relatively speaking, the impact of the fundamental variables on exchange

14 It should be pointed out that the levels of these economic variables may also matter. For example, a country with a high level of foreign exchange reserves is expected to be less likely to experience speculative attacks or a currency crisis than a country which is running out of reserves.

15 This is of course not the only way through which currency crises spread across countries. For a brief survey of the different theoretical models of contagion, see Drazen (1999).

16 For example, Baig and Goldfajn (1999) find the South-east Asian currencies to be highly correlated with each other during the crisis period, but Forbes and Rigobon (1999) find the coefficients, when "properly" estimated, to be insignificant.

rate changes was not very prominent, judging from the signs of the parameter estimates and their statistical significance.[17] These findings are consistent with most, if not all, empirical findings in the literature that short-run changes in exchange rates are highly volatile and unlikely to be fully reflected by changes in economic fundamentals (see, e.g. Frankel and Rose, 1995 for a survey). Using R^2 as a measure of goodness-of-fit, our specification apparently does not explain much of the monthly changes in the Hong Kong dollar over this period. But this result is understandable and intuitively clear because the Hong Kong dollar is pegged to the US dollar under the current linked exchange-rate system. For the other countries, the R^2 ranges from 0.21 for Indonesia to roughly 0.40 for Singapore in value for the pre-crisis sample period, indicating that a large proportion of variability in exchange rates is not captured by economic fundamentals.[18] Although we do not have strong evidence to overturn the classic results of Meese and Rogoff (1983), we would like to stress that not all fundamental variables are immaterial in affecting short-run changes in exchange rates. For example, money supply growth is statistically significant and has the correct sign as predicted by theory in the equations for Korea and the Philippines; and export growth for Hong Kong and Taiwan. As our objective here is to control for the impact of the fundamentals on exchange rates, we should not ignore them no matter how small their effects are.[19]

The regime shifts as a result of the Asian currency crisis are formally confirmed by the results of the Chow tests and the likelihood ratio tests for each of the nine economies. This is consistent with the findings of Tornell (1999). As Table 7 reveals, the null hypothesis that the coefficients of the regression model are maintained after the currency crisis is rejected for all economies except Hong Kong and Taiwan. In other words, all economies except these two experienced a regime shift at the same time as when the currency crisis broke out. Though preliminary, the above results are consistent with the informational effects hypothesis: the speculative attacks on the Thai baht and its subsequent devaluation released information that affected traders' expectations about other currencies, thus causing structural changes in the equations for these currencies at the same time. For the post-crisis period, the fundamentals remain largely insignificant in explaining short-run exchange rate movements, except in a couple of examples: interest rate differentials for Malaysia and the Philippines, export growth for Hong Kong and import growth for Malaysia. The OLS and SUR results for the post-crisis period are tabulated as Tables 8 and 9 respectively. There are a couple of interesting, and somewhat puzzling, findings when the results for the pre- and post-crisis periods are compared. First, the t-statistics of the lagged dependent variables have become less significant, with the exception of the Japanese yen and, marginally, the Malaysian ringgit. Second, the explanatory power of our model in terms of R^2 improves considerably across the board, except Taiwan, for which the R^2 remains virtually intact.[20] One plausible explanation

17 In this as well as the post-crisis estimation, the low statistical significance may also be a consequence of the well-known stylized fact of multicollinearity among the *time-series* variables.

18 Following general practice, we also report the adjusted R^2, which ranges from 0.12 for Indonesia to roughly 0.33 for Singapore. That for Hong Kong is even negative.

19 While Flood and Rose (1999) argue recently that there are no macroeconomic fundamentals capable of explaining the dramatic rise in exchange rate volatility, Macdonald (1999) argues that fundamentals have a role to play in explaining exchange rate behaviour.

