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Crisis, Contagion, and East Asian Stock Markets

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Following the 1997 financial crisis in East Asia, the issue of contagion has resurfaced. Contagion has most often been associated with high frequency events; hence, it has been measured on stock market returns, interest rates, the exchange rate, or linear combinations of them. This paper tests for evidence of contagion between selected East Asian stock markets, thereby exploring the importance of the linkages between stock markets as a transmission channel during the crisis.

Keywords: Asian financial crisis; contagion; stock markets.

1. Introduction

The crisis that struck Thailand when it devalued its baht in July 1997, and the subsequent contagion that crippled East Asian economies throughout the following two years surprised many due to its rapidity and its pervasiveness — by mid-1998, most of the economies in the region were in crises of a similar nature, and the effects of contagion impacted both the real and monetary sectors for the economies in which they afflicted.

Indeed, even as globalization proceeds apace, the increased capital flows between economies is likely to exacerbate, not reduce, the interdependence of economies and consequently, the heightened possibility of contagion. This

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was clearly illustrated by the contagion scare in late 2000 when unfavorable developments in both Argentina and Turkey threatened afresh fears of a new round of emerging market crises and contagion.

Perhaps, foremost in the list of pressing questions is the extent to which contagion might affect or influence otherwise sound economies, and how these effects might somehow be mitigated. Research efforts have consequently been directed toward these two aspects: the first as an *ex ante* preventive and precautionary measure, and the other an *ex post* control and recovery one.

This paper proposes to address the former aspect of the question in greater detail. In particular, it will apply a range of empirical tests on the stock markets in East Asia, in order to draw some tentative conclusions as to how far these markets are interrelated, and implicitly, the degree to which a collapse in one might lead to a similar phenomenon in another. Specifically, it employs two of the four strategies commonly encountered in the literature — namely, correlation methods (the most basic), and the Vector Autoregressive (VAR) approach (the workhorse model in the empirical literature). Its primary contribution, in employing rigorous empirical tools to study the existence and extent of contagion in the equity markets of East Asia, is to inform the policy debate, especially since the performance of stock markets are a commonly used leading indicator.

This study contributes to the existing literature in a number of ways. First, this study concentrates only on East Asian stock markets, and therefore takes on a unique regional, rather than a global, perspective. This prevents global developments from muting key developments in the region. Second, the data used in this study consists of time series of daily stock market indices, in terms of local currency units, of the nine East Asian stock markets. The data set was chosen for two main reasons: since a month or even a week may be long enough to conceal interactions that may last only for a few days, it is more appropriate to use daily data as opposed to data with longer spans; in addition, the use of local-currency denominated indices in these markets facilitate an examination of the diversification effects of local stock market risk while abstracting from currency risk. Third, in order to investigate the effects of contagion on regional stock markets, the data set is divided into two sub-periods: a first, tranquil sub-period, and a second sub-period involving crisis.

The paper will proceed as follows. Section 2 will briefly review the data on capital flows to the region, concentrating especially on portfolio flows and the performance of East Asian equity markets. Section 3 goes on to examine the theoretical and empirical literature pertaining to currency crises in general, and contagion in particular. This will be followed by an empirical study of nine East Asian stock markets[1] for the period January 4, 1990 through to October 12, 2000 (Sec. 4). A final section concludes by providing an interpretation of the results as well as drawing some tentative policy conclusions.

The opinions and conclusions expressed here are those of the authors and should not be attributed to ADB, ADB Institute, its board of directors, or the countries they represent.

2. Capital Flows to the East Asian Economies

Attracting foreign private capital flows, especially those of portfolio investment, became one of the primary goals throughout the region in the 1980s, mainly because it ensured an adequate supply of capital for long-term growth. While portfolio flows in the East Asian markets were insignificant during the 1970s and 1980s, they became sizable in the early 1990s. Before the crisis,[2] portfolio flows reached US$29.4 billion in 1996 (Table 1), and hence, represented the largest component of flows between 1992 and 1996 in the region.[3]

The crisis in the region led to a sharp reversal in portfolio flows to global emerging economies. Nevertheless, as compared to before 1990, portfolio inflows to East Asian countries remained strong at the early stage of the 1997 crisis, before collapsing in 1998 as a result of the financial crisis. This trend, however, did not persist, and by 1999, capital flows resumed into the Asia-5 economies, although the rest of emerging Asia is expected to recover more slowly. This phenomenon — accompanied by an accelerated growth in GDP to pre-crisis levels — is the basis for what has widely been trumpeted as the "V"-shaped recovery of the region from the crisis.

In more recent times, however, the sustainability of this recovery has increasingly been called into question, leading some commentators to suggest that the recovery might very well be "W"-shaped instead. Although

[1]Hong Kong, Indonesia, Korea, Malaysia, Thailand, the Philippines, Singapore, Taiwan, and Japan.

[2]Although the dating of the Asian financial crisis differs among observers, this paper will use the term "pre-crisis" to refer to the period before July 1997 (where devaluation of the Thai baht is widely acknowledged as the trigger event of the crisis), and "post-crisis" to refer to the period after December 1998 (where most of the economies, save perhaps Indonesia, had recovered to pre-crisis levels of GDP).

[3]In contrast, note that foreign direct investment, a component of capital flows far less volatile than portfolio investment, rose to only approximately US$6 billion in the beginning of the 1990s. As expected, however, these flows proved to be more resilient post-crisis, and in fact reached a peak of US$13.1 billion in 1999.

Table 1. Emerging market economies: Net capital inflows. (Billions of US dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Asia-5 Economies										
Net Private Cap. Flows	21.4	22.5	33.6	53.9	67.4	−15.6	−28.2	2.9	−22.4	10.6
Direct investment, net	6.3	6.7	6.5	8.8	9.8	9.8	10.3	13.1	9.1	9.0
Portfolio Inv., net	12.4	18.3	12.0	18.8	25.5	8.4	−8.2	12.8	13.2	3.3
Other Inv. Flows, net	2.7	−2.5	15.1	26.3	32.0	−33.8	−30.4	−23.0	−44.6	−1.7
Net Official Flows	2.1	1.4	0.6	0.7	−6.1	15.7	19.5	−6.7	5.0	−2.1
Change in Reserves[a]	−18.2	−20.6	−6.1	−18.5	−5.6	39.5	−47.0	−38.8	−19.2	−30.6
Current Account Balance	−16.1	−13.5	−23.2	−40.4	−53.0	−25.0	69.7	61.7	44.3	23.2
Other Asian Emerging Economies										
Net Private Cap. Flows	−7.4	20.8	36.0	38.3	52.6	22.3	−12.5	−0.6	4.6	13.0
Direct investment, net	8.4	26.3	38.2	39.3	44.4	45.3	49.6	41.1	38.4	38.9
Portfolio Inv., net	3.4	0.9	7.0	2.6	3.9	−0.1	−7.2	−8.9	−8.0	−0.2
Other Inv. Flows, net	−19.2	−6.4	−9.2	−3.5	4.3	−23.0	−54.8	−32.8	−25.8	−25.8
Net Official Flows	8.9	8.1	2.0	−3.8	−7.6	−8.3	−1.1	−0.1	−8.1	−4.2
Change in Reserves[a]	−7.7	−14.9	−51.7	−26.2	−43.1	−46.8	−16.9	−20.9	−16.4	−30.8
Current Account Balance	14.1	−8.2	18.9	9.2	16.3	50.4	41.4	36.7	34.9	34.1

[a]Minus sign denotes a rise and vice versa.
Source: IMF (2000).

the full extent of this recovery is debatable, and may very well be muted, the performance of most[4] stock markets did rise sharply from the levels seen in 1997, before correcting to lower levels from mid-2000 onwards. This is reflected in Fig. 1, which tracks the performance of the primary equity markets in the 9 East Asian economies. In order to draw stronger conclusions on the relation between the stock market performance and portfolio flows, however, it is necessary to examine data on these flows for the time period in question.

Decomposing this into a snapshot between the end of 1996 and end of 1997, it can be seen that East Asian equities, excluding Taiwan, experienced a considerable loss in their values post-crisis (Table 2). This implies two stylized facts: first, that the fall in portfolio flows into the region has affected almost all stock markets; and second, these stock markets have experienced significant concomitant declines, all within the relatively short span of a year.

Cursory examination of these facts begs the question: is there a relation between these markets that has led to their concerted weakening, and if so, how strong is this relation? Alternatively, how integrated are the stock markets of East Asia, such that contagion effects between them are real and significant? Furthermore, what policy implications can be drawn based on the degree of interdependence of East Asian markets? These questions have provided the motivation to seek empirically based answers, and hence serve as the foundation for the current study.

