Correlation, Contagion and Asian Evidence*

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Abstract

This paper examines the existing empirical literature on financial market contagion in Asia in the light of existing tests of contagion. Empirical evidence on contagion in Asia supports the hypotheses that contagion is regional and transmitted through developed markets. Contagion occurs across both asset types and geographical borders and tends to have larger effects in equity markets than currency and bond markets. Contagion affects both developed and developing markets, and does not seem to vary with the relative economic fundamental health or trade and financial linkages of the Asian economies. The discussion of the behaviour of correlation coefficients in the presence of contagion and crises suggests they are not a reliable metric for detecting contagion.

Keywords: Contagion, financial crises, Asia, correlations, factor decompositions.

JEL Classification: D15, F31.

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1 Introduction

Despite a relatively large empirical literature addressing the issue of the existence of contagion between countries and markets during financial crises, there is little consensus on the results. Of course this creates difficulties for policy makers and researchers in assessing both whether or not contagion exists and whether it is truly a problem upon which policy should or could be focussed. This paper canvasses related issues across the literature on contagion in the context of the Asian financial crisis. Although evidence of transmission of financial crises to other countries has occurred in recent decades, particularly during the 1987 stock market collapse (King and Wadhwani, 1990) and the 1994-5 Mexican peso crisis which spawned the so-called "tequila effect" (Sachs, Tornell and Velasco, 1996), it was the Asian crisis which focussed market participants, policy makers and researchers on the issue of contagion.

An obstacle to the formation of a consensus on the relevance of contagion is that its definition in the academic literature has been an evolving concept. During the financial crisis the term contagion was used commonly in the popular press to describe the dramatic spread of the crisis, while academics had many competing definitions. In the last few years there has been a move to at least a set of terminology to distinguish the categories of contagion recognized in the existing frameworks. The major distinction is that between *fundamentals* based contagion and *pure* contagion (see Dornbusch, Park and Claessens, 2000 and Kaminsky and Reinhart, 2000). Fundamentals based contagion refers to the transmission of shocks between countries or markets routed through real links such as trade, macroeconomic similarities, financial links such as banking linkages and capital flows, or broadly linkages which could have been anticipated *ex ante* the shock to asset markets. Pure contagion refers to the transmission of shocks over and above those through fundamental linkages. Earlier literature tends to use the term contagion to refer to both fundamentals based and pure contagion effects, such as for example Eichengreen, Rose and Wyplosz (1995,1996). More recently contagion refers principally to pure contagion effects and fundamentals based contagion is considered separately, often labelled as spillovers, a term due to Masson (1999). Dungey, Fry, González-Hermosillo and Martin (2005a) show that many of the distinctions in the definitions of pure contagion in empirical work are nested.

The focus on contagion in both the policy making and empirical literature revolves around the importance of understanding linkages between financial markets during times of crisis, and a recognition that such linkages may change in unexpected ways during periods of turmoil. The optimal policy response to a crisis should differ depending on the relative importance of fundamentals based or pure contagion, as the underlying causes are presumably quite different. The aim of this paper is not to state what these policy responses should be, but to assess the evidence in the literature as to whether contagion is important in the first place, and hence whether it should be reacted to.

There is a large and growing theoretical literature explaining pure contagion through concepts such as herding behaviour and monsoonal effects (Masson, 1999), information asymmetries and portfolio rebalancing (Calvo and Mendoza, 2000, Kodres and Pritsker, 2002), and wealth effects due to rushes for liquidity (Kyle and Xiong, 2001) amongst others. Most theoretical models seek to explain why markets are more correlated during a crisis period. For a review of the theoretical models of contagion see Dungey and Tambakis (2005). The problem is that these concepts are difficult if not impossible to measure empirically, so appealing to the data for some understanding of the underlying reasons for pure contagion is quite challenging. Most empirical models of contagion instead look for evidence of contagion by examining the evidence for strengthened linkages during a crisis period. Often this is associated with some form of test for increased correlation between asset returns, although some authors point out that increasing correlation is not necessarily an indication of contagion (Corsetti, Pericoli and Sbracia, 2001; Bekaert, Harvey and Ng, 2005; and Dungey, Fry, González-Hermosillo and Martin, 2005d). A number of important overviews of the empirical literature exist, including particularly Dornbusch, Park and Claessens (2000) and Pericoli and Sbracia (2003), with Bekaert and Harvey (2003) providing a particular focus on emerging markets.

The empirical literature, in some instances supported by theory, has raised a number of important propositions about contagion during financial crises. This is augmented by agendas arising from international bodies such as the Bank for International Settlements (BIS) 1998 survey of market participants following the Russian and LTCM crises. These propositions provide a framework for understanding potential policy responses to contagion. The seven propositions synthesized here are that:

(i) Strong fundamentals imply immunity to contagion.

(ii) Trade and financial linkages between countries are associated with contagion transmission.

(iii) Regional proximity is important in transmitting/receiving contagion effects.

(iv) Developing markets experience greater contagion than developed markets.

(v) Developed markets operate as a conduit for contagion effects between regions.

(vi) Contagion effects differ by asset market.

(vii) Contagion occurs across both asset market and country borders.

The rest of this paper proceeds as follows: Section 2 presents some data relating to the Asian financial crisis along with a very brief background of events. Section 3 examines issues arising from using changes in correlation as the metric to distinguish

crises and contagion in a formal model. The paper then canvases evidence for contagion during the Asian financial crisis from the empirical literature across different asset classes in Section 4. Section 5 turns to the seven propositions listed immediately above to examine evidence as to whether pure contagion is a relatively important influence on asset returns, or alternatively, whether domestic or world/regional influences, including fundamentals based contagion, are of greater importance. Section 6 provides some concluding comments.

2 The Crisis In Asia

The events of the East Asian crisis have been examined in great detail since the crisis in 1997-1998. Some of the key events of this crisis include: the devaluation of the Thai baht of July 1997; the Hong Kong speculative attack of October 1997; the devaluation and float of other Asian currencies during the period; the co-ordinated roll over of Korea's short term debt by commercial banks in order to avoid a debt moratorium in December 1997; the closure or restructure of financial institutions in most crisis countries including Indonesia, Korea, Malaysia and Thailand; the imposition of capital controls in Malaysia in 1998; the change of political leadership in all countries excluding Malaysia (although the finance minister was sacked), and the dramatic reduction of sovereign ratings for all crisis countries. Indonesia, Thailand and Korea all sought IMF assistance packages, and many industrial countries pledged financial assistance. For chronologies of the crisis, see Bank for International Settlements (1998), Roubini (1998), IMF (1999,2000), Kaminsky and Schmukler (1999), Athukorala (2001), and Baur and Fry (2005).

Figures 1 and 2 show daily currency and equity returns for a selection of economies most affected by the crisis over the period. The currency returns are presented from June 1, 1997 to June 30, 1998. Many of the Asian currencies were pegged prior to this date. A longer period is covered in the figures of equity returns shown from January 1, 1996 to June 30, 1998. The figures highlight the speed with which the Asian crisis spread across different Asian economies.

At the time of the crisis, a number of proposals were put forward to understand the crisis period linkages which existed in addition to fundamental economic linkages. Hypothesized additional linkages included 'competitive devaluations' where terms of trade effects hastened rapid depreciations between economies; 'wake-up calls', in which market participants focussed their attention on countries with comparable fundamental indicators to crisis countries; 'portfolio adjustment', in which accounting and market structures provided incentives for individual portfolio managers to make similar moves at the same time, thus propagating crises between countries; and 'herd behaviour' where uncertainty and the possibility of information asymmetries caused investors to follow the crowd; for overviews see Goldstein (1998) and Lowell, Neu and Tong (1998).

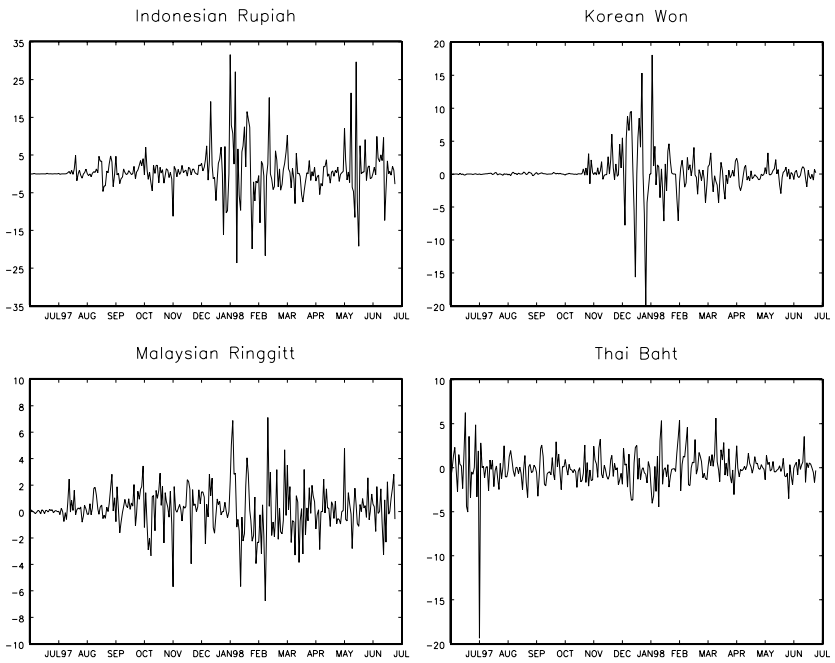

Figure 1: Local currency returns in USD for Indonesia, Korea, Malaysia and Thailand for the period June 1, 1997 to June 30, 1998.