20 It should be noted that due to small sample sizes for *both* pre-crisis and post-crisis periods for each economy, the two R^2s may suffer from considerable (either positive or negative) errors in measuring the goodness-of-fit. To the best of our knowledge, there is not a generally accepted criterion to *adjust* the R^2 in our case. The *usual* adjusted R^2 is a good criterion to compare two models with the *same* number of obsevations and *different* numbers of variables. See, for instance, Section 4.3 in Pindyck and Rubinfeld (1998). However, in our case, the numbers of observations are *different* while the number of variables is the *same*.

for the above findings is that traders have watched more closely and responded more sensitively to changes in economic fundamentals in the post-crisis period than they did in the pre-crisis period.[21]

This conjecture, however, does not rule out the possibility of contagion, as suggested by Tables 10 and 11, which show respectively the correlation matrices of the SUR residuals for the pre-crisis period and the post-crisis period. The tables show clearly that the residuals are in most cases positively related to each other, even before the onset of the currency crisis, suggesting the existence of certain random factors affecting the currencies in the same direction at the same time.[22] Several pieces of evidence in support of contagion are found by comparing the two correlation matrices in detail. First, 15 out 36 off-diagonal elements in the lower-half of the matrix shown in Table 11 have a correlation of 0.5 and above (high correlation), compared with only six in Table 10. Second, 23 of these off-diagonal elements have increased in value. Or, in other words, the correlations between the residuals of two currencies have in most cases become stronger in the post-crisis period. Third, the correlation coefficients between the residuals of the Thai baht and those of all the other currencies, except the Hong Kong dollar and the Japanese yen, have increased. This is consistent with the conjecture that contagion spread from Thailand - the first country to give up defending its currency as a result of speculative attacks - to other economies. Finally, half of the 36 correlation coefficients recorded phenomenal increases (an increase of 0.25 or more). Such considerable increases are more likely to be found in the combinations between any two currencies except the Hong Kong dollar and the Japanese yen. Put differently, pick any currency other than the Hong Kong dollar or the Japanese yen and the probability of finding such a considerable increase in correlation ranges between 0.5 to 0.75. Consider the Thai baht as an example for illustration. Substantial increases in the correlation coefficients are found between the Thai baht and the currencies of Korea (+0.39), Malaysia (+0.45), the Philippines (+0.51) and Taiwan (+0.40).

The last finding in the previous paragraph also suggests that some economies appear to be more vulnerable to contagion than others. To determine whether contagion is warranted or not, we also examine the cluster analysis results. The cluster analysis results are reported in Table 12 and depicted as Figure 2 to facilitate our exposition. The dendrogram in Figure 2 shows that Singapore and Taiwan initially form a cluster and are subsequently joined by Japan, suggesting that these three economies have very similar economic conditions. This group is subsequently joined by the Philippines, Thailand and Malaysia. The cluster analysis results suggest the three latter countries have similar economic conditions. Hong Kong appears to lie somewhere between the first group consisting of three advanced East Asian economies and the second group consisting of the three Tigers. This is followed by Korea. As can be seen from Figure 2, Indonesia's economic conditions were remarkably different from the rest, as the country stands out on its own before it merges with the other eight economies to form the final cluster. This is not implausible given the dramatic developments in political and economic stability in that country in 1998. Though imperfect, the above cluster analysis results serve reasonably well as a proxy for measuring the degree of similarity in economic conditions among these economies.

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21 That said, there should be other post-crisis developments not captured by our theoretical model. For instance, the post-crisis movements in the Indonesian rupiah were most likely driven more by political stability than economic fundamentals.

22 Out of the 36 off-diagonal elements in the lower-half of the matrix, which shows the correlation between the residuals of two currencies, 26 are positive in Table 10, compared with 23 in Table 11.

The cluster analysis results together with the correlation coefficients of the SUR residuals lend some support to the hypothesis of warranted contagion. Considering the cluster consisting of Malaysia, the Philippines and Thailand, under the hypothesis of warranted contagion, the collapse of the Thai baht in July 1997 should be more likely to spill over to Malaysia and the Philippines than to the other countries. As can be seen from Table 11, the three correlation coefficients for the post-crisis period are all notably high: 0.76 for Thailand-Malaysia, 0.4418 for Malaysia-Philippines, and 0.4011 for Thailand-Philippines. For each of these three economies, the within-cluster correlation coefficients (i.e. the correlation coefficients for any two countries from the same cluster) are in general higher than the between-cluster correlation coefficients (i.e. the correlation coefficients for any two countries from two different clusters). The average value of the correlation coefficients for Thailand-Malaysia, Thailand-Philippines and Malaysia-Philippines for the post-crisis period is 0.5075, much higher than 0.26 for its counterpart between these three countries on one hand and other countries on the other, 0.1613 for all correlation coefficients, except these three observations and 0.1902 for all the correlation coefficients (i.e. the 36 off-diagonal elements in the lower-half of the correlation matrix).