3. Crises and Contagion

3.1. *First and second generation financial crises*[5]

Since the seminal work on balance of payments crises and speculative attacks by Krugman (1979), the literature on financial crises has evolved over time. The first generation models (see, for example, Krugman, 1979, and Flood and Garber, 1984) dealt with the unsustainability of a fixed currency peg due to the inconsistency between money creation, in order to finance the budget deficit, and the maintenance of the peg that required monetary policy to be amenable to the defense of the currency. Being aware of this, rational agents will engage in a speculative attack of the exchange rate, which triggers an adjustment of the exchange rate. Later models (Flood, Garber and Kramer, 1996; Flood and Marion, 1996) extend the analyses to include

[4]Save for Thailand and Taiwan, the latter which was hardly affected by the crisis.

[5]A useful summary of the currency crisis literature is provided by Flood and Marion (1999).

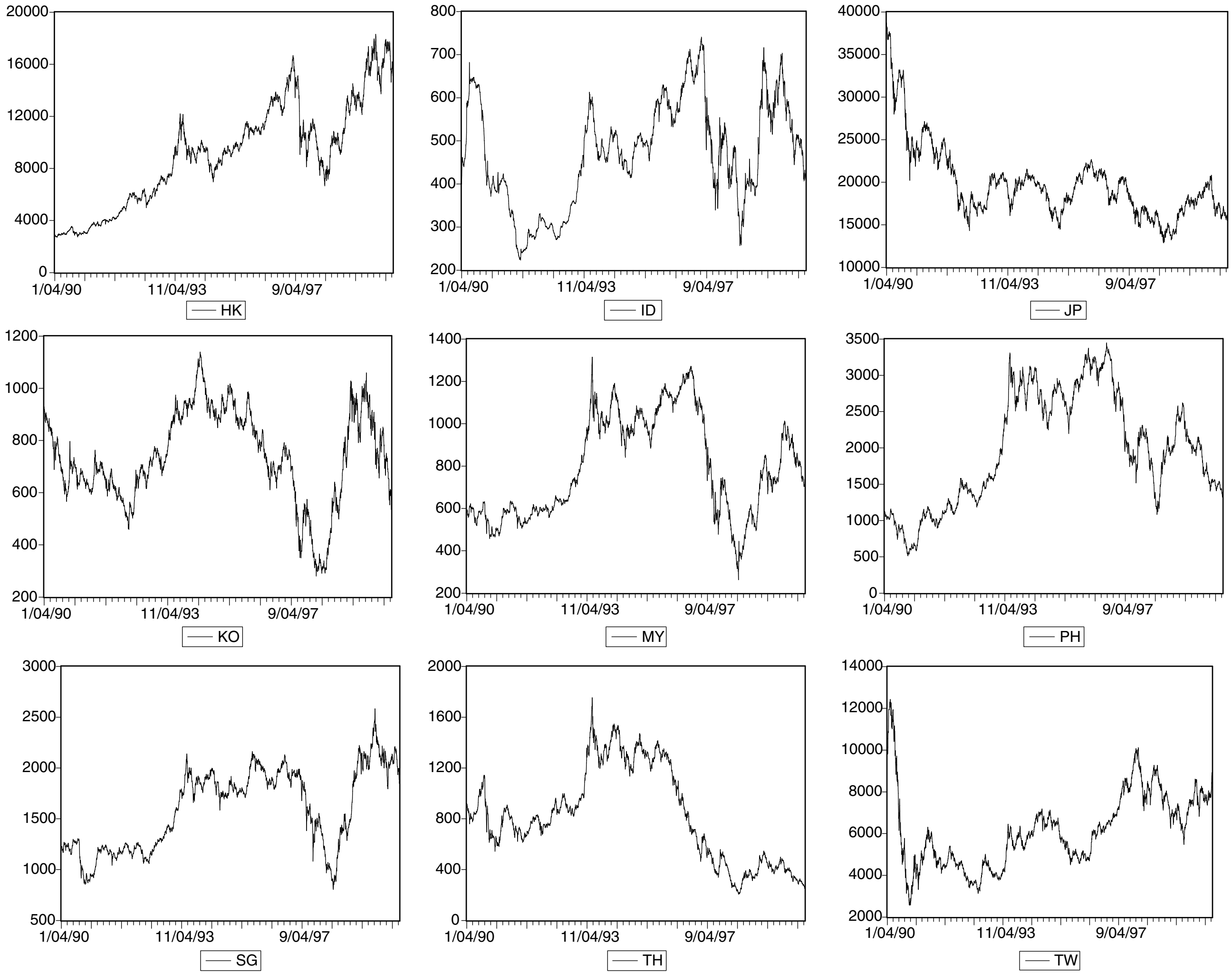

Fig. 1. Performance of regional stock markets.

Table 2. Equity market changes in 1997 (end 1996 to end 1997).

Equity Market	Index	% Change Local Currency	% Change US$
Hong Kong	Hang Seng	−20.3	−20.4
Japan	Nikkei	−21.2	−30.1
Korea	Kopsi	−42.4	−71.2
Malaysia	Composite	−52.0	−68.7
Singapore	Straits Times	−31.0	−42.5
Taiwan	Weighted	18.1	−0.5
Thailand	SET	−55.2	−76.1

Source: *World Financial Markets*, JP Morgan, 2/1/98.

scenarios where monetary authorities are non-passive as well as cases where uncertainties exist. However, these models were premised on the existence of weaknesses in macroeconomic fundamentals, and a key element missing in the first generation models is the existence of contagion and contagion effects.

The second generation models of financial crises focused on the existence of multiple equilibria as an explanation for currency and banking crises, best captured in the papers by Obstfeld (1986, 1994), introduced the notion that such crises could possibly be explained by a movement from one equilibrium towards another, which can be alluded to as a "bad" equilibrium, through nonlinearities in government behavior. These nonlinearities are often triggered by incompatibilities between the expectations of agents and government signals or incentives. Second generation models also spawned the possibility of herding behavior as a cause of currency and financial crises.

In the aftermath of the Asian financial crisis, there arose a new strand in the theoretical literature that emphasized moral hazard as well as contagion, especially in the context of emerging markets (Chang and Velasco, 1999; Corsetti, Pesenti, and Roubini, 1999). These papers provide the missing links that can possibly reconcile the two disparate trends between the first generation fundamentals-based and the second generation self-fulfilling, multiple equilibria-based models. Such models posit a linkage between banking and currency crises due to bailout and illiquidity effects, hence, breaking the purely monetary nature of earlier models and allowing financial crises to have real effects.[6] The key in such models are that unanticipated shocks

[6]Note that these models implicitly assert that there is no pure contagion phenomenon, only a concerted failure attributable to symmetric structural weaknesses across (possibly) highly integrated economies, as transmitted through trade and/or financial channels. The differences in definition are discussed below.

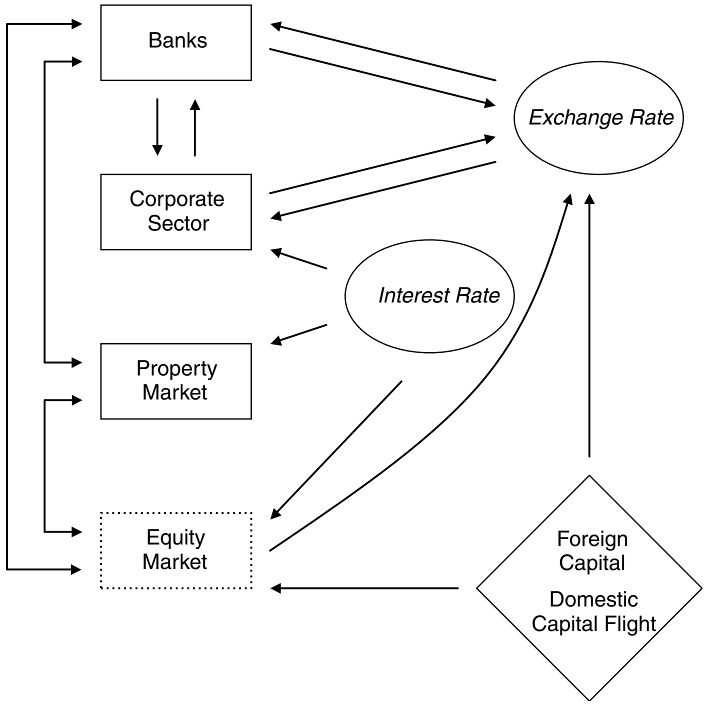

Fig. 2. Dynamics of financial turmoil.

may be exacerbated by financial sector weaknesses and kick the economy into a "bad", crisis equilibrium. Taken together, these provide the basis for a theoretical justification of the contagion phenomenon.

A useful schematic for understanding the dynamics of financial turmoil in this context, and the interrelationships between different sectors of the real and monetary sectors of the economy, is given by Fig. 2. As evident, the interrelationships between the various real and monetary sectors of the economy form a complex, interdependent web of cause and effect. For example, consider the case of an exogenous foreign capital flight, which leads to a depreciation in the exchange rate. This would impact both loans made in foreign currency by the banking sector, as well as transactions invoiced in foreign currency by the corporate sector. This in turn generates negative feedback effects where overstretched banks and companies might fail, leading to a loss of confidence in currency markets which further depreciates the exchange rate. The failure of banks could also lead to significant declines in property markets (since banks in emerging markets typically are involved in the ownership of property) as well as trigger a run in nervous stock markets.