During the Asian crisis, the term contagion was fairly broadly defined, and could mean any or all of these things.

The implications of this lack of consensus on the transmission process in the East Asian crisis is evident in the response of national and international policy making bodies. There were numerous calls for the reform of international financial infrastructure to halt potential transmission of crises via contagion; for example the edited volume by Claessens and Forbes (2001) arose out of a conference funded by the World Bank, IMF and Asian Development Bank titled "Contagion: How it Spreads and How it can be Stopped", and other volumes of reforming international financial infrastructure such as Goldstein (1998), Eichengreen (1999) and for a more recent consideration of the arguments, Vines and Gilbert (2004). Many of the original proposals focussed on reforms to national economic systems through transparency, domestic regulation, improved national economic management and development of domestic financial markets. This agenda has not been universally popular with the crisis countries, as it puts the burden of adjustment on those countries who have already borne the greatest cost. For example, Radelet and Sachs (1998) and Germain (2002) argue that the crucial change needed post-crisis is to reshape international finance as inclusive of emerging market economies and that this is indeed a political agenda rather than a purely economic one.

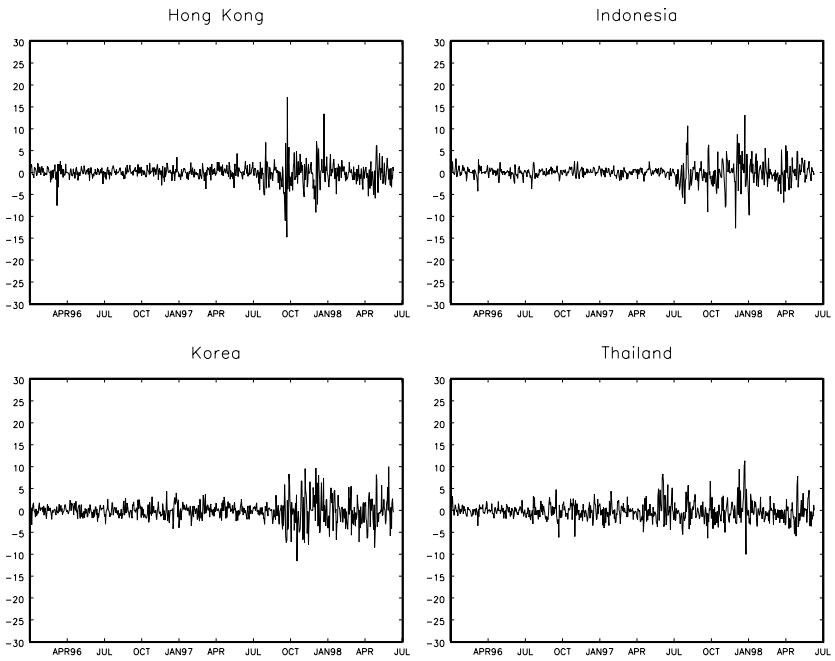

Figure 2: Equity returns data for Hong Kong, Indonesia, Korea and Thailand for the period Jan 1, 1996 to June 30, 1998.

3 Preliminary Tests of Contagion Using Correlations

The preliminary work on testing for contagion involved testing for a change in the correlation in asset markets between crisis and non-crisis periods. Early work was by King and Wadhwani (1990) and Baig and Goldfajn (1999). Forbes and Rigobon (2002) are associated with a heteroskedasticity adjusted correlation test which famously finds little evidence of contagion during a number of financial crises, including from Hong Kong equity markets in 1998.

Figure 3 presents selected rolling correlations between daily equity returns for Hong Kong (HK), Indonesia (I), Korea (K), Malaysia (M) and Thailand (T) for four crisis events. The window width equals one month. The four rows of the figure correspond to the four events selected. These are: the Thai baht devaluation of July 1997, with the panel covering June 3 to July 31 1997; the Hong Kong speculative attack from October 1, 1997 to November 14, 1997; the period surrounding the successful avoidance of the Korean debt moratorium on December 24, 1997, with the figure covering the month of December; and the turmoil in Indonesia from January 1 to February 27, 1998. There are two columns in Figure 3. The first contains correlation coefficients calculated on equity returns and the second contains correlation coefficients calculated on the residuals of a vector autoregression (VAR) model containing all returns with one lag. The

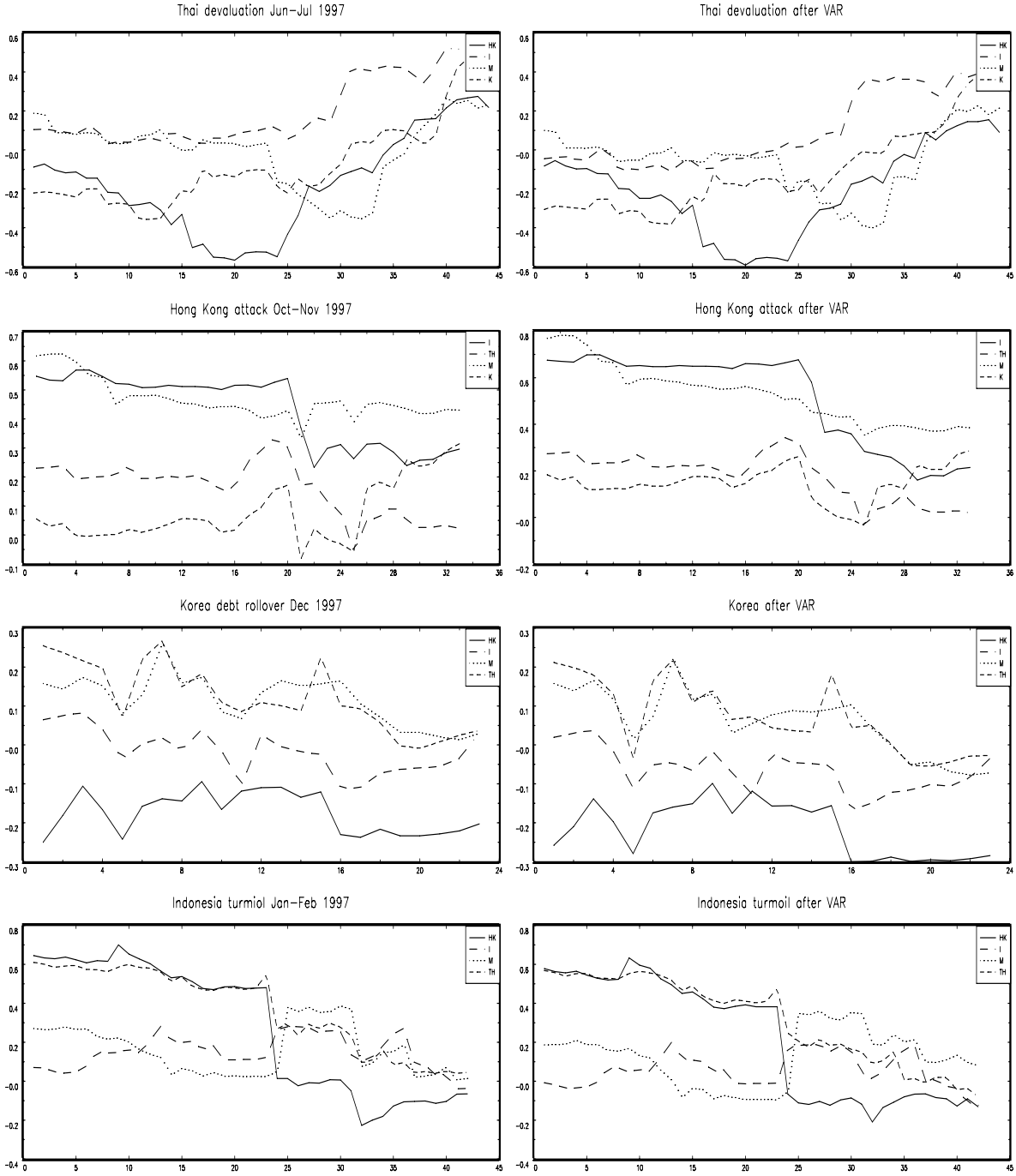

Figure 3: Rolling correlations of daily equity returns calculated over a monthly window around four key events. First column based on actual data, second column based on the residuals from a VAR containing all equity returns with one lag. Panel a) correlation with Thailand Jun 3 to Jul 31 1997; b) with Hong Kong Oct 1 to Nov 14; c) with Korea Dec 1 to 31 1997; d) with Indonesia Jan 1 to Feb 27, 1998.

correlations of the residuals of the VAR are reported, as tests for contagion such as that proposed by Forbes and Rigobon (2002) attempt to capture fundamental relationships through a VAR, so contagion is identified through the modelling of outliers.

From inspection of Figure 3 it is immediately obvious that the correlations are not stable, either before or after controlling for fundamentals. More pertinently, after a shock, it is not clear that correlations necessarily increase: The Thai baht devaluation is an example where correlations increase, whereas the Hong Kong shock is an example of where they tend to decrease.