As already noted in a previous paragraph, the correlation coefficients between the SUR residuals for these three countries increased considerably in value after the onset of the Asian currency crisis. The average increase is 0.4161, much higher than the corresponding figures of 0.1239, 0.0024 and 0.0369 respectively (see Table 13). Overall, the above results are in favour of warranted more than unwarranted contagion.[23]

4. Conclusions

In this paper we have employed the SUR framework and cluster analysis techniques to analyse exchange rate dynamics in nine East Asian economies for the period from January 1991 to December 1998 on a monthly basis with respect to contagion effects, informational effects and economic fundamentals. Our findings suggest that macroeconomic fundamentals played an important role in determining exchange rate dynamics during the crisis. First, they appear to have a higher explanatory power in explaining exchange rate movements in the post-crisis period than before. Second, and more importantly, they played a crucial role in the propagation of currency crisis. While the high correlations between the exchange rates and their significant increases after the onset of the currency crisis suggest the existence of contagion during the Asian currency crisis, such high correlations and increases are found more prominently among economies of similar economic conditions. Therefore, we reject the notion of pure or unwarranted contagion in favour of warranted contagion. Like the results of Tornell (1999), ours indicate that financial crises do not spread across countries in a purely random way, and that the severity of crises can be explained by fundamentals.

23 It should also be pointed out that while our results hold *on average*, there are a few exceptions. This suggests that the criteria used in our cluster analysis may have omitted certain key factors that also play a crucial role in the transmission of contagion. For example, as a member of ASEAN, Singapore has close inter-regional trade and investment relationships with other ASEAN member countries and therefore its exchange rate is highly inter-related to the exchange rates of other ASEAN member countries.

Our findings of warranted contagion have significant policy implications. When a currency crisis occurs in a country, policymakers of countries with economic conditions or policies similar to the crisis country should be alert to the possibility of warranted contagion spilling over and hence, before it is too late, announce commitments and implement credible policies to maintain financial stability. As history reveals, sound macroeconomic policies to maintain consistency between economic fundamentals and the external value of the currency are the best measures to avoid currency crises (see e.g. Bordo and Schwartz, 1996).

Our findings also have implications for theoretical research in financial crises. "Macroeconomic conditions" as defined in our study are only one of the many possible factors affecting the transmission of currency crises. Others include information cascade (Shiller, 1995), strong trade links with the crisis country (Eichengreen, Rose and Wyplosz, 1995 & 1996), high and variable volume of capital flows (Meng and Velasco, 1999) and political contagion (Drazen, 1999), to name just a few. Our results indicate that (warranted) contagion, informational effects and economic fundamentals are not necessarily mutually exclusive forces in driving exchange rates. Further research that integrates these driving forces is necessary before we can have a fully-fledged understanding of currency crises.

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Appendix

Table 1: Predicted Signs of Regression Coefficients

Macroeconomic Variable	Predicted Sign	Theory
Money Supply	+	All Four Theories
Interest Rate Differential	+	FB
	-	DF, HM, HMR
Industrial Production	-	All Four Theories
Foreign Reserves	0	FB, DF, HM
	-	HMR
International Debt	0	FB, DF, HM
	+	HMR
Exports	0	FB, DF, HMR
	-	HM
Imports	0	FB, DF, HMR
	+	HM

Notes:

(1) A "+" sign means a depreciation of the currency as a result of an increase in the value of the macroeconomic variable, whereas a "-" sign means an appreciation. An "0" means that the theory either predicts that the variable has no impact on the exchange rate or does not consider its impact.

(2) BF, DF, HM, HMR denote respectively the Bilson-Frenkel approach, Dornbusch-Frankel approach, the Hooper-Morton model without risk, and the Hooper-Morton model with risk.