These, in turn, continue to influence the (already weak) exchange rate, and the financial turmoil continues its spread through the economy. The schematic is easily extended to account for international negative spillover effects, either by the inclusion of an export sector, or through pressures on the exchange rates of otherwise sound economies through the medium of competitive devaluations.[7]

3.2. *Defining contagion*

There is no singular definition of contagion. The World Bank has represented contagion according to three definitions: one broad, another more restrictive, and the last very restrictive. The broad definition of contagion defines it as the cross-country transmission of shocks or any general cross-country spillover effect — whether real, financial, or from exogenous sunspots. Contagion can then take place both during the tranquil and crisis periods; here, contagion does not need to be related to crises. However, studies on contagion have tended to emphasize crisis periods, such as the EMS crisis of 1992–1993, or, more relevant to this study, the Asian financial crisis.

A slightly more restrictive definition of contagion is that it is the transmission of shocks to other countries or, more generally, significant cross-country correlations that exist beyond any fundamental links between countries and beyond common shocks. This definition is usually referred as excess co-movement, and is commonly explained by herding behavior leading to sunspots.

The most restrictive definition of contagion, is that the phenomenon occurs when cross-country correlations increase during the crisis period relative to correlations during the tranquil period. However, this final definition tends to be too exclusive, as it lends itself to the possibility of strong statistical relationships that might not be related to any underlying economic theory.

The literature has generally been divided as to whether transmission through real or financial channels constitutes contagion.[8] Later researchers

[7] Glick and Rose (1999) argue that trade linkages are a potential transmission channel for currency contagion.

[8] Real linkages have been identified by the theoretical literature to be shocks propagated via trade, policy coordination, country reevaluation, and random real global shocks (the so-called non crisis-contingent theories), whilst monetary linkages include multiple equilibria due to shifts in investor expectations, endogenous liquidity shocks, political contagion, and random global monetary shocks (the crisis-contingent theories). For an overview of this literature, see Forbes and Rigobon (1999b).

have therefore tended to adopt the semantic that "pure" contagion is unrelated to these two transmission channels, and is hence entirely captured by shifts in market actors' perceptions and attitudes towards risk. The first two forms are referred to merely as interdependence or spillovers.

However, it has been argued that contagion is best defined as a significant increase in cross-market linkages after a shock to an individual country or group of countries (Dornbush, Park, and Claessens, 2000). This definition is attractive as it asserts that contagion arises due to a shift in cross-market linkages; a tendency that is often phrased as "shift-contagion" (Forbes and Rigobon, 2002). For this reason, this definition will form the basis of this current study, and the problems that arise from the somewhat contrived notions of interdependence versus pure contagion can be safely omitted.

3.3. *Empirical studies of contagion*

Given the above definitions, four major strategies have been applied by researchers in order to identify contagion: correlation of asset prices, conditional probability of currency crises, the transmission of volatility changes, and co-movements of capital flows and rates of return. Among these four groups, this study is most related to the study of correlations and co-movements of asset prices.

The estimation of correlation coefficients among stock returns is the most common method used in estimating contagion effects (Calvo and Reinhart, 1996).[9] In a typical example of the literature, Calvo and Reinhart (1996) examine the contagion effects of capital flows by analyzing the cross-country correlations among emerging market stock returns. By breaking the sample period into three sub-samples, with the first sub-period being described as having heavy capital inflows, the second as having moderate capital flows and the third as being the crisis period, they found that stock return correlations tend to be higher during the crisis period. However, the presence of high correlation coefficients may have different interpretations, and as Forbes and Rigobon (2002), *inter alia*, have argued, a reliance on unadjusted correlation coefficients are a necessary but not sufficient condition to guarantee the existence of contagion. This is because simple correlation coefficients

[9] Corsetti, Pericoli, and Sbracia (2001) provide both an overview as well as a critique of the existing literature that is based on the correlation analysis approach.

are subjected to biases that arise due to the presence of heteroscedasticity, endogeneity, and omitted variables.

The probability approach seeks to predict the probability that other countries will be affected by a crisis given that one country has already experienced it. The literature can be traced to Eichengreen, Rose and Wypolsz (1996), who, using a Probit model, test for contagion in the abandonment of a fixed exchange rate regime in the ERM episode. Alternative approaches in the same vein of utilizing statistical probability tests include the application of multinomial logistic regression (Bae, Karolyi, and Stulz, 2003).

Studies have also been based on the extent to which volatility in one financial market influences the volatility in another. In particular, research has attempted to explore how, when one country is in the midst of a crisis, the volatility of the financial markets in another is dramatically increased. Empirical work along this line has engaged either ARCH or GARCH methodology (examples include Edwards, 1998; and Hamao, Masulis and Ng, 1990).

Finally, contagion can be studied via examining the increase in the degree of co-movement during the crisis period, as compared to the tranquil period, given normal independence of economies. In this case, an alternative approach to assess the extent of any co-movements is used in order to test cross-country stock prices for cointegration.

The correlation and cointegration studies measure the co-movements across markets but fall short in terms of exploring changes in the existence and the directions of causality. Hence, another approach to determining contagion is to apply Granger-causality approach and to estimate vector autoregressions, analyze the corresponding impulse response functions, and conduct innovation accounting. As noted by Rogers (1994), impulse responses and variance decompositions may change during periods of a crisis. In order to assess changes in the behavior of the system, we can conduct innovation accounting as well as examine the impulse response functions. Innovation accounting provides information on the extent to which innovations in the stock price in one market explain variations in another. Contagion effects manifest themselves when the percentage of variation explained by their own innovations decline, while that of innovations in other stock markets increase. Similarly, abrupt changes in impulse responses, as compared to periods of relative normalcy, may indicate the existence of contagion effects.

4. Empirical Analysis

An important idiosyncratic of emerging and developing economies is that a crisis tends to result in contagion effects that are largely regional in scope. Hence, rather than looking through a global perspective, this study will focus on nine East Asian stock markets. These include six major crisis-stricken economies — Hong Kong, Indonesia, Korea, Malaysia, Thailand, and the Philippines; two less affected economies — Singapore and Taiwan; and one developed market — Japan. These markets will be analyzed based on their recent developmental experience — from January 1990, up till October 2000 — the aftermath of the East Asian financial crisis. To understand the trends, the sample will be divided into two stages: Pre-crisis (January 1990 to May 1997) and post-crisis (June 1997 to October 2000). By covering about 10 years of rapid economic and financial developments, it is hoped that a more conclusive analysis of these markets will be generated.

The empirical analysis starts with one basic question: how integrated are the East Asian stock markets? To address that first question, the co-movements of the stock markets in those nine economies will be evaluated. Standard correlation tests will be conducted to highlight the short-run relations between the movements of the stock price indices in the region. In addition, pair-wise Granger-causality tests will also be performed to determine the temporal ordering of each pair of stock markets in question. To supplement the short-run analysis, cointegration tests are also run to distil long-run co-movements between those stock indices.

To take the study one step further, a Vector Autoregressive (VAR) model will be employed. The objective here is to analyze the degree to which a change in one country's stock price exerts an influence on a change in other countries' stock price series. The technique in the VAR model will test the proportion of the movements in the stock index that is due to its own shocks, versus those originating from other markets. From the test, the time-span in which a shock in one market takes to exert an impact on the other market can also be analyzed. This allows us to see if there was indeed significant transmission of pressure in the respective markets, as well as how persistent those shocks were.

Before proceeding on to the analysis, there are a few caveats about the results that follow. First, since this study only considers regional stock markets rather than a global perspective, these results may be sensitive to the US stock market. We have chosen not to condition on this variable for several reasons. First, by doing so, the possible first-order effect of US stock prices would wash out any residual interrelationships between the East Asian stock markets, and hence detract from the research question of interest (to examine contagion effects in East Asian markets). Second, the US market did not experience a decline in the Asian financial crisis period. As such, we exercise the *ceteris paribus* assumption that any influences the US stock market may have, would be equally transmitted to all stock markets in the region. Third, as the empirical hyperinflation literature has demonstrated, in periods of financial crisis, it is the rapidly changing monetary factors that are predominant. This suggests that, during the crisis, spillover effects from other regional markets may be more important in determining stock prices, rather than the usual influence of the US stock market.

Second, it should be noted that both bivariate tests are limited to short-run interrelationships, and should be interpreted accordingly. Third, it is important to note that the tests for Granger-causality are more of a temporal ordering with predictive ability, rather than "causal" as that word is commonly understood. Hence, although this study liberally makes use of the word "causal", such relationships should perhaps be seen and understood better as "preceding". Henceforth, cointegration tests do not measure the extent of interdependency among the East Asian stock markets. Therefore, an absence of cointegration should simply mean that it rules out the existence of a long-run equilibrium tending relationship.