3.1 A Model Of Asset Returns

To better assess what the correlation analysis presented above might represent in identifying contagion, a financial market model with its origins in the factor models of Arbitrage Pricing Theory is specified (see Sharpe, 1964; Solnik, 1974). Two periods are distinguished in the model. The first is a factor model where assets are priced based on "normal" shocks associated with a non-crisis period. The second is a factor model which extends the tranquil period factor model by allowing for additional linkages arising from contagion and various types of structural breaks which potentially may also arise during financial crises.

3.1.1 A Model For Tranquil Times

The model in a non-crisis period in the case of three assets consists of a one factor model where returns $(x_{i,t})$ are specified as a function of a common factor (w_t) and an idiosyncratic component $(u_{i,t})$

$$x_{i,t} = \lambda_i w_t + \phi_i u_{i,t}, \qquad i = 1, 2, 3, \tag{1}$$

where for simplicity

$$w_t \sim N(0,1) \tag{2}$$

$$u_{i,t} \sim N(0,1), \qquad i = 1, 2, 3, \tag{3}$$

are assumed to be independent. The common factor captures market fundamentals or systemic risk which impact upon asset returns with a loading of λ_i. The idiosyncratic components capture those periods where returns deviate from their market fundamentals, and impact upon asset returns with a loading of ϕ_i. In the special case where $\lambda_1 = \lambda_2 = \lambda_3 = 0$, the markets are segmented with volatility in asset returns driven entirely by their respective idiosyncratic components. The assumption that the world and idiosyncratics are distributed as $N(0,1)$ can be relaxed by including autocorrelation and conditional volatility in the form of GARCH, as in Dungey, Fry and Martin (2003).

3.1.2 A Model For Crisis Times

Crisis period relationships can be accounted for by extending the non-crisis model in (1) to (3) by allowing for structural breaks in the world factor and idiosyncratic factors, as well as for increases in asset return volatility from an additional propagation mechanism from one country to another arising from contagion. To distinguish the crisis period from the non-crisis period, returns for the former period are denoted as $y_{i,t}$. The factor structure during the crisis period for a trivariate system is specified as

$$\begin{aligned} y_{1,t} &= \lambda_1 w_t + \phi_1 u_{1,t} && (4)\\ y_{2,t} &= \lambda_2 w_t + \phi_2 u_{2,t} + \delta_2 \phi_1 u_{1,t} && (5)\\ y_{3,t} &= \lambda_3 w_t + \phi_3 u_{3,t} + \delta_3 \phi_1 u_{1,t}, && (6) \end{aligned}$$

where

$$\begin{aligned} w_t &\sim N\left(0, \omega^2\right) && (7)\\ u_{i,t} &\sim N\left(0, \kappa_i^2\right), \qquad i = 1, 2, 3. && (8) \end{aligned}$$

Structural breaks If the common factor is interpreted as representing market fundamentals, a change in the pricing of assets during the crisis period as a result of a change in w_t is captured by the parameter ω^2 in (7). For $\omega^2 > 1$, this leads to an increase in volatility of all asset returns during the crisis period. An alternative form of a structural break which increases asset market volatility is where there are changes in the idiosyncratic components in the crisis period, with $\kappa_i^2 > 1$. It is more typical to model the structural break in the country directly experiencing the crisis, otherwise known as the source country. However, for the crisis to spread from the source country to the other countries in this situation, it is necessary for additional linkages, commonly known as contagion, to exist.

Contagion Contagion is defined as shocks originating in the source country over and above the influence of the common factor (w_t), which impact upon the asset returns of the remaining countries. In the case of the crisis model in (4) to (8), country 1 represents the source country, with the strength of contagion to countries 2 and 3 controlled by the parameters δ_2 and δ_3 respectively.

3.1.3 Changes In Correlations

The factor model given above has the advantage that it provides convenient expressions for the correlations between asset returns. Using equations (1) to (3), the correlation between asset 1 and asset 2 during a non-crisis period is

$$\rho_{x_{1,t},x_{2,t}} = \frac{E\left[x_{1,t}x_{2,t}\right]}{\sqrt{E\left[x_{1,t}^2\right] E\left[x_{2,t}^2\right]}} = \frac{\lambda_1\lambda_2}{\sqrt{\lambda_1^2+\phi_1^2}\sqrt{\lambda_2^2+\phi_2^2}}. \qquad (9)$$

From equations (4) to (8) the corresponding correlation in the crisis period is

$$\rho_{y_{1,t},y_{2,t}} = \frac{E\left[y_{1,t}y_{2,t}\right]}{\sqrt{E\left[y_{1,t}^2\right]E\left[y_{2,t}^2\right]}} = \frac{\lambda_1\lambda_2\omega^2 + \delta_2\phi_1^2\kappa_1^2}{\sqrt{\lambda_1^2\omega^2 + \phi_1^2\kappa_1^2}\sqrt{\lambda_2^2\omega^2 + \phi_2^2\kappa_2^2 + \delta_2^2\phi_1^2\kappa_1^2}}. \tag{10}$$

As a number of theoretical and empirical definitions of contagion involve the observation of an increase in correlation coefficients between the non-crisis and crisis periods, it is natural to look at the change in correlation by subtracting (9) from (10)

$$\rho_{y_{1,t},y_{2,t}} - \rho_{x_{1,t},x_{2,t}} = \frac{\lambda_1\lambda_2\omega^2 + \delta_2\phi_1^2\kappa_1^2}{\sqrt{\lambda_1^2\omega^2 + \phi_1^2\kappa_1^2}\sqrt{\lambda_2^2\omega^2 + \phi_2^2\kappa_2^2 + \delta_2^2\phi_1^2\kappa_1^2}} - \frac{\lambda_1\lambda_2}{\sqrt{\lambda_1^2 + \phi_1^2}\sqrt{\lambda_2^2 + \phi_2^2}}. \tag{11}$$

There are several parameters which govern the difference in correlations across the two sub-periods. These are δ_i^2, ω^2 and κ_i^2, which are now explored. This analysis is closely related to that of Corsetti, Pericoli and Sbracia (2001).

3.2 Understanding Changes In Correlations

To understand the underlying relationships governing changes in correlations, equation (11) is computed for various parameterisations. This analysis is based on a simplified version of the model in Dungey, Fry, González-Hermosillo and Martin (2005d). The parameterised system is

$$y_{1,t} = 4w_t + 2u_{1,t} \tag{12}$$

$$y_{2,t} = 2w_t + 3u_{2,t} + \delta_2 2u_{1,t} \tag{13}$$

$$y_{3,t} = 3w_t + 4u_{3,t} + \delta_3 2u_{1,t}, \tag{14}$$

and in this case there are no structural breaks in the common or idiosyncratic factors so $\omega^2 = \kappa_i^2 = 1$, $\forall i$. In the non-crisis period the data generating process for $x_{i,t}$ is the same as equations (12) to (14) by setting $\delta_2 = \delta_3 = 0$, and redefining $y_{i,t}$ as $x_{i,t}$. Figure 4 presents the results of the experiments for the difference in correlations, with all parameters held constant except for one. The first and second panels explore the behaviour of the difference in the correlation coefficients between assets 1 and 2 and assets 2 and 3 respectively as the strength of contagion $\delta_i = \delta$ increases. The third and fourth considers the case where there is no contagion, but a structural break in the common factor (ω^2).

3.2.1 Changes In Correlation Due To Contagion

Asset One to Asset Three Panel (a) of Figure 4, shows the change in correlation between $y_{1,t}$ and $y_{3,t}$ for increasing values of contagion from $\delta = 0$ to $\delta = 20$, based on equation (11) with $\omega^2 = \kappa^2 = 1$. The correlation initially rises but hits a peak and eventually falls and in the limit becomes negative. The initial increase in correlation

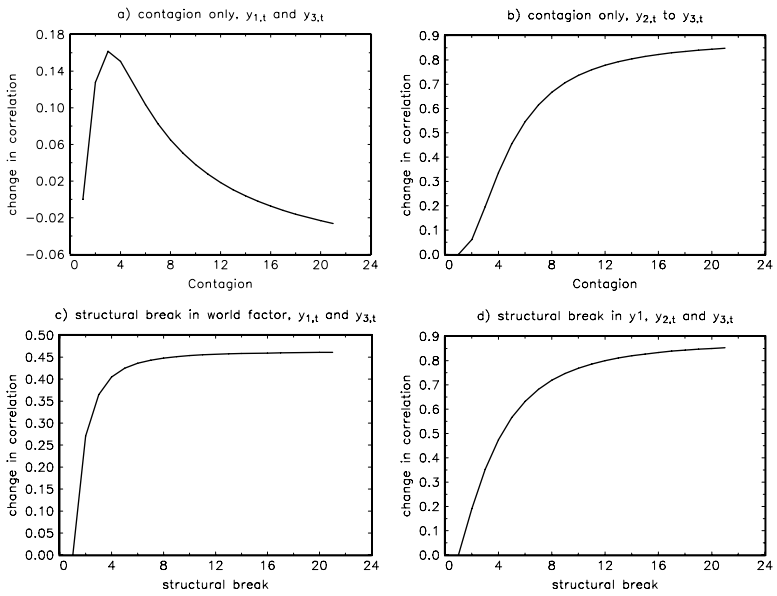

Figure 4: Simulation results for change in correlation coefficients under various contagion and structural break assumptions.

is consistent with much of the empirical literature whereby an increase in correlation indicates evidence of contagion. However, the fall in correlation for strong levels of contagion, that is higher values of δ, contradicts the premise that increasing correlation is only associated with contagion. This result casts doubt on empirical evidence that finds no contagion based on non-increasing correlation.[1]

Asset Two to Asset Three Panel (b) of Figure 4 repeats the analysis for $y_{2,t}$ and $y_{3,t}$. This figure appears to provide support for the hypothesis that higher correlation is associated with higher levels of contagion. However, this result is purely spurious as the increase in correlation is fully generated by a common component, namely u_{1t}. By construction, there are no contagious linkages between assets 2 and 3.