Figure 1

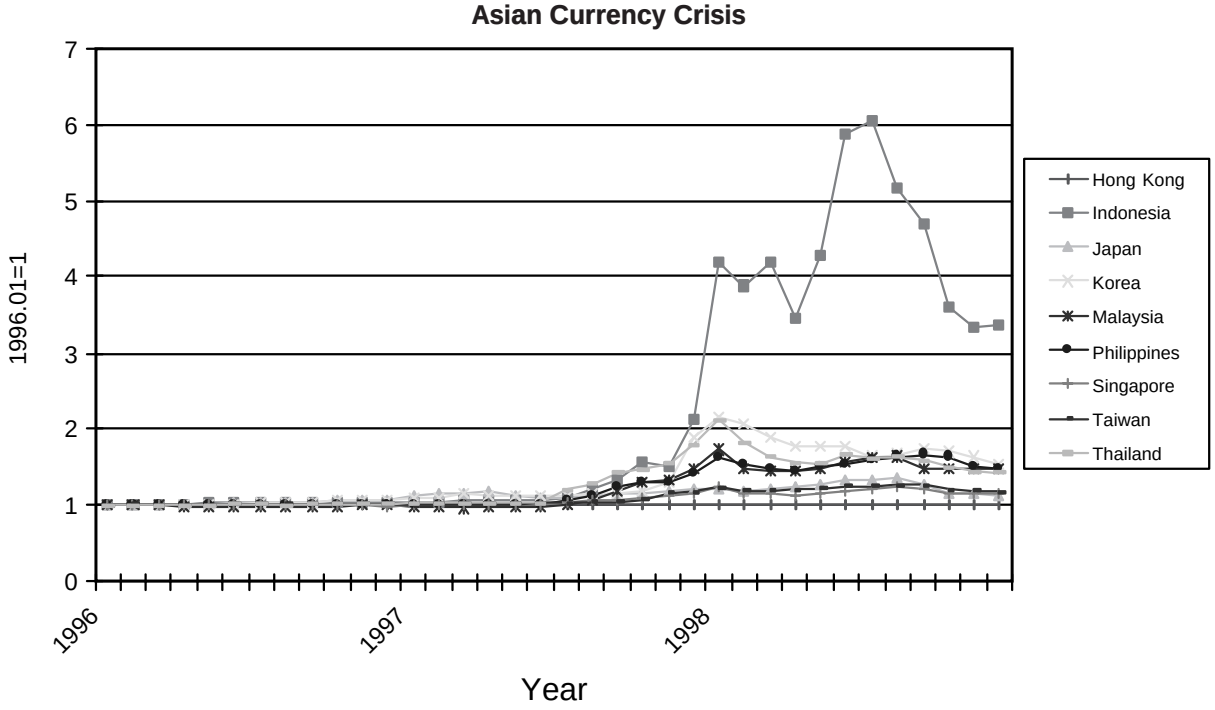

Table 2: Summary of Statistics of Rates of Return on Exchange Rates

	Pre-Crisis				Post-Crisis			
Currency of	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.
Hong Kong	-0.010	0.110	-0.515	0.258	0.007	0.070	-0.129	0.129
Indonesia	0.330	0.229	-0.617	1.259	6.407	22.491	-26.884	67.722
Japan	-0.201	2.801	-8.167	8.070	0.163	3.815	-10.397	4.043
Korea	0.279	0.782	-1.558	3.330	1.716	10.584	-8.857	36.954
Malaysia	-0.088	1.182	-3.403	5.304	2.282	6.979	-14.101	15.680
Philippines	-0.076	1.323	-4.553	3.504	2.182	5.379	-7.126	13.776
Singapore	-0.244	0.906	-2.091	2.299	0.795	3.028	-5.343	5.884
Taiwan	0.034	0.943	-2.305	3.665	0.817	2.748	-4.569	7.273
Thailand	0.030	0.426	-1.045	1.305	1.895	9.119	-15.378	17.237

Note: A positive rate of return means a depreciation of the currency against the US dollar, whereas a negative rate means an appreciation.

Table 3. Cross Correlation Matrix of Exchange Rate Changes for the Pre-Crisis Period

	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand
Hong Kong	1.0000								
Indonesia	0.1261	1.0000							
Japan	-0.0179	0.1071	1.0000						
Korea	-0.0156	-0.0059	0.3731	1.0000					
Malaysia	-0.0014	0.0484	0.2272	0.0332	1.0000				
Philippines	0.0289	0.0550	-0.1443	0.0604	0.0910	1.0000			
Singapore	-0.0774	0.1498	0.6012	0.3311	0.2955	-0.1218	1.0000		
Taiwan	0.0851	-0.0337	0.4185	0.1614	0.0703	0.0170	0.4435	1.0000	
Thailand	0.0118	0.1588	0.9005	0.3224	0.2724	-0.0902	0.7306	0.4010	1.0000

Table 4. Cross Correlation Matrix of Exchange Rate Changes for the Post-Crisis Period