4.1. *Bivariate tests*

4.1.1. *The correlation test: short-term interrelationships*

This section uses daily stock returns to examine the correlation between nine East Asian stock markets. Correlation coefficients are used to measure the extent of the association between the stock returns. The basic aims here are: to compare the relationships among the East Asian stock markets pre- and post-financial crisis, to determine if any short-term co-movement exists in the region, and to determine whether there are any contagion effects.

The test results of the correlation coefficients between the daily stock returns in nine East Asian markets indicate that there was a significant difference between sub-periods 1 and 2 in terms of the degree of association in these markets. As shown in Tables 3 and 4, an overall improvement of correlation coefficients for each pair from sub-periods 1 to 2, except for Malaysia and Taiwan, can clearly be observed. Furthermore, the results of this study provide further evidence corroborating the strong relationship between Singapore and Malaysia. Singapore and Malaysia display

Table 3. Correlation coefficients (first sub-period).

	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Thailand	Taiwan
Hong Kong	1.000000	0.172982	0.254087	0.077327	0.456927	0.156181	0.507175	0.312401	0.087549
Indonesia		1.000000	0.060144	0.014882	0.208835	0.093019	0.222056	0.158269	0.028950
Japan			1.000000	0.047531	0.258712	0.111206	0.320317	0.150763	0.128479
Korea				1.000000	0.115473	0.026914	0.133794	0.144925	0.097832
Malaysia					1.000000	0.200528	0.670796	0.380867	0.124496
Philippines						1.000000	0.230745	0.147125	0.109296
Singapore							1.000000	0.396313	0.140173
Thailand								1.000000	0.138149
Taiwan									1.000000

Table 4. Correlation coefficients (second sub-period).

	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Thailand	Taiwan
Hong Kong	1.000000	0.374571	0.405360	0.285305	0.331905	0.229516	0.664979	0.392422	0.046512
Indonesia		1.000000	0.212605	0.182135	0.261296	0.206955	0.456000	0.363466	0.022818
Japan			1.000000	0.232292	0.222164	0.091728	0.350110	0.231754	0.048840
Korea				1.000000	0.203134	0.175718	0.292203	0.304163	0.063359
Malaysia					1.000000	0.167283	0.379458	0.318320	−0.003500
Philippines						1.000000	0.269644	0.239944	0.021215
Singapore							1.000000	0.473169	0.029627
Thailand								1.000000	−0.042946
Taiwan									1.000000

the highest correlation coefficients in both sub-periods, giving weight to the widely held belief that the mutual economic interdependence of their economies that has led them to be regarded as a single market. One notable fact in the second period is that the correlation coefficients between Malaysia and other markets, especially with Singapore, drop sharply. This may be due to the capital controls imposed in Malaysia after crisis. Another interesting point here is that Taiwan yields lower correlation coefficients *vis-à-vis* other markets in the region. This result may explain why Taiwan was less affected by the crisis, due to the fact that the Taiwanese market is very independent of the other markets.

Overall, the results from the correlation coefficients may suggest some conclusions concerning the short-term relations between East Asian stock markets. One is that the correlation coefficients indicate there are short-term co-movements among East Asian stock markets, which suggests that contagion effects exist in the region. Another conclusion is that the correlation coefficients in this study suggest that capital controls may have an impact on the role of short-term relations between East Asian stock markets.

4.1.2. *Pairwise Granger-causality tests*

The Granger-causality test (Granger, 1969) involves estimating the following equations:

$$\mathrm{Y}_t = a + b_i \mathrm{Y}_{t-i} + c_i \mathrm{X}_{t-i} + u_t, \tag{1}$$

$$\mathrm{X}_t = a' + b_i' \mathrm{X}_{t-i} + c_i' \mathrm{Y}_{t-i} + u_t', \tag{2}$$

where a and a' are constant coefficients, u and u' are random disturbance terms, Y_t is a stock return time series Y, and X_t is a stock return series X.

Briefly, the Granger-causality test consists of running regressions of one stock return on its lagged values and on other stock returns. Hence, if the lagged values of one stock return do not yield a statistically significant relationship, then it can be stated that the stock return does not Granger-cause the other stock return. ADF and Phillips–Perron tests are used to check the stationarity of the series. The null hypotheses of the Granger-causality being tested are that the joint significance of all c_i is zero, if each stock return does not Granger-cause one and another. Hence, the test is the standard F-test. The results of pairwise Granger-causality tests are reported in Tables 5 and 6.

Several interesting observations emerge from the Granger-causality analysis. First, the findings show, and perhaps to some surprise, that Japan

Table 5. Pairwise Granger-causality tests (first sub-period).

Null Hypothesis	Obs	F-Statistic	Probability
DLID does not Granger Cause DLHK	1935	0.06047	0.94132
DLHK does not Granger Cause DLID		9.48763	7.9E-05
DLJP does not Granger Cause DLHK	1935	1.64032	0.19419
DLHK does not Granger Cause DLJP		0.64539	0.52457
DLKO does not Granger Cause DLHK	1935	1.43958	0.23728
DLHK does not Granger Cause DLKO		2.47346	0.08456
DLMY does not Granger Cause DLHK	1935	4.30233	0.01367
DLHK does not Granger Cause DLMY		1.76116	0.17212
DLPH does not Granger Cause DLHK	1935	38.6370	0.00000
DLHK does not Granger Cause DLPH		4.35718	0.01294
DLSG does not Granger Cause DLHK	1935	3.28741	0.03756
DLHK does not Granger Cause DLSG		0.67464	0.50946
DLTH does not Granger Cause DLHK	1935	5.34820	0.00483
DLHK does not Granger Cause DLTH		19.1119	6.0E-09
DLTW does not Granger Cause DLHK	1935	0.11012	0.89573
DLHK does not Granger Cause DLTW		5.24541	0.00535
DLJP does not Granger Cause DLID	1935	1.18495	0.30598
DLID does not Granger Cause DLJP		0.23583	0.78994
DLKO does not Granger Cause DLID	1935	3.44927	0.03196
DLID does not Granger Cause DLKO		1.55044	0.21242
DLMY does not Granger Cause DLID	1935	25.5563	1.1E-11
DLID does not Granger Cause DLMY		0.36554	0.69387
DLPH does not Granger Cause DLID	1935	33.1601	6.9E-15
DLID does not Granger Cause DLPH		0.63104	0.53215
DLSG does not Granger Cause DLID	1935	20.9336	1.0E-09
DLID does not Granger Cause DLSG		1.70684	0.18171
DLTH does not Granger Cause DLID	1935	13.8367	1.1E-06
DLID does not Granger Cause DLTH		0.46407	0.62879
DLTW does not Granger Cause DLID	1935	9.77816	6.0E-05
DLID does not Granger Cause DLTW		1.06366	0.34539
DLKO does not Granger Cause DLJP	1935	3.26977	0.03823
DLJP does not Granger Cause DLKO		2.92319	0.05400
DLMY does not Granger Cause DLJP	1935	1.56308	0.20975
DLJP does not Granger Cause DLMY		0.18312	0.83268
DLPH does not Granger Cause DLJP	1935	7.06111	0.00088
DLJP does not Granger Cause DLPH		2.09606	0.12322
DLSG does not Granger Cause DLJP	1935	4.35902	0.01292
DLJP does not Granger Cause DLSG		0.28027	0.75561
DLTH does not Granger Cause DLJP	1935	0.07118	0.93129
DLJP does not Granger Cause DLTH		2.15955	0.11566

Table 5. (*Continued*).

Null Hypothesis	Obs	F-Statistic	Probability
DLTW does not Granger Cause DLJP	1935	0.06250	0.93942
DLJP does not Granger Cause DLTW		1.81890	0.16248
DLMY does not Granger Cause DLKO	1935	2.67907	0.06888
DLKO does not Granger Cause DLMY		0.97914	0.37582
DLPH does not Granger Cause DLKO	1935	2.68883	0.06821
DLKO does not Granger Cause DLPH		0.13876	0.87044
DLSG does not Granger Cause DLKO	1935	4.00820	0.01832
DLKO does not Granger Cause DLSG		3.49818	0.03044
DLTH does not Granger Cause DLKO	1935	1.09122	0.33601
DLKO does not Granger Cause DLTH		1.02090	0.36047
DLTW does not Granger Cause DLKO	1935	1.10421	0.33168
DLKO does not Granger Cause DLTW		0.27173	0.76209
DLPH does not Granger Cause DLMY	1935	45.5501	0.00000
DLMY does not Granger Cause DLPH		1.69037	0.18472
DLSG does not Granger Cause DLMY	1935	15.1383	3.0E-07
DLMY does not Granger Cause DLSG		2.47036	0.08482
DLTH does not Granger Cause DLMY	1935	2.02024	0.13290
DLMY does not Granger Cause DLTH		25.2450	1.5E-11
DLTW does not Granger Cause DLMY	1935	0.24909	0.77953
DLMY does not Granger Cause DLTW		18.2001	1.5E-08
DLSG does not Granger Cause DLPH	1935	1.28428	0.27709
DLPH does not Granger Cause DLSG		57.7128	0.00000
DLTH does not Granger Cause DLPH	1935	2.86520	0.05721
DLPH does not Granger Cause DLTH		41.7807	0.00000
DLTW does not Granger Cause DLPH	1935	0.84266	0.43072
DLPH does not Granger Cause DLTW		13.5190	1.5E-06
DLTH does not Granger Cause DLSG	1935	1.20760	0.29914
DLSG does not Granger Cause DLTH		35.5234	7.1E-16
DLTW does not Granger Cause DLSG	1935	0.30919	0.73408
DLSG does not Granger Cause DLTW		18.7559	8.6E-09
DLTW does not Granger Cause DLTH	1935	2.61550	0.07339
DLTH does not Granger Cause DLTW		3.98990	0.01865

has no influence on other markets pre- and post-crisis. This suggests that, contrary to a purely regional explanation, contagion effects may also be related to the levels of economic development. This is somewhat corroborated by the result that Singapore, the other regional economy that is relatively well-developed, has had the least influence on other markets post-crisis.