3.2.2 Changes In Correlation Due To Systemic Structural Breaks

The effects of increasing systematic shocks (ω^2) on the change in correlations between $y_{1,t}$ and $y_{3,t}$ and between $y_{2,t}$ and $y_{3,t}$, is given in panel (c) of Figure 4. In this case there

[1] Dungey, Fry, González-Hermosillo and Martin (2005d) show that (11) yields a fall in correlation for high levels of contagion if

$$\sqrt{1+\left(\frac{\phi_2}{\lambda_2}\right)^2} < \frac{\lambda_1}{\phi_1}.$$

Corsetti, Pericoli and Sbracia (2001) also discuss the problem of measuring contagion via correlation coefficients from this angle in some depth.

is no contagion ($\delta = 0$), and no idiosyncratic structural break ($\kappa_i^2 = 1$). Despite the fact that the true process does not contain contagion, there is still an increase in correlation between the two periods. In the limit, the correlation in the crisis period approaches unity, reflecting that the asset returns are totally dominated by the common factor (w_t). This result further highlights the danger of misdiagnosing increasing correlation as evidence of contagion. Most applications for tests of contagion specifically assume that the appropriate process describing the data is the presence of contagion and not a structural change in the common factor; for example Forbes and Rigobon (2002), Dungey and Martin (2004). Forbes and Rigobon (2001) specifically designates the situation of a structural change in the common factor as shift contagion.

3.2.3 Relationship With Regression Analysis

The occurrence of a structural break in the common factor brings out an important relationship between correlation and regression analysis in testing for contagion. To highlight this relationship, consider as a special case of the non-crisis and crisis models in (1) to (8) where $\phi_1 = 0$, so country 1 becomes the common factor. From (1) and (4) the asset returns can be expressed in terms of the first asset return. For example, the second asset return equations for the non-crisis and crisis periods are respectively

$$\begin{aligned} x_{2,t} &= \frac{\lambda_2}{\lambda_1} x_{1,t} + \phi_2 u_{2,t} = \beta x_{1,t} + \phi_2 u_{2,t} \\ y_{2,t} &= \frac{\lambda_2}{\lambda_1} y_{1,t} + \phi_2 u_{2,t} = \beta y_{1,t} + \phi_2 u_{2,t}, \end{aligned} \tag{15}$$

with $\beta = \lambda_2/\lambda_1$, and where it is still assumed that there is no contagion ($\delta_i = \delta = 0$) and no idiosyncratic structural break ($\kappa_i^2 = 0$). The strength of the transmission mechanism between country 1 and 2 is given by the parameter β. As this parameter is the same over both non-crisis and crisis periods, it can be estimated by simply regressing the returns of country 2 on the returns of country 1 using the full sample of data, despite the structural break in the common factor.

The fact that the parameter β in (15) is constant over the two sample periods, does not imply that the correlations are also constant. To see this, in (11) set $\phi_1, \delta_1, \kappa_i^2 = 0$, so the change in the correlation between the crisis and non-crisis periods reduces to

$$\rho_{y_{1,t},y_{2,t}} - \rho_{x_{1,t},x_{2,t}} = \frac{1}{\sqrt{1 + \left(\frac{\phi_2}{\lambda_2 \omega}\right)^2}} - \frac{1}{\sqrt{1 + \left(\frac{\phi_2}{\lambda_2}\right)^2}}.$$

This expression is positive for $\omega^2 > 1$, whereby the structural break in the common factor results in an increase in correlation even though the regression parameter in (15) is constant. This point is first made by Loretan and English (2000) and Forbes and

Rigobon (2002). This result suggests that a test of the stability of the relationship between countries one and two can be undertaken by performing a test of parameter constancy. If the null hypothesis of constant parameters is rejected, this would be evidence of an additional transmission mechanism during the crisis period, and hence would constitute contagion. This forms the basis of the regression based test of contagion suggested by Dungey Fry González-Hermosillo and Martin (2005a).

4 A Review of the Empirical Evidence for Asian Financial Markets

Although there are limitations in many of the suite of contagion tests as demonstrated by the correlation coefficient example above, some generalities can be drawn from the evidence presented in the empirical literature. Apart from techniques based on correlation analysis, there are several other methodologies by which researchers test empirically for contagion; these tests are reviewed in Dungey, Fry, González-Hermosillo and Martin (2005a). The main empirical tests include those based on modelling outliers from a VAR system such as in Faverro and Giavazzi (2002), dummy variable based tests such as in Pesaran and Pick (2003), and the probability based measure of Bae, Karolyi and Stulz (2003), which is related to the previous work of Eichengreen, Rose and Wyplosz (1995,1996). Tests based on latent factor models such as those examined by the current authors, Corsetti, Pericoli and Sbracia (2001) and Baekart, Harvey and Ng (2005), are also commonly used. As most papers in this literature focus on a particular asset market during the crisis period, this is how the evidence is organised here. A number of the papers included here are also reviewed in Pericoli and Sbracia (2003).

4.1 Currency Markets

Contagion during the East Asian financial crisis is widely believed to have originated with the float and depreciation of the Thai baht on 2 July 1997. This date is often used in empirical applications to mark the start of the crisis despite the fact that others claim that turmoil was evident in equity markets earlier; see McKibbin and Martin (1998). The problems in dating financial crises are quite pronounced, and represent one of the issues which make comparisons of results across empirical studies difficult. Despite the importance of currency markets in the crisis, the literature on testing for contagion in Asian currencies is limited, reflecting that these markets were largely running fixed exchange rate regimes prior to 1997, making pre-crisis period volatility comparisons difficult.

Under the alternative hypothesis that the contemporaneous spread of currency crises is consistent with contagion, Glick and Rose (1999) using a large panel of five Asian countries find that the most important economic linkages explaining these trans-

missions are trade linkages. Van Rijckeghem and Weder (2001) using a similar methodology, find that financial links are more important, although they also note that as a result of the close relationship between financial and trade linkages it is difficult to disentangle the two.

Baig and Goldfajn (1999) show a pronounced increase in correlation coefficients during the crisis period as evidence of contagion. However, the effects of this contagion on developed markets in the region is muted; notably both Debelle and Ellis (2005) and Dungey, Fry and Martin (2004) using an alternative statistical framework show very small effects of contagion to Australia and New Zealand in both papers and to Japan in the second paper.

Substantial contagion effects within the East Asian region are revealed in Dungey and Martin (2004). In investigating the links between Malaysia, Indonesia, Korea and Thailand during 1997-1998, they find statistically significant contagion effects of up to 46% of total volatility for Korea, mostly sourced from Thai based shocks. However, although Thailand is the major source of shocks for Korea and Malaysia, the majority of the effects on Indonesia are transmitted indirectly through Malaysia.

4.2 Equity Markets

Equity markets have probably received the most attention in empirical applications of contagion tests in East Asian markets. A number of these applications have examined the effects of contagion during the period associated with the turmoil in the Hong Kong equity market in late October 1997; including Baig and Goldfajn (1999), Forbes and Rigobon (2002), Baur and Schulze (2005), Baur and Fry (2005), Bond, Dungey and Fry (2005) and Dungey, Fry, González-Hermosillo and Martin (2005b). Of these, Forbes and Rigobon (2002), Baur and Schulze (2005) and Bond, Dungey and Fry (2005) focus on Hong Kong as the identified source of the potentially contagious shocks, where the others look more generally at contagion in the region. Kleimeier, Lehnert and Verschoor (2003) and Baur and Schulze (2005) focus on Thailand as the source country for the potentially contagious equity market shock.

The papers are divided in their results on the importance of contagion effects in Asian equity markets. On the one hand, Forbes and Rigobon (2002) and Kleimeier, Lehnert and Verschoor (2003) find little or no evidence of contagion using tests based on a statistically significant increase in the correlation coefficient between returns in these markets. Both papers use the same methodology, although Kleimeir, Lehnert and Verschoor control precisely for the timing of the observations on the various equity markets, whereas other studies use market closing observations resulting in differences in the effective times across the day.

On the other hand a number of papers do find significant contagion effects in East Asia. Caporale, Cipollini and Spagnolo (2003) find evidence for contagion between

almost all pairs of eight Asian economies using conditional correlation analysis.[2] During the period of 1997-1998 associated with turmoil in Hong Kong, Bond, Dungey and Fry (2005) show that equity and real estate markets behave somewhat differently, but both indicate statistically significant contagion effects. This paper also emphasises the role of the Japanese and Singaporean markets in helping to transmit the contagion effects around the region. Contagion from Hong Kong is found to be significant to Singapore and the Philippines by Corsetti, Pericoli and Sbracia (2001) and from Hong Kong to a wide range of Asian economies in Baur and Schulze (2005). Baur and Fry (2005) find that contagion is significant across eleven countries during eight percent of days over the period of the Asian crisis, with Hong Kong being an important factor.[3]

Bekaert, Harvey and Ng (2005) and Wongswan (2003) also find evidence of significant contagion effects within Asia, but not to other countries or regions. Wongswan (2003) controls for common effects by fitting a CAPM model, including GARCH conditional variances and examines the correlations amongst the residuals across countries and regions. Baig and Goldfajn (1999) uncover mixed evidence of contagion in equity markets; finding evidence for pairwise contagion between Korea and each of Indonesia, Malaysia, the Philippines and Thailand and between Indonesia and Malaysia and Thailand, but not between other pairings of these countries. There is also evidence of contagion from both Korean and Thai equity markets to Indonesian equities in Cerra and Saxena (2002) who use a Markov switching modelling approach.