	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand
Hong Kong	1.0000								
Indonesia	0.2303	1.0000							
Japan	-0.0038	0.4237	1.0000						
Korea	0.1335	0.5204	0.2202	1.0000					
Malaysia	0.0507	0.6918	0.4688	0.4871	1.0000				
Philippines	0.1302	0.6957	0.3141	0.5385	0.7887	1.0000			
Singapore	0.0158	0.7590	0.6364	0.5440	0.8032	0.7537	1.0000		
Taiwan	-0.2392	0.5405	0.6540	0.4804	0.5808	0.5302	0.7569	1.0000	
Thailand	0.0035	0.6380	0.4051	0.6220	0.7935	0.8369	0.8197	0.6051	1.0000

Table 5. OLS Results for the Pre-Crisis Period

Equation	Intercept	LDV	M2	INT	IP	RES	FD	EXP	IMP	R^2	Adj. R^2	DW
Hong Kong	-0.997×10^{-4}	-0.0106	0.0011	-0.111×10^{-3}	0.850×10^{-3}			-0.0060	0.0046	0.060	-0.021	2.03
	(-0.720)	(-0.087)	(0.191)	(-0.301)	(0.748)			(-1.979)*	(1.625)†			
Indonesia	0.0021	0.3017	-0.0055	-0.178×10^{-3}	-0.006	0.0173	0.0017	-0.0019	0.0013	0.213	0.119	1.97
	(4.036)***	(2.675)***	(-0.308)	(-1.221)	(-1.405)†	(2.151)**	(0.399)	(-0.622)	(0.572)			
Japan	0.0021	0.0805	-0.3655	0.0256	-0.2277	-0.0278	0.3814	-0.0081	0.0058	0.314	0.232	2.02
	(0.634)	(0.641)	(-1.220)	(2.052)**	(-1.243)	(-0.260)	(3.792)***	(-0.241)	(0.134)			
Korea	0.227×10^{-3}	0.3840	0.1670	0.0011	0.0391	-0.0187	0.0054	-0.0083	-0.0259	0.385	0.312	1.79
	(0.199)	(3.650)***	(3.692)***	(1.748)*	(1.589)†	(-0.737)	(0.213)	(-1.006)	(-1.901)*			
Malaysia	-0.0025	0.3019	0.1185	-0.0020	-0.0085	0.0094	0.0216	0.0183	-0.0262	0.216	0.122	1.77
	(-1.506)†	(2.581)**	(1.583)†	(-0.494)	(-0.274)	(0.411)	(1.343)†	(0.952)	(-1.129)			
Philippines	-0.0020	0.4357	0.1286	-0.0011	-0.0265	-0.0081	0.0063	-0.0149	0.0065	0.281	0.195	1.80
	(-1.147)	(3.927)***	(2.178)**	(-0.857)	(-1.147)	(-0.527)	(0.281)	(-0.969)	(0.374)			
Singapore	0.633×10^{-3}	-0.0111	0.0612	0.0046	0.0053	-0.2967	0.0913	-0.0390	0.0063	0.403	0.332	1.92
	(0.432)	(-0.082)	(0.634)	(2.304)**	(0.342)	(-3.715)***	(2.221)**	(-2.191)**	(0.355)			
Taiwan	-0.918×10^{-4}	0.4383	-0.0431	-0.0016	-0.0425	0.1107	0.0414	0.0297	-0.0098	0.344	0.266	1.68
	(-0.070)	(4.097)***	(-0.423)	(-1.289)	(-3.067)***	(1.622)†	(1.619)†	(2.309)**	(-0.777)			
Thailand	0.201×10^{-3}	0.3454	-0.0238	-0.450×10^{-3}	0.0134	0.0192	0.0019	0.245×10^{-3}	-0.0129	0.217	0.123	1.86
	(0.259)	(3.078)***	(-0.441)	(-2.093)**	(1.439)†	(0.957)	(0.161)	(0.036)	(-1.882)*			

Notes:

(1) Figures in parentheses are t-statistics.

(2) The symbols ***, **, *, and † denote statistical significance at the 1%, 5%, 10% and 20% levels respectively. The critical values (of two-tailed tests) used are those from t(57) for all economies, except Hong Kong which are from t(59).