Table 6. Pairwise Granger-causality tests (second sub-period).

Null Hypothesis	Obs	F-Statistic	Probability
DLID does not Granger Cause DLHK	880	3.19174	0.04158
DLHK does not Granger Cause DLID		5.09884	0.00629
DLJP does not Granger Cause DLHK	880	1.56317	0.21006
DLHK does not Granger Cause DLJP		2.03179	0.13172
DLKO does not Granger Cause DLHK	880	4.40210	0.01252
DLHK does not Granger Cause DLKO		3.71222	0.02481
DLMY does not Granger Cause DLHK	880	1.08065	0.33983
DLHK does not Granger Cause DLMY		4.65737	0.00973
DLPH does not Granger Cause DLHK	880	98.0939	0.00000
DLHK does not Granger Cause DLPH		0.63750	0.52886
DLSG does not Granger Cause DLHK	880	2.71395	0.06683
DLHK does not Granger Cause DLSG		0.81168	0.44445
DLTH does not Granger Cause DLHK	880	4.99068	0.00700
DLHK does not Granger Cause DLTH		2.33387	0.09752
DLTW does not Granger Cause DLHK	880	1.55076	0.21267
DLHK does not Granger Cause DLTW		0.08082	0.92237
DLJP does not Granger Cause DLID	880	0.06219	0.93971
DLID does not Granger Cause DLJP		1.98042	0.13863
DLKO does not Granger Cause DLID	880	12.4734	4.6E-06
DLID does not Granger Cause DLKO		1.18099	0.30746
DLMY does not Granger Cause DLID	880	0.33281	0.71700
DLID does not Granger Cause DLMY		12.7050	3.6E-06
DLPH does not Granger Cause DLID	880	54.5325	0.00000
DLID does not Granger Cause DLPH		0.69164	0.50103
DLSG does not Granger Cause DLID	880	3.01994	0.04931
DLID does not Granger Cause DLSG		4.73956	0.00897
DLTH does not Granger Cause DLID	880	5.84690	0.00300
DLID does not Granger Cause DLTH		5.10883	0.00622
DLTW does not Granger Cause DLID	880	1.22293	0.29487
DLID does not Granger Cause DLTW		1.09146	0.33618
DLKO does not Granger Cause DLJP	880	3.17048	0.04247
DLJP does not Granger Cause DLKO		1.59689	0.20312
DLMY does not Granger Cause DLJP	880	3.04409	0.04814
DLJP does not Granger Cause DLMY		0.13112	0.87713
DLPH does not Granger Cause DLJP	880	19.7516	4.1E-09
DLJP does not Granger Cause DLPH		0.51857	0.59555
DLSG does not Granger Cause DLJP	880	1.68383	0.18626
DLJP does not Granger Cause DLSG		0.59779	0.55025
DLTH does not Granger Cause DLJP	880	2.37562	0.09356
DLJP does not Granger Cause DLTH		1.15805	0.31458

Table 6. (*Continued*).

Null Hypothesis	Obs	F-Statistic	Probability
DLTW does not Granger Cause DLJP	880	0.79010	0.45412
DLJP does not Granger Cause DLTW		0.49814	0.60783
DLMY does not Granger Cause DLKO	880	0.88959	0.41119
DLKO does not Granger Cause DLMY		3.54187	0.02937
DLPH does not Granger Cause DLKO	880	23.7327	9.2E-11
DLKO does not Granger Cause DLPH		1.43582	0.23848
DLSG does not Granger Cause DLKO	880	6.34514	0.00184
DLKO does not Granger Cause DLSG		1.78706	0.16806
DLTH does not Granger Cause DLKO	880	5.23759	0.00548
DLKO does not Granger Cause DLTH		9.00929	0.00013
DLTW does not Granger Cause DLKO	880	1.97109	0.13992
DLKO does not Granger Cause DLTW		0.73457	0.48001
DLPH does not Granger Cause DLMY	880	22.3047	3.6E-10
DLMY does not Granger Cause DLPH		0.28844	0.74950
DLSG does not Granger Cause DLMY	880	3.14868	0.04340
DLMY does not Granger Cause DLSG		2.77461	0.06292
DLTH does not Granger Cause DLMY	880	3.65134	0.02635
DLMY does not Granger Cause DLTH		0.33342	0.71656
DLTW does not Granger Cause DLMY	880	0.28394	0.75288
DLMY does not Granger Cause DLTW		0.15692	0.85479
DLSG does not Granger Cause DLPH	880	1.85875	0.15648
DLPH does not Granger Cause DLSG		138.410	0.00000
DLTH does not Granger Cause DLPH	880	0.61442	0.54119
DLPH does not Granger Cause DLTH		60.5143	0.00000
DLTW does not Granger Cause DLPH	880	0.15800	0.85388
DLPH does not Granger Cause DLTW		2.32321	0.09856
DLTH does not Granger Cause DLSG	880	3.35558	0.03534
DLSG does not Granger Cause DLTH		9.48539	8.4E-05
DLTW does not Granger Cause DLSG	880	0.43682	0.64623
DLSG does not Granger Cause DLTW		0.78831	0.45494
DLTW does not Granger Cause DLTH	880	2.80019	0.06134
DLTH does not Granger Cause DLTW		0.24920	0.77948

Second, the findings that the Philippine stock market responds much earlier to shocks as compared to other regional stock markets may be surprising, but this need not be so. The Philippine stock market has historically displayed a weak — and sometimes negative — correlation with the US stock market, in contrast with other East Asian markets (Poon and Lin, 2001). To the extent that portfolio diversification may result in an asynchronous response of the Philippine stock holdings to US shocks *vis-à-vis* other regional stock holdings, this acyclicality may have led to the somewhat counterintuitive causality result. As such, an economic interpretation should not be imputed too strongly to this anomaly.

Third, Taiwan is again independent of other markets in both sub-periods, for reasons elaborated upon above.

4.2. *Unit root and cointegration tests: long-term interrelationships*

4.2.1. *Unit root tests*

The unit root issue arises in the presence of non-stationary variables. The major problem associated with regression of non-stationary variables are the "spurious regressions" resulting from the non-stationarity of a particular time series. Therefore, to avoid the problem of spurious regressions, it is necessary to test the order of integration of each variable in a model, in order to establish whether it is non-stationary and how many times the variable needs to be differenced such that a stationary series can be recovered. The Phillips–Perron unit-root test will be employed here.

Following Phillips and Perron (1988), three regression models are used to test for the unit roots. These are:

Model 1: With constant and trend

$$\mathrm{Y}_t = \alpha + \beta(t - (T/2)) + \gamma \mathrm{Y}_{t-1} + \mathrm{e_t} \quad \mathrm{H_0}: \gamma = 1 \tag{3}$$

Model 2: With constant but not trend

$$\mathrm{Y}_t = \alpha + \gamma' \mathrm{Y}_{t-1} + \mathrm{e_t} \qquad \mathrm{H_0}: \gamma' = 1 \tag{4}$$

Model 3: Without constant and trend

$$\mathrm{Y}_t = \gamma'' \mathrm{Y}_{t-1} + \mathrm{e_t} \qquad \mathrm{H_0}: \gamma'' = 1 \tag{5}$$

where Y_t represents a stock price series (in logarithmic form), ù and ü are constant terms; T is the total number of observations, and $\mathrm{e_t}$ are error terms. The Phillips–Perron (PP) test statistics are based on the Phillips Z-Test.

The results for both sub-periods show that the null hypothesis of a unit root cannot be rejected, which indicates the presence of a unit root in the levels of all indices (Table 7). There is no evidence to support the presence of a unit root in first differences of the stock price indices; hence, changes in stock prices are stationary. In other words, all stock price series are integrated of order one, I(1), in both sub-periods. Thus, the uniqueness of a unit root in the stock price level is confirmed.

Table 7. Augmented Dickey–Fuller unit root test.