The effect of a change in the propagation of the common factor during the Asian crisis as an alternative explanation is explored in Rigobon (2003) using his Determinant of Change in Covariance (DCC) test. The test does not suggest any break in the propagation in Asia during the Asian crisis, but provides some limited evidence that other countries experienced a change in their propagation coefficients associated with the crisis in Thailand during 1997-1998, notably India, South Africa and Russia. Other evidence on structural breaks suggests that there was some increase in the intensity of the integration between the Asian equity markets during the crisis period; Yang, Kolari and Min (2003).

4.3 Fixed Income Markets

Studies of contagion in fixed income markets for Asia are far less common than for other asset types. This partly arises from the relative stability in these markets up until the events of August-September 1998 when the Russian Government suspended payment and subsequently defaulted on sovereign bond payments, creating substantial volatility in international bond markets; see the analysis of the period in the BIS report

[2] The countries considered are Hong Kong, Indonesia, Korea, Malaysia, the Philippines, Singapore, Taiwan and Thailand.

[3] The countries considered are China, Hong Kong, India, Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, Taiwan and Thailand.

by the Committee on the Global Financial System (1999).

Only three studies have paid particular attention to bond markets with East Asian markets as the focus. Baig and Goldfajn (1999) conduct a similar correlation analysis for bond spreads as for the currency and equity markets and find evidence of contagion between the Asian sovereign bond markets. Debelle and Ellis (2005) consider links from East Asia to Australia and New Zealand through bond markets and find evidence of significant but small contagion effects. Sander and Kleimeier (2003) view contagion as a change in cross market interdependencies, which they assess using Granger causality tests during pre-crisis and crisis periods. They find evidence for crisis related changes in the short term propagation mechanism, which they denote as contagion, namely from the Philippines to Malaysia and Korea; Indonesia to the Philippines, Thailand and Malaysia; Malaysia to Thailand; and Korea to Indonesia. They attribute their finding of no contagion from Thailand as suggesting that Korea was a more important influence. However, this may well relate to the fact that the crisis in Thailand erupted in currency and equity markets and was not particularly visible in sovereign debt markets.

4.4 Cross Country Linkages And Cross Market Linkages

In some cases a particular asset market is hit by an identifiable shock, but this does not result in unusual levels of volatility in the returns for that asset. The clearest examples of this phenomena are the successful defence of managed or fixed exchange rate arrangements, such as the currency board in Hong Kong over a number of instances in 1997-1998. However, it would be misplaced to conclude that it is possible to isolate economies from the effects of such shocks, as the volatility was transferred to alternative asset types. In October 1997, and January, June and August of 1998, speculators attacked the Hong Kong currency board. In each case the currency was successfully defended, but substantial volatility emerged in equity markets.[4] The general principle is that financial markets are closely interrelated, and studying the transmission in crises across one asset market type in isolation may not give the appropriate conclusions, particularly for policy makers who need to consider the impact on all asset markets and the economy in general.[5]

Given the well known linkages between markets and economies in East Asia, it is somewhat surprising that contagion in multiple markets has tended to be under-studied. One possible reason is the obvious difficulties in combining models of the different markets. However, there are some developments in this vein of the literature. A few papers consider modelling linkages between different asset classes during a crisis

[4]See Goodhart and Dai (2003) for a detailed review of the HKMA's subsequent defence of their currency through equity market intervention.

[5]The seminal work on crises by Kindelberger (1996) discusses the importance of cross market financial interlinkages well before the East Asian crisis.

within a particular country; Granger, Huang and Yang (2000), Fang and Miller (2002), Hartmann, Straetmans and de Vries (2004), and recently for pairs of asset types across geographical borders in Hartmann, Straetmans and de Vries (2004). Bond, Dungey and Fry (2005) attempt to differentiate transmissions between real estate market instruments from those in the related equity markets by using orthogonal shocks obtained from regressing equity market returns on real estate returns. Some papers consider different asset types during the same crisis but not the potential interactions between them; Baig and Goldfajn (1999) and Debelle and Ellis (2005) both consider a range of markets during the Asian crisis of 1997-1998.

More related to the current discussion are models which consider transmissions between multiple markets across potentially different asset types and a number of economies. The relevant studies are Ito and Hashimoto (2005) who use a Tobit model on extreme returns to test for contagion across equity markets and currency markets during the East Asian crisis of 1997-1998, Khalid and Kawai (2003) who conduct Granger causality tests on the residuals of a VAR across equity, currency and bond markets and Kaminsky and Reinhart (2002) who identify the commonalities in equity, bond and currency markets across a range of countries using principal component methods.

The conclusions from these papers almost always find evidence of statistically significant contagion across different asset market types. Dungey and Martin (2005) find that equity market shocks are contagiously transmitted to currency markets and vice versa. This is supported by the Granger causality tests in Granger, Huang and Yang (2000), who find feedback between equity and currency markets for Malaysia, Singapore, Thailand and Taiwan during the period of 1 June 1997 to 16 June 1998.[6] The exception to the finding of cross market, cross country linkages is Khalid and Kawai (2003) who conclude that the evidence for significant contagion is limited.

A further important conclusion to be drawn from comparing both cross-market and cross-country evidence is that crises seem to propagate through different asset classes differently. This is shown to be the case for equity markets and currency markets in Dungey and Martin (2005), for equity markets and real estate instruments in Bond, Dungey and Fry (2005), for equity and bonds in Hartmann, Straetmann and de Vries (2004).

5 Propositions And Evidence

This section addresses, in turn, the seven propositions about contagion outlined in the Introduction. These propositions are investigated using the recent factor decomposition approach of the authors. An advantage of the structure is that it is possible to

[6] For other countries in the study they find unidirectional Granger causality from equity to currency markets for Hong Kong and the Philippines, and from currency to equity markets for Korea.

decompose volatility into a set of latent factors including a common factor, an idiosyncratic factor and contagion factors and thereby quantifying the magnitude of contagion as a proportion of overall volatility. Other specifications include some combination of regional factors, asymmetric contagion factors to account for positive or negative contagion effects, multiple asset markets, sub-periods of contagion within a crisis, and in some applications the simultaneous modelling of multiple crises. This factor structure is related to the model in equations (1) to (8) of Section 3. These papers are summarised in Table 1 in terms of the acronym used to identify the paper, the crisis addressed, the asset market investigated, the sample of countries considered and a guide to the factor structure specified in the paper.[7]

5.1 Strong Fundamentals Imply Immunity To Contagion

Sachs, Tornell and Velasco (1996) suggest that countries with strong fundamentals experience less contagion than other countries. Athukorala and Warr (2002) go further by saying that contagion cannot occur in countries which do not have some underlying 'vulnerability', by which they mean some fundamental weakness; see also Kaminsky and Reinhart (1999). The evidence for Asia is mixed in this respect. Furman and Stiglitz (1998) suggest that the standard macroeconomic fundamentals in the main crisis countries showed little evidence of weakness ahead of the crisis. In contrast, Athukorala and Warr (2002) examine the financial fragility, reserve adequacy and real exchange rate misalignment of the key crisis countries in comparison to a set of non-crisis countries and find the opposite result. Using the method of Frankel and Rose (1996), Furman and Stiglitz (1998) predicted a less than 7 percent probability of a currency crisis in 1997 for Malaysia, Indonesia, Thailand and the Philippines. In contrast there were 17 other countries with higher probabilities of crisis.

The focus of existing studies has been on whether fundamentals in Asia were strong or weak relative to other countries which have experienced financial crises, such as comparisons with the Mexican peso crisis in Sachs, Tornell and Velasco (1996), Furman and Stiglitz (1998) and Kaminsky and Reinhart (1999). However, there may also be insights to be gained by comparing the relative strength of fundamentals within the crisis affected countries in conjunction with the degree of contagion they experienced. The top panel of Table 2 provides details on the relative values for a selection of fundamental macroeconomic variables for Indonesia, Korea, Malaysia and Thailand. These variables reflect those found to be important in the financial crisis literature represented by Sachs, Tornell and Velasco (1998), Furman and Stiglitz (1998), Frankel and Rose (1996) particularly.

A good set of economic fundamentals in Table 2 would constitute a high GDP per capita, strong GDP growth, a low short term debt to reserves ratio, low and stable

[7]For information on estimation of this suite of models consult any of the papers in Table 1 for details.

Table 1:
Summary of papers on contagion by authors using factor models.