Table 6. Summary of SUR Results for the Pre-Crisis Period

Equation	Intercept	LDV	M2	INT	IP	RES	FD	EXP	IMP	DW
Hong Kong	-0.103×10^{-3}	-0.0461	0.775×10^{-3}	-0.995×10^{-4}	0.560×10^{-3}			-0.0062	0.0048	1.98
	(-0.745)	(-0.394)	(0.146)	(-0.281)	(0.511)			(-2.126)**	(1.761)*	
Indonesia	0.0020	0.3257	-0.0068	-0.211×10^{-3}	-0.0067	0.0170	0.0015	-0.0022	0.807×10^{-3}	1.99
	(3.997)***	(2.947)***	(-0.387)	(-1.477)†	(-1.587)†	(2.161)**	(0.370)	(-0.738)	(0.351)	
Japan	-0.0010	0.1447	-0.3563	0.410×10^{-3}	-0.1090	0.0182	0.2125	0.0271	-0.0099	1.74
	(-0.330)	(1.550)†	(-1.821)*	(0.051)	(-0.947)	(0.261)	(3.364)***	(1.225)	(-0.334)	
Korea	0.562×10^{-3}	0.4060	0.1460	0.0012	0.0437	-0.0158	-0.0065	-0.0033	-0.0292	1.86
	(0.516)	(4.228)***	(3.511)***	(1.986)*	(1.945)*	(-0.683)	(-0.282)	(-0.440)	(-2.345)**	
Malaysia	-0.0023	0.3301	0.1097	-0.0028	0.0027	0.0051	0.0209	0.0183	-0.0305	1.86
	(-1.404)†	(2.943)***	(1.526)†	(-0.714)	(0.090)	(0.231)	(1.354)†	(0.994)	(-1.367)†	
Philippines	-0.0023	0.5092	0.1369	-0.0013	-0.0384	0.0024	0.848×10^{-3}	-0.0234	0.0142	1.95
	(-1.377)†	(5.031)***	(2.516)**	(-1.140)	(-1.819)*	(0.166)	(0.042)	(-1.661)†	(0.889)	
Singapore	0.729×10^{-3}	-0.0039	0.0526	0.0026	0.0153	-0.2654	0.0518	-0.0325	-0.0090	1.65
	(0.574)	(-0.036)	(0.681)	(1.676)*	(1.231)	(-4.208)***	(1.598)†	(-2.295)**	(-0.643)	
Taiwan	-0.387×10^{-3}	0.3591	0.0115	-0.0027	-0.0382	0.0596	0.0415	0.0303	-0.0129	1.62
	(-0.321)	(4.000)***	(0.137)	(-2.659)***	(-3.228)***	(1.068)	(1.980)*	(2.884)***	(-1.247)	
Thailand	0.505×10^{-4}	0.1673	0.205×10^{-3}	-0.156×10^{-3}	0.0052	0.0025	0.0058	0.0015	-0.0035	1.43
	(0.083)	(1.861)*	(0.006)	(-1.144)	(0.916)	(0.205)	(0.807)	(0.332)	(-0.808)	

Notes:

(1) Figures in parentheses are t-statistics.

(2) The symbols ***, **, *, and † denote statistical significance at the 1%, 5%, 10% and 20% levels respectively. The critical values (of two-tailed tests) used are those from t(57) for all economies, except Hong Kong which are from t(59).

Table 7. Results of Tests for Structural Changes

	Chow	Likelihood Ratio
Hong Kong	0.238	1.952
Indonesia	7.962***	62.169***
Japan	3.158***	29.943***
Korea	8.840***	66.986***
Malaysia	10.684***	76.341***
Philippines	4.381***	39.302***
Singapore	2.426**	23.840***
Taiwan	0.601	6.522
Thailand	11.308***	79.298***

Notes: ***, **, *, and † denote statistical significance at the 1%, 5%, 10% and 20% levels respectively. The critical values for Chow tests are those from F(9,72) for all economies, except Hong Kong which are from F(7,76). The critical values for likelihood ratio tests are those from $\chi^2(9)$ for all economies, except Hong Kong which are from $\chi^2(7)$.