Country	Test Statistic Level [I(0)]	First-Difference [I(1)]	
Hong Kong	−0.973074	−25.22287	I(1)
Indonesia	−2.586475	−25.65932	I(1)
Japan	−1.174225	−26.76874	I(1)
Korea	−2.203421	−26.60454	I(1)
Malaysia	−1.87965	−24.51459	I(1)
Philippines	−1.51815	−24.00112	I(1)
Singapore	−1.852325	−25.83624	I(1)
Taiwan	−2.507961	−24.99134	I(1)
Thailand	−1.206445	−23.65029	I(1)
1% Critical Value	−3.4354	−3.4354	
5% Critical Value	−2.8631	−2.8996	

Note: MacKinnon critical values for rejection of hypothesis of a unit root.

4.2.2. *Cointegration tests*

Given the I(1) properties of all the stock market indices, the cointegration (long-run) relationship between them can then be tested. In the study, the Johansen Maximum Likelihood test is employed to test the long-run relationship among the stock market indices of the East Asian region. If two or more stock market price indices are found to be cointegrated, it implies that there is a long-run equilibrium relationship between them, and even though the price series themselves may be non-stationary, they will nevertheless move closely together over time. This section uses the logarithms of the daily stock market indices to examine the long-term interrelationships between eight East Asian stock markets pre- and post-financial crisis.

This study (Tables 8 and 9) finds no evidence of cointegration for the second sub-period. Unlike results from short-run tests, no long run co-movements exist among East Asian stock markets. The absence of cointegration in the second sub-period rules out the existence of a long-term equilibrium trending relationship among East Asian stock markets.

4.3. *Interdependencies among East Asian stock markets: evidence using a Vector Autoregression (VAR) model*

Using a Vector Autoregression (VAR) model, this section analyses the degree to which a change in one country's stock price series exerts an influence on a change in other countries' stock price series, and the time path of the latter. Hence, the major difference between this section on interdependencies, and

Table 8. Cointegration tests (first sub-period). Included observations: 1935.

Eigenvalue	Likelihood Ratio	5% Critical Value	1% Critical Value	Hypothesized No. of CE(s)
0.031153	235.9390	192.89	205.95	None**
0.025559	174.6987	156.00	168.36	At most 1**
0.018064	124.5992	124.24	133.57	At most 2*
0.016671	89.32595	94.15	103.18	At most 3
0.011574	56.79659	68.52	76.07	At most 4
0.008528	34.26948	47.21	54.46	At most 5
0.005787	17.69718	29.68	35.65	At most 6
0.002587	6.465979	15.41	20.04	At most 7
0.000751	1.452952	3.76	6.65	At most 8

*(**) denotes rejection of the hypothesis at 5% (1%) significance level.
L.R. test indicates 3 cointegrating equation(s) at 5% significance level.

Table 9. Cointegration tests (second sub-period). Included observations: 880.

Eigenvalue	Likelihood Ratio	5% Critical Value	1% Critical Value	Hypothesized No. of CE(s)
0.054362	190.4862	192.89	205.95	None
0.040171	141.2986	156.00	168.36	At most 1
0.032098	105.2182	124.24	133.57	At most 2
0.025123	76.50874	94.15	103.18	At most 3
0.022899	54.11772	68.52	76.07	At most 4
0.019492	33.73266	47.21	54.46	At most 5
0.013488	16.40990	29.68	35.65	At most 6
0.004298	4.459586	15.41	20.04	At most 7
0.000760	0.669345	3.76	6.65	At most 8

*(**) denotes rejection of the hypothesis at 5% (1%) significance level.
L.R. rejects any cointegration at 5% significance level.

the earlier section on co-movement among national stock price series, lies in the fact that this VAR test examines the dynamic structure of stock price developments. First, the study looks at the effect that a shock (through an innovation or news) in one stock market has on others. Then, it examines whether this pattern has changed after the East Asian crisis and discusses whether contagion effects could be the reason for any such change.

The VAR model is used to investigate the strength and persistence of the effects of a shock or innovation in one market on the other markets in the model. Impulse Response Functions (IRFs) and Variance Decomposition techniques (VDCs) are employed for the interpretation of the model.

The same data sets of the daily stock indices described earlier will be used. The daily stock indices for each of the nine stock markets are transformed to daily rates of return by taking first differences of their logarithms. Since most of the stock price series in this study are found to be I(1), and no cointegrating relationship exists in the second period, the application of an unrestricted VAR in first differences is appropriate for this case.

The IRFs and VDCs will not be discussed in detail as the test methodologies have been covered widely by previous literature (Sims, 1980; Pesaran and Shin, 1998). Tables 10 and 11 report the results of the Impulse Response Functions. The Variance Decomposition results, which provide decompositions of 1-day, 2-day, 5-day, and 10-day forecasts of stock market return into fractions that are accounted for by innovations in different markets, are presented in Tables 12 and 13 for both sub-periods, respectively.

The test results show an overall increase in the response of all markets to shocks in the second sub-period. However, the shocks tend to be short-lived in both sub-periods. These test results indicate that variances in East Asian stock markets are mostly due to their own innovations for the first sub-period. Moreover, this study finds a substantial increase in the degree of interdependence after the 1997 crisis, and hence, a reflection of the contagion effects in the region. Yet, as shown in the second sub-period, no stock market is completely autonomous in that a market's own innovations "fully" account for their variance.

It is also noteworthy that a substantial decrease in the degree of interaction is detected between Malaysia and other markets, especially Singapore and Hong Kong, after the financial crisis. Hence, this leads to the conclusion that capital controls may in fact generate an impact on the interrelations between stock markets. The results also further indicate that Taiwan's low responsive sensitivity to innovations in other markets could be due to the restriction on capital investment in this market, which is quite severe.

In order to examine this implication more fully, an index of capital controls for a selected subset of countries is presented in Fig. 3.[10] The index values are scaled from 1–10, with 10 being the highest level of capital restrictions. As can be seen, capital controls for Taiwan, Korea, Malaysia and Thailand were the highest of the group in 1999. Note that whereas controls

[10]The index was constructed using the data from Chinn and Ito (2002) (for Taiwan), and Edison and Warnock (2003) (for the remaining countries), and were rescaled to a 10-point index scale. Due to data limitations, capital controls for Hong Kong were unavailable. The actual values are available from the authors upon request.

Table 10. Impulse response functions (first sub-period).

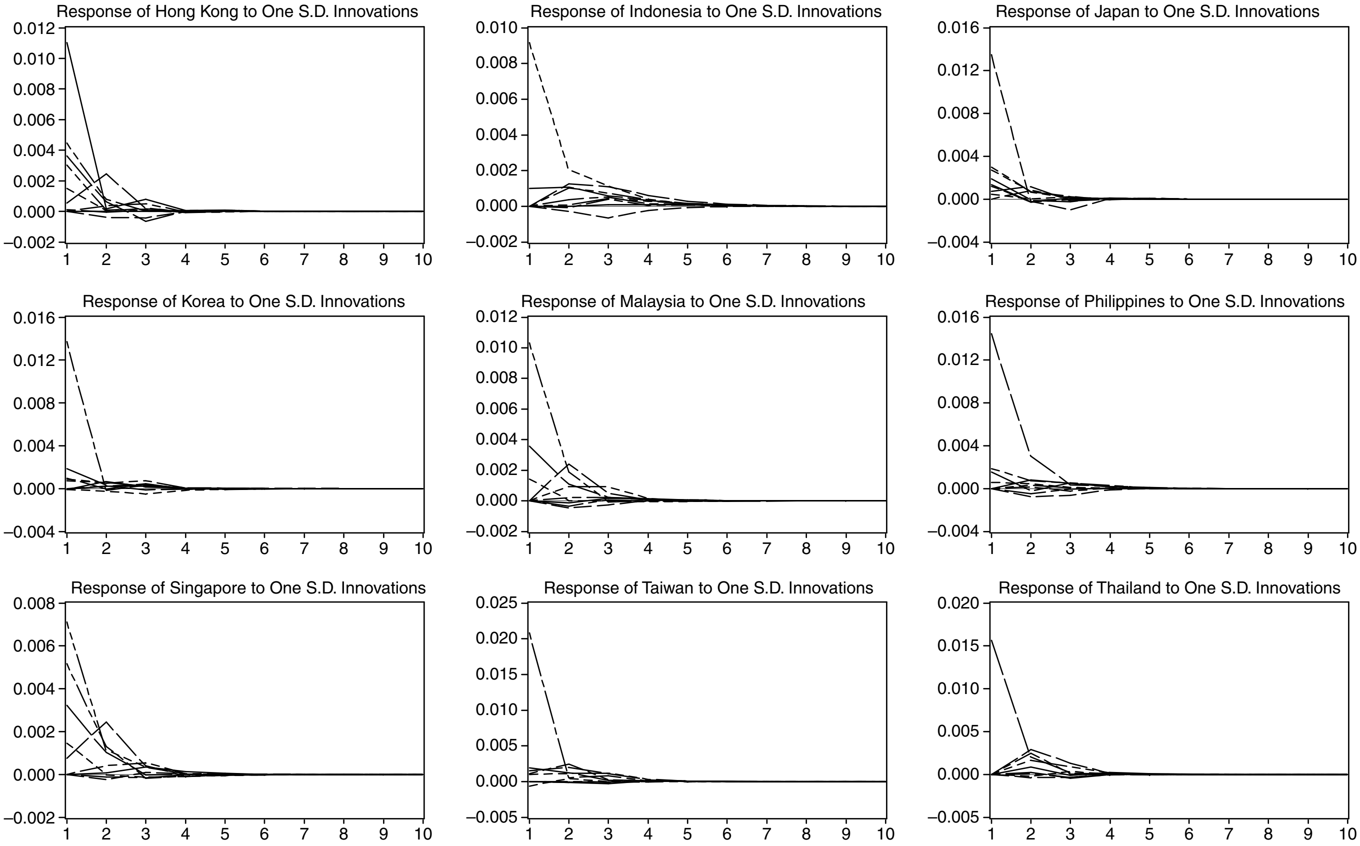

Table 11. Impulse response functions (second sub-period).