Paper[a]	Crisis	Market	Countries[b]	Factors[c]
DFGM (2002)	Russia /LTCM	bond	I,K,T,B,P,R,Ar, Br,Me,N,UK,US	com,idio,reg,cont
DFM (2003)	Asia	equity	A,HK,I,K,M,T	com,idio,cont
DM (2004)	Asia	currency	I,K,M,T	com,idio,cont
DFM (2004)	Asia	currency	I,K,M,T,A,J,NZ	com,num,idio,reg,cont
BDF (2005)	Asia	real estate and equity	A,HK,S,J,US	com,idio,cont
DM (2005)	Asia	equity/currency modelled jointly	A,K,I,M,T,US	com,idio,mkt,cnty,cont
DFGM (2005b)	1. Asia	equity	1. HK,K,M	com,idio,cont
	2. Tequila	equity	2. Ar,C,Me	com,idio,cont
	3. Argentine	equity	3. Ar,Br,C	com,idio,cont
DFGM (2005c)	Russia /LTCM	bond	I,K,T,B,P,R,Ar,Br, Me,N,UK,US	com,idio,reg,cont
DFGM (2005e)	Russia /LTCM	equity	Ar,Br,HK,T,P, R,DM,J,UK,US	com,idio,reg,cont

[a]Authors: D=Dungey, F=Fry, M=Martin, G=González-Hermosillo, B=Bond.
[b]Countries: A=Australia, Ar=Argentia, B=Bulgaria, Br=Brazil, C=Chile, DM=Germany, HK=Hong Kong, I=Indonesia, J=Japan, K=Korea, M=Malaysia, Me=Mexico, N=Netherlands, NZ=New Zealand, P=Poland, R=Russia, S=Singapore, T=Thailand, UK=United Kingdom, US=United States.
[c]com=common, idio=idiosyncratic, cont=contagion, reg=regional, mkt=market, cnty=country

inflation, a low rate of non-performing loans and an exchange rate near its equilibrium value.[8] More difficult to interpret is the role of openness and export growth. Typically openness is seen as a requirement to development and a high degree of openness is desirable. Export growth is also generally seen as important to an economy, indicating strong domestic growth. Although it may also be associated with overheating as in the case of Thailand; see Athukorala and Suphachalasai (2004).

The country with the strongest fundamentals in Table 2 is Korea. It has higher GDP per capita and higher average GDP growth in the run up to the crisis, a low rate of non-performing loans and an exchange rate close to equilibrium. However, it also has the highest short term debt to reserves ratio of the four countries. Its' openness and export growth are only slightly higher than those of Indonesia, which is clearly the worst performing country in the sample on the basis of these indicators. Note that Kenward (1999) describes the lack of macroeconomic indicators of weakness in Indonesia prior to the crisis and Iriana and Sjöholm (2002) find less evidence of weakness than other economies in the region, but point to the role of the larger share of short term debts.[9] Table 2 shows that Indonesia has the least favourable GDP per capita, ratio of non-performing loans, openness and export growth criteria. Thailand stands out in the sample of data here only in terms of its high export growth.

The Malaysian experience places it as the strongest amongst the four countries in terms of inflation, short term debt to reserves ratio and openness. However, it also features substantial exchange rate misalignment and lower GDP growth than the other countries. From this particular selection of economic indicators the relative economic strength of these economies looks to favour Korea as the strongest, Indonesia as the weakest and Malaysia as stronger than Thailand. Although the economic indicators selected here are not comprehensive they are indicative of those in use in the financial crisis literature.

With this broad ranking in mind the contributions of contagion to observed volatility in currency and equity returns and sovereign debt spreads over US Treasuries can be assessed. The lower panel of Table 2 presents evidence of the proportion of observed volatility due to contagion while controlling for fundamentals from a number of the studies carried out by the present authors. The currency market study in DM (2004) is most informative as it contains all the countries considered in this Table.

[8] The real exchange rate misalignment in Table 2 is computed relative to an equilibrium measure based on the predicted value of the real exchange rate in 1996 estimated with levels of real GDP per capita taking into account the Balassa-Samuelson effect. Furman and Stiglitz (1998) give four alternate measures of which this is one, and the extent (and even sign) of the deviation from equilibrium differs across the measures. Two of the measures given in Furman and Stiglitz agree with the relative ordering of the extent of misalignment here. That is, that Malaysia is the most misaligned and Korea the least. The other two measures suggest that Korea is the most misaligned and Indonesia the least. Hence the results vary enormously with the measure chosen and undue weight should not be placed on the indicator adopted in Table 2.

[9] Cerra and Saxena (2002) investigate the perception that Indonesia suffered from substantial contagion despite having relatively good fundamentals in the lead up to the crisis.

Korea experiences the greatest contribution to currency market volatility from contagion (46.31%), despite its relatively stronger fundamental position revealed in the first panel of Table 2. Malaysia, however, which is arguably also relatively well positioned fundamentally, displays the lowest contribution of contagion at 9.59% in this market. In the equity market study of DFGM (2005b) contagion effects from Hong Kong are a greater proportion of volatility in Korea (74.45%) than Malaysia (49.92%), suggesting that Korea had more vulnerability to contagion than Malaysia. In contrast, contagion effects from Korea to Malaysia were a greater part of Malaysian volatility (22.65%) than were contagion effects from Malaysia to Korea on Korean volatility (10.11%). Hence the evidence is somewhat mixed in the equity markets as to whether Malaysia or Korea experienced greater contagion effects.

In bond markets, Thailand experienced the largest contagion effects from the Russian collapse and LTCM crisis in August 1998 (7.78%), while Indonesia experienced very little. The very small extent of contagion to Indonesia suggests that perhaps after its own crisis it developed an immunity, at least for a period, to contagion from further crises; DFGM (2005c).

The combination of the evidence on market fundamentals and the extent of contagion effects identified provides a mixed picture. While the more general literature on crises may have drawn the conclusion that poor fundamentals are associated with more contagion effects, this is hard to discern clearly in comparing the relative performance of these economies with this set of economic indicators.

5.2 Trade And Financial Linkages Are Important

Trade links are regarded as primary mechanisms for contagion in Glick and Rose (1999). Van Rijckeghem and Weder (2001) find that financial effects through common lenders are a more important route of transmission, although trade links may still be important. A difficulty with separating trade and financial links arises if the two effects are highly correlated, as Van Rijckeghem and Weder demonstrate is the case for Asia. Athukorala and Warr (2002) argue that trade links cannot be a mechanism of propagation in Asia, as bilateral trade flows are relatively small between these countries. But, this overlooks the trade related effects of competitive devaluation due to export competition which is argued as a primary driver of the spread of the Asian crisis by Goldstein (1998). Baig and Goldfajn (1999) find little evidence for either trade or competitive devaluation, while De Gregorio and Valdés (2001) provide empirical evidence that the regional nature of crises and contagion is largely unrelated to trade links. Karolyi (2003) argues that the focus on trade is misplaced and rather contagion reflects rational behaviour on the basis of liquidity - those with the most liquid markets may suffer more.

Indicators of financial fragility explored in the existing literature include net investment flows, domestic financial liberalisation and banking linkages; see for example Wyplosz (2001), Van Rijckeghem and Weder (2001,2003) and Furman and Stiglitz

Table 2:
Fundamental indicators and extent of contagion experienced by country.

		Indonesia	Korea	Malaysia	Thailand
Fundamentals					
GDP per capita 1997 (USD)[a]		4137	14704	9689	7051
Average GDP growth (%) 1970-1996[a]		5.06	6.63	4.54	5.49
Short term debt to reserves ratio June 1997[b]		1.70	2.07	0.61	1.45
Consumer price inflation (%) 1997[c]		4.67	4.37	1.01	4.37
Non performing loans (% of total) 1996[d]		8.8	0.8	3.0	...
Openness[a] (X+M)/Y		56.04	67.63	178.26	84.16
Export growth 1986-1996 (%)[e]		236	274	471	528
Exchange rate overvaluation 1996 (%)[f]		-16	1	-41	-18
Moody's rating[g]		Baa3	A1	A1	A3
Standard and Poors' rating[h]		BBB	AA-	A+	A
Financial Links					
Net capital flows 1996 US$mil[k]		9841	14535	13824	10487
US direct investment 1996 US$mil[k]		956	752	1298	849
Net FDI flows 1996 US$mil[k]		5594	-2345	7927	1404
Extent of volatility due to contagion					
Market	*Source*	*Contagion proportion of volatility(%)*			
Currency market					
DM(2004)	Asia	19.75	46.31	9.59	29.14
Equity market					
DFGM (2005b)	Hong Kong		74.45	49.92	
	Korea			22.65	
	Malaysia		10.11		
DFGM (2005e)	Russia & US				11.00
Bond market					
DFGM (2005c)	Russia & US	0.68	5.32		7.78

Sources:[a] Penn World Tables v 6.1 accessed via NBER website.
[b] Radelet and Sachs (1998) Table 3.
[c] IMF IFS statistics, authors calculations; average monthly annual inflation rate.
for January-June 1997; Datastream series identifier XX64...F where XX is the
appropriate country abbreviation.
[d] Radelet and Sachs (1998) Table 10.
[e] IMF IFS statistics, authors calculations; Datastream series identifier XXI70..DA.
[f] Furman and Stiglitz (1998) Table 2; column 3 per-capita GDP adjusted.
[g] Moody's sovereign rating foreign currency country ceiling for bonds and notes prior to crisis.
[h] S&P foreign currency sovereign credit rating prior to crisis.
[k] Athukorala (2003) Tables 1 and 4.