Table 8. OLS Results for the Post-Crisis Period

Equation	Intercept	LDV	M2	INT	IP	RES	FD	EXP	IMP	R^2	Adj.R^2	DW
Hong Kong	$0.142x10^{-3}$	-0.3307	-0.0150	$0.457x10^{-5}$	0.0031			-0.0067	0.0038	0.595	0.248	2.51
	(0.965)	(-0.915)	(-1.322)	(0.041)	(1.059)			(-2.149)*	(0.767)			
Indonesia	0.0092	1.1865	0.9171	$0.341x10^{-4}$	0.9533	0.0568	-0.2265	-2.1623	-0.4707	0.608	-0.019	1.15
	(0.177)	(1.306)	(0.364)	(0.009)	(0.998)	(0.045)	(-0.384)	(-1.595)†	(-0.468)			
Japan	-0.0055	0.9861	3.1452	0.2156	-1.4289	0.0763	0.1639	0.3326	0.2221	0.778	0.423	1.85
	(-0.417)	(2.864)**	(2.424)*	(1.832)†	(-2.207)*	(0.093)	(0.329)	(2.187)*	(1.444)			
Korea	-0.0043	0.1446	0.4853	0.0061	-0.2151	0.0505	0.1685	-0.4316	0.1279	0.677	0.160	1.62
	(-0.197)	(0.198)	(0.290)	(0.424)	(-0.294)	(0.140)	(0.458)	(-1.950)†	(0.282)			
Malaysia	0.0035	0.5965	-0.8961	0.0366	-0.2749	-0.3106	-0.0278	0.3894	0.4332	0.823	0.539	1.71
	(0.299)	(1.856)†	(-1.149)	(3.333)**	(-1.062)	(-1.338)	(-0.139)	(1.820)†	(2.460)*			
Philippines	0.0184	-0.3263	1.0887	0.0246	-0.0650	0.0065	0.2459	0.0644	-0.0482	0.799	0.476	1.60
	(1.576)†	(-0.607)	(0.945)	(1.403)	(-0.325)	(0.019)	(0.775)	(1.381)	(-0.508)			
Singapore	0.0118	-0.2968	0.0031	0.0081	-0.1286	-0.6249	-0.0621	0.0822	0.0494	0.717	0.265	1.34
	(1.770)†	(-0.676)	(0.019)	(0.734)	(-1.119)	(-1.482)†	(-0.307)	(0.542)	(0.836)			
Taiwan	0.0033	0.1730	0.2894	0.0056	-0.1342	-0.3138	0.2104	0.1584	-0.1082	0.335	-0.729	1.76
	(0.411)	(0.271)	(0.200)	(0.226)	(-0.446)	(-0.344)	(0.860)	(0.801)	(-0.506)			
Thailand	$0.847x10^{-4}$	-0.8190	4.0270	0.0096	-0.8061	-0.4405	0.6449	-0.1992	0.1621	0.753	0.359	2.83
	(0.004)	(-1.156)	(1.255)	(1.153)	(-1.027)	(-1.261)	(1.090)	(-0.284)	(0.489)			

Notes:

(1) Figures in parentheses are t-statistics.

(2) The symbols ***, **, *, and † denote statistical significance at the 1%, 5%, 10% and 20% levels respectively. The critical values (of two-tailed tests) used are those from t(5) for all economies, except Hong Kong which are from t(7).

Table 9. Summary of SUR Results for the Post-Crisis Period

Equation	Intercept	LDV	M2	INT	IP	RES	FD	EXP	IMP	DW
Hong Kong	$0.138x10^{-3}$	-0.5144	-0.0145	$-0.632x10^{-5}$	0.0040			-0.0080	0.0056	2.74
	(0.946)	(-1.549)†	(-1.364)	(-0.060)	(1.484)†			(-2.729)**	(1.207)	
Indonesia	0.0172	0.8080	0.0888	-0.0019	0.7962	0.1688	-0.0482	-1.0453	-1.0164	1.50
	(0.347)	(1.308)	(0.050)	(-0.654)	(1.171)	(0.174)	(-0.107)	(-1.030)	(-1.458)	
Japan	-0.0085	0.8478	2.5615	0.1701	-1.5388	-0.0982	0.3017	0.3370	0.2321	2.00
	(-0.713)	(2.903)**	(2.305)*	(1.682)†	(-3.219)**	(-0.136)	(0.705)	(2.546)*	(1.757)†	
Korea	0.0043	-0.1006	-0.0409	0.0062	-0.0972	0.0348	0.3602	-0.5309	0.0796	1.74
	(0.207)	(-0.145)	(-0.026)	(0.475)	(-0.142)	(0.102)	(1.035)	(-2.545)*	(0.185)	
Malaysia	0.0045	0.4739	-0.7337	0.0335	-0.2682	-0.3319	$0.294x10^{-3}$	0.4245	0.4327	1.99
	-0.422	(2.087)*	(-1.224)	(4.743)***	(-1.367)	(-2.034)*	(0.002)	(2.728)**	(3.891)**	
Philippines	0.0191	-0.4684	1.6251	0.0282	-0.0261	0.1522	0.1783	0.0709	-0.0375	1.91
	(1.860)†	(-1.209)	(2.344)*	(2.639)**	(-0.187)	(0.765)	(0.871)	(2.150)*	(-0.650)	
Singapore	0.0105	-0.1749	0.0062	0.0078	-0.0944	-0.5188	-0.0772	0.0943	0.0438	1.60
	(1.679)†	(-0.483)	(0.052)	(0.955)	(-1.078)	(-1.592)†	(-0.510)	(0.782)	(1.013)	
Taiwan	0.0296	0.0288	0.6520	0.0051	-0.0778	-0.7166	0.2245	0.2291	-0.1853	1.84
	(0.384)	(0.061)	(0.610)	(0.306)	(-0.323)	(-1.090)	(1.215)	(1.654)†	(-1.193)	
Thailand	0.0073	-0.5890	2.8985	0.0073	-0.4894	-0.4322	0.5563	-0.2530	0.1479	2.65
	(0.323)	(-0.929)	(1.026)	(0.977)	(-0.695)	(-1.366)	(1.049)	(-0.408)	(0.501)	