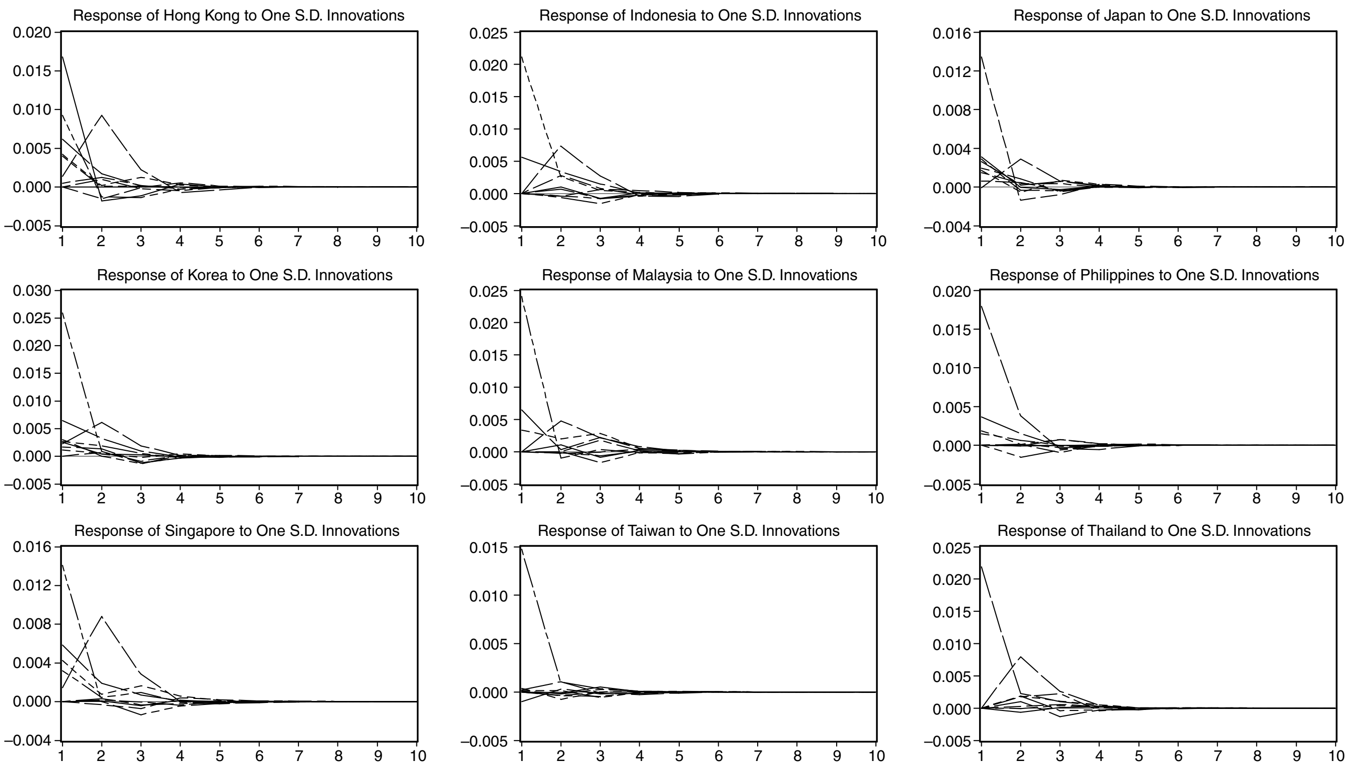

Table 12. Variance decompositions (first sub-period).

Period	S.E.	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand
Variance Decomposition of Hong Kong										
1	0.012904	72.97650	1.355655	0.000000	0.000000	12.03393	0.172925	5.510268	0.006243	7.944477
2	0.013189	69.87667	1.298443	0.093860	0.072822	11.88831	3.650236	5.277744	0.006900	7.835010
5	0.013251	69.58718	1.303510	0.201684	0.208501	11.78123	3.650177	5.245392	0.010310	8.012014
10	0.013251	69.58708	1.303512	0.201689	0.208505	11.78121	3.650197	5.245398	0.010334	8.012075
Variance Decomposition of Indonesia										
1	0.009233	0.000000	98.84288	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.157124
2	0.009671	5.44E-05	94.62606	0.106910	0.008478	1.136247	1.695356	0.005228	0.149404	2.272267
5	0.009950	0.025325	90.81725	0.591839	0.168147	1.765768	3.288311	0.291129	0.437370	2.614860
10	0.009951	0.027692	90.78950	0.592798	0.169210	1.769260	3.301486	0.294842	0.437779	2.617430
Variance Decomposition of Japan										
1	0.014354	0.860935	0.100210	88.39372	0.000128	4.324256	0.265426	3.583272	0.698891	1.773166
2	0.014459	0.879188	0.098777	87.13521	0.306676	4.452316	0.886291	3.760823	0.726265	1.754456
5	0.014503	0.881191	0.122257	87.09811	0.307529	4.426616	0.894653	3.765690	0.724512	1.779445
10	0.014503	0.881191	0.122267	87.09794	0.307532	4.426627	0.894674	3.765702	0.724514	1.779555
Variance Decomposition of Korea										
1	0.013943	0.002414	0.005844	0.000000	97.07794	0.386457	0.003095	0.286051	0.477596	1.760603
2	0.013988	0.029410	0.043062	0.022703	96.47542	0.511301	0.222413	0.435327	0.475080	1.785285
5	0.014039	0.058259	0.185487	0.098908	95.83028	0.777670	0.236754	0.456823	0.571658	1.784156
10	0.014039	0.058267	0.186320	0.099190	95.82695	0.778022	0.238096	0.457036	0.571707	1.784409
Variance Decomposition of Malaysia										
1	0.011013	0.000000	1.669151	0.000000	0.000000	87.85616	0.000000	0.000000	0.000000	10.47469
2	0.011532	0.012928	1.522257	0.171243	0.024648	82.76604	4.301424	0.658151	0.099088	10.44422
5	0.011589	0.051632	1.515101	0.225527	0.060828	81.95769	4.421057	1.281217	0.100108	10.38684
10	0.011589	0.051697	1.515386	0.225574	0.060849	81.95599	4.421616	1.281416	0.100203	10.38726

Table 12. (*Continued*).

Period	S.E.	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand
Variance Decomposition of Philippines										
1	0.014680	0.000000	0.154379	0.000000	0.000000	1.598697	97.14730	0.000000	0.000000	1.099626
2	0.015068	0.289757	0.229379	0.266781	0.009631	1.756715	96.24188	0.043369	0.093821	1.068671
5	0.015120	0.410945	0.232717	0.441237	0.034332	1.879223	95.66231	0.045852	0.094905	1.198478
10	0.015120	0.411159	0.232729	0.441248	0.034345	1.879226	95.66194	0.045952	0.094906	1.198490
Variance Decomposition of Singapore										
1	0.009509	0.000000	2.320902	0.000000	0.000000	29.57477	0.627944	55.92989	0.000000	11.54650
2	0.010035	0.005239	2.084964	0.062950	0.163445	28.22768	6.485917	51.53034	0.013654	11.42580
5	0.010076	0.136612	2.101569	0.070152	0.446396	28.03805	6.611151	51.21753	0.042952	11.33559
10	0.010076	0.136614	2.101892	0.070230	0.446391	28.03749	6.611752	51.21655	0.043019	11.33606
Variance Decomposition of Taiwan										
1	0.021043	0.000000	0.092616	0.000000	0.000000	0.287487	0.532636	0.215939	98.02106	0.850264
2	0.021355	0.003292	0.129185	0.003831	0.000281	1.600828	1.393389	0.469893	95.24129	1.158014
5	0.021438	0.025241	0.129590	0.005395	0.006372	1.601228	1.642299	0.784967	94.64680	1.158110
10	0.021438	0.025345	0.129756	0.005436	0.006437	1.601239	1.642354	0.784978	94.64628	1.158169
Variance Decomposition of Thailand										
1	0.015668	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	100.0000
2	0.016371	0.287065	0.024179	0.067775	0.003295	2.290677	3.191969	1.003598	0.020673	93.11077
5	0.016463	0.307690	0.060359	0.110972	0.051587	2.267488	3.761614	1.263609	0.094997	92.08168
10	0.016464	0.307867	0.060372	0.110980	0.051629	2.267481	3.761614	1.263750	0.094999	92.08131

Table 13. Variance decompositions (second sub-period).