(1998), inter alia. A number of indicators of the financial position of four East Asian economies are given in the middle panel of Table 2. The choice of these indicators is again drawn from the relevant literature on financial crises. Similarly to the fundamentals indicators there is not a clear relationship between the financial linkages positions of the four countries and the extent of contagion experienced by each.

While the empirical papers of the current authors canvassed here do not provide direct evidence on the importance of trade and financial linkages there are some comments that can be drawn out. In the investigations of the Russian and LTCM crises in DFGM (2005c,2005e), some of the strongest contagion effects from Russia are felt by countries with strong financial linkages with Russia. Consistent with the evidence of Van Rijckeghem and Weder (2001,2003), Kaminsky and Reinhart (1999) and Pritsker (2001), the banking exposure of the Netherlands and Germany to Russia seems consistent with the relatively large contributions of contagion to volatility in their financial markets compared with other developed markets in the period. On the trade side, the East Asian crisis was widely anticipated to affect the Australian and New Zealand economies given their strong trade linkages; see Summers (2001) for Australian evidence. In the event, however, the contagion effects documented in DFM (2003) and DFM (2004) to the Antipodes are quite small. This small amount of evidence suggests that perhaps trade links are a less important prerequisite for contagion than are financial linkages in the region.

5.3 Regional Proximity Is Important

A common observation is that crises and contagion pertain to geographically clustered regions, with little spillover to other countries. This proposition is intrinsically related to the hypothesis that trade linkages, which are often with geographically proximate nations, are important for contagion and may also arise due to portfolio balancing arguments as well as similarity of fundamentals. The validity of this proposition is examined by considering the importance of contagion within regions, and the importance of contagion across regions. Although potentially the analyses of the regional nature of contagion through the empirical work presented here is limited in that generally countries that generally did not suffer during the crises are omitted from the sample, there are several instances where cross regional linkages are modelled.

Table 3 summarises the proportion of observed asset market volatility due to contagion across various papers relating to the Asian financial crisis. It shows that within the Asian region there is a lot of contagion during the Asian financial crisis. In particular, contagious linkages in currency markets are strong from Thailand to Korea and Malaysia with the contribution of contagion to volatility of currency markets of Korea and Malaysia of more than 28 percent. Contagion in equity and real estate markets during the Asian crisis is always strong from Hong Kong to the other Asian economies. Evidence from other crises in DFGM (2005c, 2005e) shows that during the Russian

Table 3:
Percentage contribution of contagion to the volatility of various asset markets during the Asian crisis.

Paper	Contagion to	Contagion from[a] Asia	HK	I	K	M	T	J	S	US
Equity Markets										
DFM (2003)										
	Australia		0.59	0.9	0.24	0.67	5.6			
BDF (2005)[b]										
	Australia		33-65					1-12	16-30	<0.5
	HK							3-20	2-70	1-19
	Japan		23-40						7-36	0.6-18
	Singapore		10-74					2-70		<0.5
	US		<0.5					1-19		
DFGM (2005a)										
	Hong Kong				74.45	49.92				
	Korea		60.51			22.65				
	Malaysia		18.10		10.11					
Currency Markets										
DM (2004)										
	Indonesia				6.2	13.1	0.45			
	Korea			5.3		10.0	31.0			
	Malaysia			0.5	0.2		28.5			
	Thailand			0.6	4.5	4.5				
DFM (2004)										
	Australia	1.7								
	Japan	0.13								
	New Zealand	3.1								
Real Estate Markets										
BDF (2005)										
	Australia	39-67						7-20	4-38	<0.5
	Hong Kong							0.5-14	44-88	<0.5
	Japan	7-21							16-17	0.01-3.6
	Singapore	4-38						28-57		<0.5
	US	<0.5						7-38		

[a]Asia - Joint contagion from Indonesia, Korea, Malaysia and Thailand.

[b]The range represents results from two separate periods of turmoil in Hong Kong equity markets.

Countries: HK= Hong Kong, I=Indonesia, K=Korea, M=Malaysia, T=Thailand, J=Japan S=Singapore, US=United States.

Table 4:
Percentage of important contagious linkages within and across regions as evident in selected papers.[a]

	Level of Contagion		
	minimal	moderate	strong
percentage of volatility:	$< 5\%$	$5 - 30\%$	$> 30\%$
Contagion within regions			
All regional linkages	34%	39%	27%
Regional linkages excluding US	27%	35%	24%
Regional linkages excluding US and Australia	38%	39%	23%
Contagion across regions			
All cross regional linkages	56%	32%	12%
Cross regional linkages excluding US	54%	46%	0%

[a]Papers include DFM (2003), DM (2004), DFM (2004), DFGM (2005b), DFGM(2005c), DFGM (2005e), BDF (2005).

crisis, contagion from Russia to Eastern Europe (Poland) is strong in equity markets, but less so in bond markets (Bulgaria and Poland), probably because of thin bond markets in the even less developed Eastern European economies. Contagion during the US based LTCM crisis transmits strongly to Latin America in equity markets, but not in bond markets.

DFM (2003,2004) and BDF (2005) analyze contagion from Asia to asset markets in Australia, Japan and New Zealand. Systematically there is no contagion to any of these countries from the key crisis countries, although there is substantial contagion to Australia and Japan in equity and real estate markets from the developed regional countries of Hong Kong, Singapore and Japan for Australia, and Australia, Hong Kong and Singapore for Japan. Debelle and Ellis (2005) also find little evidence of contagion to Australia from the Asian crisis. The role of developed markets in the crisis will be discussed in Sections 5.4 and 5.5.

DFGM (2005c, 2005e) model contagion in bond and equity markets in the Russian and LTCM crises across and within regions, with the result that there is cross regional equity market contagion from both Russia (17 percent) and the US (14 percent) to Hong Kong, and from Russia to Brazil (16 percent) in bond markets. During this period Hong Kong was experiencing it's own financial turmoil associated with another speculative attack on its currency board successfully defended by intervention in equity markets (Goodhart and Dai, 2003), and Brazil was to experience it's own crisis in early 1999. Baig and Goldfajn (2001) discuss the transmission of the Russian crisis to Brazil.

To clarify further the evidence presented from the latent factor models, Table 4

collates the percentage of total contagious linkages which are classified as small (less than five percent of total volatility), moderate (between five and 30 percent of total volatility) and strong (more than 30 percent of total volatility) within and across regions as evident in the selected papers. The table shows that 66 percent of all linkages within a region across the papers are deemed to be either moderate or strong. If linkages due to the US which may be considered to be systemic are excluded, the number is still substantial with 59 percent of linkages considered to be moderate or strong. Of the cross regional linkages, 54 percent are regarded as minimal, with the remainder considered moderate once the US is excluded.

Several other studies support the hypothesis that crises are regional. Yang, Kolari and Min (2003) examine the integration of Asian equity markets during the crisis, and find that the key crisis countries are more integrated during the crisis period, and are also more responsive to external shocks. Goldstein (1998), Kaminsky and Reinhart (2000), Glick and Rose (1999) and Gerlach and Smets (1995) all emphasize the importance of regional effects in the transmission of crises.

5.4 Developing Markets Experience More Contagion Than Developed Markets

Although generally financial crises are thought to be the domain of developing markets, sometimes crises are "mysteriously on a worldwide basis" (Wypolsz 2001), that is, systemic. The Committee on the Global Finance System (1999) claim that the Russian crisis affected only developing markets, while the LTCM crisis affected developed markets. A similar conclusion is put forward by Bae, Karyoli and Stultz (2003) who find that for a range of international equity markets, developing markets are more susceptible to international financial crises than developed markets. Clear examples of developed countries affected by crises are Korea, who is a member of the OECD, and Hong Kong, who has one of the most liberalised financial systems in the world. Potential linkages that exist between the markets of developed and developing nations include increasing globalisation, trade linkages, foreign direct investment particularly through the direct investment of financial intermediaries, as well as portfolio investment decision of investors who seek to diversify their portfolios by investing in emerging markets.

The proposition that developing markets experience more contagion than developed markets is also difficult to disentangle from the proposition that strong fundamentals mean immunity to contagion. In general, but not always, developed markets have stronger fundamentals than developing economies. The evidence presented in DFGM (2002,2005c,2005e) does not support this proposition. The results are instead mixed, and depend on how the impact of a crisis is measured. In the study of bond markets in the Russian and LTCM crises by DFGM (2005c), contagion contributes an equivalent proportion to volatility in developed markets as in developing markets. For the same

crisis the proportion of volatility due to contagion in equity markets from Russia is higher for developed markets than developing markets.

Because of the overall higher level of volatility in developing markets in general, the levels effect of contagion is generally smaller in developed markets than developing. This point is clearly demonstrated in Table 5 which presents the volatility decompositions of changes in bond market premia into common, country specific, regional and contagion factors for nine developing and three developed countries. The volatility decompositions are presented in both percentage contribution to volatility, and in terms of squared basis points. The volatility decomposition in percentage terms shows that the world factor contributes more than 80 percent to volatility in both types of countries. For the developing countries, contagion contributes between 0.1 percent in the case of Russia to 16 percent in the case of Brazil, while for the developed countries the range is between 0.25 percent for the UK and 17 percent for the Netherlands. Even though in percentage terms contagion is of similar magnitude across the types of countries, the second panel of the table shows that 17 percent contagion to the Netherlands is equivalent to just 4.99 basis points squared, while 16 percent contagion to Brazil is equivalent to 585.6 squared basis points!