Notes:

(1) Figures in parentheses are t-statistics.

(2) The symbols ***, **, *, and † denote statistical significance at the 1%, 5%, 10% and 20% levels respectively. The critical values (of two-tailed tests) used are those from t(5) for all economies, except Hong Kong which are from t(7).

Table 10. Cross Correlation Matrix of Residuals for the Pre-Crisis Period

	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand
Hong Kong	1.0000								
Indonesia	0.1860	1.0000							
Japan	0.0151	-0.0071	1.0000						
Korea	0.0734	-0.0072	0.3560	1.0000					
Malaysia	0.0148	0.0618	0.2495	-0.0733	1.0000				
Philippines	0.0053	-0.0284	-0.1883	0.1552	0.0732	1.0000			
Singapore	-0.0543	0.0299	0.5147	0.1756	0.2045	-0.3394	1.0000		
Taiwan	0.1681	-0.0016	0.5071	0.2649	0.1631	-0.0598	0.5298	1.0000	
Thailand	0.0094	0.0599	0.8822	0.3464	0.3100	-0.1091	0.6282	0.4010	1.0000

Table 11. Cross Correlation Matrix of Residuals for the Post-crisis Period

	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand
Hong Kong	1.0000								
Indonesia	-0.4300	1.0000							
Japan	0.0617	0.6193	1.0000						
Korea	-0.1453	-0.4249	-0.7476	1.0000					
Malaysia	-0.0694	0.5238	-0.7350	0.5365	1.0000				
Philippines	0.1860	0.2654	-0.3378	0.6128	0.3613	1.0000			
Singapore	-0.1483	0.9068	-0.5888	0.6410	0.7837	0.6800	1.0000		
Taiwan	-0.3872	0.6438	-0.5100	0.5548	0.4418	0.2860	0.5549	1.0000	
Thailand	-0.1099	0.1975	-0.7853	0.7373	0.7600	0.4011	0.7092	0.8003	1.0000

Table12. Cluster Analysis Results

Number of Clusters	Clusters Joined	Pseudo F	Centroid Distance
8	Singapore, Taiwan	3325	0.2425
7	Cluster 8, Japan	1657	0.2427
6	Cluster 7, Philippines	654	0.4245
5	Cluster 6, Thailand	485	0.4046
4	Cluster 5, Malaysia	440	0.4149
3	Cluster 4, Hong Kong	419	0.5243
2	Cluster 3, Korea	509	0.6377
1	Cluster 2, Indonesia	509	1.9565

Table 13: Analysis of Correlation Coefficients

Description of Correlation Coefficients	Number of Observations	Average Value for the post-crisis period	Average Increase over the pre-crisis period
Between Malaysia, Thailand, and the Philippines	3	0.5075	0.4161
Between the Above Three Countries and the Remaining Six Countries	18	0.2624	0.1239
Between All Countries Except Those Three in the First Row	33	0.1613	0.0024
Between All Countries	36	0.1902	0.0396

Figure 2: Dendrogram Showing the Merging Process