Period	S.E.	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand
Variance Decomposition of Hong Kong										
1	0.021023	63.96210	4.017899	0.000000	0.000000	3.600466	0.418361	19.39338	0.046986	8.560807
2	0.023256	52.88023	3.291966	0.442444	0.165742	2.942580	16.26030	16.15096	0.328805	7.536978
5	0.023502	52.04491	3.514034	0.486902	0.223821	2.884261	16.94393	16.17419	0.345193	7.382758
10	0.023502	52.04295	3.514048	0.486930	0.226471	2.884327	16.94391	16.17366	0.345220	7.382480
Variance Decomposition of Indonesia										
1	0.021912	0.000000	93.45952	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	6.540482
2	0.023698	0.184480	81.09899	0.038119	1.384006	0.032544	9.511661	0.079519	0.076171	7.594514
5	0.024037	0.287058	78.86596	0.137761	1.472992	0.160212	10.57780	0.520298	0.226066	7.751856
10	0.024037	0.287292	78.86347	0.137875	1.473900	0.160258	10.57854	0.520845	0.226107	7.751719
Variance Decomposition of Japan										
1	0.014641	4.481812	1.348061	84.05531	1.036560	1.738816	0.003419	3.932823	0.163594	3.239606
2	0.015037	4.249144	1.421374	80.48795	1.030216	1.950831	3.737125	3.780961	0.254352	3.088048
5	0.015131	4.227427	1.645829	79.81269	1.069134	2.046069	3.859650	3.811452	0.315839	3.211907
10	0.015131	4.227493	1.645818	79.81152	1.069196	2.046074	3.860244	3.811704	0.316065	3.211887
Variance Decomposition of Korea										
1	0.027302	0.864044	0.167887	0.000000	90.16394	1.224344	0.683293	0.937971	0.372803	5.585714
2	0.028281	0.828742	0.178722	0.060861	84.12781	1.141099	5.276192	1.320568	0.573379	6.492627
5	0.028477	0.831495	0.207423	0.168144	83.15337	1.368430	5.632142	1.346336	0.774395	6.518266
10	0.028477	0.831494	0.207444	0.168209	83.15179	1.368484	5.633446	1.346494	0.774470	6.518171
Variance Decomposition of Malaysia										
1	0.025115	0.000000	1.754317	0.000000	0.000000	91.60943	0.000000	0.000000	0.000000	6.636255
2	0.025686	0.176471	2.266502	0.012797	0.000164	87.73181	3.447887	0.000149	0.006563	6.357653
5	0.026194	0.290568	3.381348	0.037366	0.456390	84.39618	4.076063	0.432655	0.084059	6.845375
10	0.026194	0.290609	3.381433	0.037644	0.456479	84.39392	4.077064	0.432885	0.084762	6.845201

Table 13. (*Continued*).

Period	S.E.	Hong Kong	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand
Variance Decomposition of Philippines										
1	0.018458	0.000000	1.028429	0.000000	0.000000	0.633961	94.38961	0.000000	0.000000	3.948004
2	0.018979	0.001385	0.975316	0.005981	0.002675	0.706142	93.28239	0.669848	0.001953	4.354314
5	0.019063	0.003565	1.119976	0.149169	0.278029	0.702987	92.59496	0.779254	0.043328	4.328732
10	0.019063	0.003581	1.120327	0.149185	0.278622	0.703219	92.59305	0.779762	0.043355	4.328899
Variance Decomposition of Singapore										
1	0.016209	0.000000	6.909869	0.000000	0.000000	3.887333	0.806729	75.42425	0.000000	12.97182
2	0.018575	0.001678	5.427943	0.034096	0.008135	3.012663	23.13833	57.43078	0.030235	10.91614
5	0.018998	0.054552	6.034621	0.227483	0.045096	3.137946	24.36102	55.49098	0.081305	10.56700
10	0.018998	0.054732	6.034424	0.227722	0.047522	3.138557	24.36189	55.48733	0.081493	10.56632
Variance Decomposition of Taiwan										
1	0.014791	0.000000	0.068700	0.000000	0.000000	0.002261	0.020818	0.010816	99.43556	0.461848
2	0.014897	0.008772	0.323031	0.068073	0.062978	0.018738	0.529281	0.020307	98.47598	0.492842
5	0.014937	0.131509	0.321591	0.068848	0.156995	0.047070	0.576279	0.171172	98.00087	0.525663
10	0.014938	0.131516	0.321793	0.068870	0.157074	0.047080	0.576601	0.171249	98.00015	0.525662
Variance Decomposition of Thailand										
1	0.021889	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	100.0000
2	0.023639	0.070323	0.637852	0.011591	0.556802	0.000885	11.26000	0.630604	0.179194	86.65275
5	0.023999	0.076394	0.859254	0.065491	1.398575	0.037455	12.14771	0.663162	0.497713	84.25424
10	0.023999	0.076823	0.859483	0.066159	1.399179	0.037538	12.14804	0.663436	0.497903	84.25143

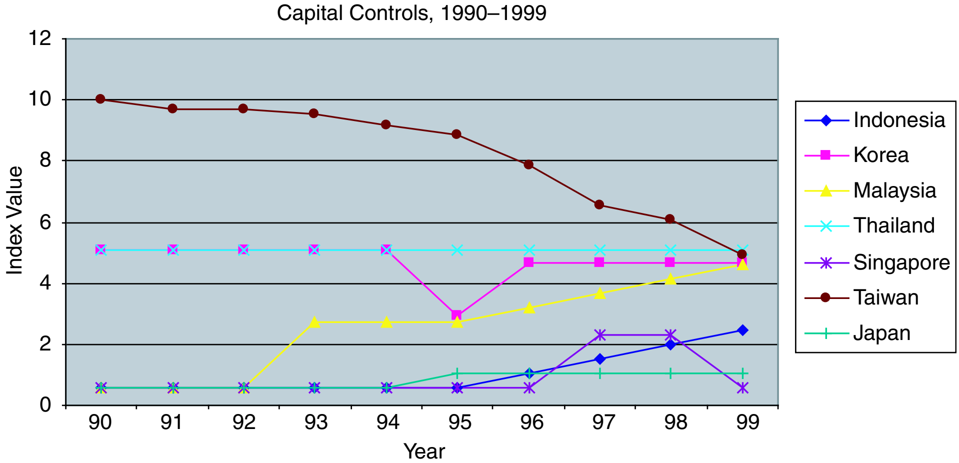

Fig. 3. Index of capital controls.

for Korea and Thailand were consistently high throughout (save for the dip for Korea in 1995), those for Malaysia and Taiwan displayed an increasing and decreasing trend, respectively. This provides further evidence that the low sensitivity of the Taiwanese and Malaysian stock markets may be due to capital flow restrictions. For Malaysia, the upsurge in capital controls during the period of the study might have dominated other regional factors; while the overall much stricter controls on capital for Taiwan *vis-à-vis* the rest of the region may be responsible for the general insensitivity of its stock market.

5. Conclusion

The East Asian crisis suggests that during a period of financial market instability, market participants tend to move together across a range of countries. Shocks originating from one market readily get transmitted to other markets, thus becoming a source of substantial instability. This paper sheds light on the extent of contagion effects in a sample of East Asian countries during the 1997–1998 financial crisis.

Comparing all tests results in tranquil periods versus crisis periods, we present evidence that no long term co-movements exist among East Asian stock markets, only short-term correlations. This finding is further confirmed by the VAR model, that shocks or impacts of innovations to a market are very short-lived (often as little as two days). Moreover, this study finds a substantial increase in the degree of interdependence after the 1997 crisis, and hence, reflects the presence of contagion effects in the region. Another interesting point here is that Taiwan is very independent from other markets — a finding which may be useful in explaining why Taiwan was less affected by the crisis. The results obtained in this paper also suggest that capital controls may have an impact on the interrelationships between stock markets in the region.

Some policy implications can also be formulated from the analysis. First of all, the possibility of contagion implies that there is a rationale for greater coordination of multilateral and regional action in order to stem the spread of contagion. Secondly, crises do not spread randomly; vulnerability is often related to fundamentals. Hence, it is important to develop economies that possess more effective fundamental economic structures, and pursue policies that strengthen financial market accountability and stability, which then correspondingly reduces a country's vulnerability to contagion. Finally, contagion may also provide a rationale for slower capital account liberalization or the use of controls on short-term capital inflows. This final suggestion, in particular, is a potential for research agenda, and it is believed that future research should be directed toward this direction.

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