This is not quite the same as saying that developing markets experience more contagion than developed markets. Although clearly the absolute level of contagion experienced does matter for a country's policymakers, it is not as clear whether a policy maker should be concerned about the proportionate or the absolute contribution of contagion.

5.5 Developed Financial Markets Can Transmit Contagion Between Regions

The hypothesis that developed markets are a conduit for financial contagion between developing markets as suggested in Frankel and Schmukler (1996) and Kaminsky and Reinhart (2003), is consistent with the evidence reported in the papers listed in Table 1. Support for this proposition is highlighted in comparing DFM (2003) and BDF (2005) which both study the impact of contagion during the Asian crisis to Australian equity markets. DFM (2003) examines contagion from the countries traditionally considered crisis countries including Hong Kong, Indonesia, Korea, Malaysia and Thailand, whilst BDF (2005) focus on the more developed countries of the Asian region during the same crises including Japan, Singapore, Hong Kong and the US. DFM (2003) find little evidence of contagion to Australia from the traditional crisis countries, while there is much more evidence of contagion to Australia from the more developed Asian economies and the US, particularly from Hong Kong, Singapore and Japan. Both Singapore and Japan seem to play a key role in transmitting contagion between the countries within the Asian region. Further supporting evidence can be found in DM (2004, 2005), where the majority of the effects transmitted to Australia tend to come

Table 5:
Comparison of contagion volatility decomposition of bond markets during the Russian crisis: percentage and squared basis points.

Country	Common	Country	Regional	Contagion
Percentage decomposition				
Industrials				
UK	99.74	0.01	-	0.25
US	84.97	11.83	-	3.20
Netherlands	82.29	0.52	-	17.19
Eastern Europe				
Bulgaria	91.33	0.20	0.52	7.95
Poland	93.71	0.05	0.66	5.59
Russia	94.73	5.06	0.11	0.10
Asia				
Indonesia	98.85	0.27	0.21	0.68
Korea	88.85	4.95	0.88	5.32
Thailand	90.52	1.32	0.38	7.78
Latin America				
Argentina	86.83	12.68	0.05	0.45
Brazil	83.15	0.18	0.01	16.66
Mexico	99.74	0.00	0.01	0.26
Squared basis points decomposition				
Industrials				
UK	13.88	0.00	-	0.04
US	6.38	0.89	-	0.24
Netherlands	23.91	0.15	-	4.99
Eastern Europe				
Bulgaria	9138.09	20.38	51.62	795.11
Poland	494.42	0.25	3.48	29.48
Russia	55685.89	2973.20	62.97	59.94
Asia				
Indonesia	3085.45	8.39	6.41	21.21
Korea	728.81	40.60	7.22	43.62
Thailand	452.58	6.59	1.88	38.92
Latin America				
Argentina	984.34	143.71	0.51	5.12
Brazil	2923.10	6.47	0.14	585.60
Mexico	525.31	0.01	0.03	1.35

through the US market.

Contagion may also be reinforced by transmissions from other developing countries involved in the crisis. In many of the studies examined two or more countries showed substantial contemporaneous contagious links. For example, in the DFGM (2005b) application of equity markets during the collapse of the Hong Kong equity market, there is strong contagion to Malaysia originating in Hong Kong and strong contagion to Hong Kong originating from Malaysia. The inclusion of developed markets in estimating the effects of contagion helps to provide a clearer picture of the propagation mechanisms.

5.6 Contagion Effects Differ By Asset Market

While the characteristics of alternative asset markets are known, it also seems that different asset markets have different vulnerabilities to contagion effects. In general the variation in returns attributable to contagion is relatively smaller in currency markets and relatively larger in equity markets. It is harder to characterize bond markets given the smaller body of research, but DFGM (2005c, 2005e) investigate the same crisis (Russia and LTCM) for both bond and equity markets, with the result that the proportion of volatility due to contagion in the bond markets is relatively much smaller. The evidence suggests that amongst countries actually involved in a financial crisis, as opposed to those on the periphery, contagion is largest in equity markets and smallest in bond markets, with currency markets in between.[10] This generalisation seems to stand regardless of the asset market in which the initial shock occurred. In the Russian/LTCM crisis of 1998, which is broadly considered to have originated in the Russian bond markets, although see Dungey, Goodhart and Tambakis (2005) for the role of turmoil in Hong Kong equity and currency markets, the bond market shows less contagion than in corresponding equity markets. A comparison of equity and currency markets in the East Asian crisis shows stronger contagion effects in equities: Compare DFM (2004) for currency markets with DFM (2003) for equity markets.

5.7 Contagion Occurs Between Different Economies And Different Asset Types

Models which capture linkages both across asset types and across international borders provide a clearer picture of a crisis; for an historical perspective see Kindelberger (1996). An important question for researchers and policy makers is understanding how crises evolve. The examples discussed here suggest that single asset type investigations are far too restrictive. The implication is that there is limited scope for policy or infrastructure reform that concentrates on a single asset type. It is necessary to consider the interrelationships between all financial assets. This argument is analogous to the

[10] Kaminsky and Schmulker (1999) find volatility in USD denominated stock returns during the Asian crisis to be predominantly equity market related with the notable exception of Indonesia.

one against the implementation of Tobin taxes in currency markets, where such taxes simply encourage innovation into other markets. This suggests also that one potential source for aiding reform is the development of alternative financial derivatives; see Allen and Gale (2004).

The empirical results in DM (2005) and BDF (2005) support the importance of cross asset market linkages. DM (2005) specifically model contagion between equity and currency markets across multiple countries in the Asian crisis. The results indicate the contagion effects from currency markets account for up to 11% of equity market volatility, while contagion effects from equity markets account for up to 36% of volatility in currency markets. This proposition has an important implication for minimising risk via portfolio diversification. The results clearly show that risk management should consider both cross border diversification and cross asset type diversification. The traditional approach in the 1990s of segmenting asset types and managing the risks for each asset type separately is clearly not risk minimising in a crisis period.

6 Conclusions: How Important Is Contagion?

The empirical evidence and propositions presented above suggest that contagion both exists and to some extent can be characterised as more likely to occur in developing countries without clear regard to fundamentals. Contagion is generally regionally clustered and occurs amongst countries with strong financial linkages. In addition, contagion effects spread via developed financial markets, across both country borders and asset types, and the nature of the spread of contagion differs by asset market. Having ascertained these characteristics it now remains to examine just how important these effects are in comparison with the myriad of other factors which may impact on international and domestic financial markets.

The issue to be decided is whether domestic policies or international reforms are the more appropriate means of dealing with financial market contagion. If crises spread due to pure contagion, then perhaps there is merit in reform of international financial architecture. Glick and Rose (1999) argue that the regional nature of contagion, associated with trade linkages, suggests that there is a role for international monitoring. Alternatively, if the main cause of asset market volatility during crises is factors associated with market, country specific or idiosyncratic factors, then the appropriate response is for more attention to be paid to national policies; Karolyi (2003).

An additional complication is finding the source of potentially contagious shocks. As is evident from the discussion above it is often not clear which asset markets are involved in the transmission of financial crises. In many crises turmoil in one asset type seems to transmit to another asset. It can be difficult to identify the true trigger of a crisis, as for example in the ongoing debate as to whether the East Asian crisis can be truly credited to have begun with the float of the Thai baht as used in many studies,

or was detectable much earlier in equity markets.

The calculations on the contribution of contagion to observed crisis period volatility during various crises presented in Table 3 and other tables provide an indication of the importance of other factors in explaining volatility. The message of the results is that most of the observed volatility is not due to contagion. There are a number of exceptions to this, where contagion effects exceed 50 percent of observed volatility. However, the general picture suggests that other factors, or a combination of other factors, are more important. Other literature with similar outcomes are Khalid and Kawai (2003) who find little evidence of contagion and De Gregorio and Valdés (2001) who support this result with their findings of the strong role of fundamentals in crises, compared with contagion effects. For a contrary view, Cartapanis, Dropsy and Mametz (2002) find the role of contagion dominates that of fundamentals.

Contagion effects in currency markets seem to be uniformly small. Potentially, Karolyi (2003) is correct to single out exchange market reform as a cure to contagion effects as probably ineffective; see also the mixed results on the effectiveness of exchange rate flexibility in limiting contagion effects in De Gregorio and Valdés (2001). The fixed income markets example of DFGM (2005c) also suggests very small contagion effects and that volatility reflects primarily other factors. Equity markets experience the most contagion effects, yet there are no analyses considering reform to equity markets to limit such effects.

The extent of interest in international reform and the measure of contagion effects seem to be in inverse proportion in the literature: the most attention has been paid to currency market reform where the contagion effects are limited, and the least attention to equity market reform where substantial contagion effects are more evident.

The different asset markets have different contributors to volatility in crisis periods, and crises spread both across asset markets and across countries. This implies that there is no one solution for handling a particular crisis; responses will depend on the source shock(s) and the propagation mechanism. Whilst it is known that financial crises are costly (Bordo et al, 2001), it may also be that avoiding financial crises is costly in terms of lost economic opportunities. Assessing these relative costs is an extremely difficult task, but it is one on which the decisions of international and national policy makers should focus in attempting to draw up solutions to reduce financial contagion and crises. Some of these issues may be about the distribution of costs rather than their reduction to zero.

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