Was the Asian Financial Crisis a Transmission of Shocks Through Fundamental Links Between Countries, or a Case of Pure Contagion?: Comparing Evidence from Alternative Measures of Contagion

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Abstract

Traditional tests for contagion effects do not distinguish between different types of transmission mechanisms of crisis. In this paper we examine evidence on contagion effects surrounding the crises of 1997-9 that affected emerging markets. Traditional correlation-based measures presented in this paper confirm the spread of market volatility for the 1997-9 crises for exchange rates, but not for equity markets. However, such evidence does not serve to distinguish between crisis-contingent and non-crisis-contingent contagion nor does it distinguish between broad (structural) and restrictive (herding) types of contagion. Alternative evidence based on testing for breaks in the presence of long-run equilibrium relationships between markets suggests that crisis-contingent propagation of the crisis dominated non-crisis-contingent propagation, and does so for both exchange rates and equity markets. Two new tests are introduced in the present paper, which assume either the presence or absence of simultaneity between market indicators. In the absence of simultaneity, the proposed test suggests that East Asia was characterized predominantly by shift contagion for exchange rates and equity markets, while pure contagion characterized the South African exchange rate, and the South African, Brazilian and Taiwanese equity markets. Under the assumption of simultaneity, all countries included in the study faced pure contagion for exchange rates, while in equity markets all countries faced shift contagion except South Africa, Brazil and Hong Kong for whom the evidence favours pure contagion. While evidence in favour of pure contagion emerges from this study, we conlude by noting that the ability to distinguish between pure and shift contagion remains critically dependent on the presence or absence of simultaneity between markets.

KEYWORDS: Contagion, Financial Markets, Emerging Markets, Asian Crisis.

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1. Introduction

An integral concern of discussions surrounding the financial crisis of 1997-98, which had its origins in East Asia, has been the possibility of "contagion." The question of how the crisis that had its origins in Thailand, came to be propagated from one country to another, and to what extent such "contagion" effects were evident is crucial not only to an understanding of the unfolding of the crisis, but to both policy makers and actors in financial markets.

This paper provides an analysis of the extent of contagion that occurred during the course of the crisis, focussing on a range of emerging market economies. Concern is with both exchange rates and equity markets. Particular attention is paid to the question of whether the transmission of the crisis across countries took place through fundamental real or financial links between economies, or can be attributed to herding behaviour, and how one might distinguish between the two sorts of transmission.

We unfold the argument through a number of subsections. We begin with the definitional question of what is meant by the term "contagion." The literature has come to attach a number of alternative meanings to the term which we review briefly. For the purposes of the present paper we employ a typology derived from Rigobon and Forbes (2000), to distinguish between crisis-contingent and non-crisis-contingent contagion, and the typology of the World Bank (2003) which differentiates broad and restrictive concepts of contagion. Use of the typology allows us to draw a distinction between three distinct types of crisis transmission mechanisms, which we term "spillover" transmission, "shift" and "pure" contagion. Of these only shift and pure contagion alter the association between markets, and only pure contagion is not a manifestation of shock transmission over fundamental links between markets. Instead, it might be viewed as an instance of pure herding.

In the empirics of the paper, we begin with an examination of two traditional tests that have been used in order to establish the presence of contagion. In conjunction, the tests serve to provide evidence on whether the crisis transmission was crisis-contingent or non-crisis-contingent. Based on the work of Rigobon (1998), the paper then presents some new tests advanced as a means of distinguishing between broad and restrictive contagion, as a means of establishing whether contagion was pure or shift in nature.

To preempt the conclusions reached by the study, we suggest that the 1997-99 crisis was mixed in character, with evidence of both shift and pure contagion emerging from the empirical tests. In particular, the nature of the contagion differs between countries, between exchange rate and equity markets, and also depends crucially on whether simultaneity is assumed present or absent between markets. In the absence of simultaneity, the new proposed test presented in the paper suggests that over the 1997-9 period East Asia was characterized predominantly by shift contagion for exchange rates and equity markets, while only South Africa faced pure contagion for its exchange rate, and South Africa, Brazil and Taiwan faced pure contagion in their equity markets. Under the assumption of simultaneity, all countries included in the study faced pure contagion in exchange rate markets, while in equity markets all countries faced shift contagion except South Africa, Brazil and Hong Kong for whom the evidence favours pure contagion.

In section 2 of the paper we present a brief outline of alternative concepts of contagion. Section 3 presents a brief description of the unfolding of the 1997-99 crises. Traditional measures of contagion are presented in section 4 of the paper, in order to have a standard of comparison against which to compare the results from the two new measures examined. The new tests are introduced and applied in section 5. We conclude in section 6.

2. The concept of contagion

The intuitive appeal of the concept of contagion is immediate. Essential to the idea is that of a spreading impact of crisis from an initial trigger effect. In the context of the 1997-99 Asian crisis, this might be thought of as the spreading effects of the initial problems experienced by Thailand to other countries in the subregion, Malaysia, Indonesia, South Korea, Taiwan, Singapore, and Hong Kong, but later potentially to more remote countries such as South Africa, Brazil, and Russia. Paradoxically, while there is widespread study of contagion, there is less uniformity on what contagion means precisely (see the discussion in Rigobon 2001:4).

While contagion can be broadly defined as the transmission of crises from one country to another (or from one market to another), for the purpose of the present discussion we distinguish between two distinct types of contagion.[1] "Shift" contagion denotes crisis propagation through economic linkages between markets. The literature suggests several channels that would come to constitute channels of interdependence between markets, including interdependence through trade links, both through direct trade among countries and through competition in third markets;[2] similar initial conditions, whereby countries co-move insofar as they have similar macroeconomic (or other) characteristics;[3] and financial linkages.[4]

[1] There are a number of alternative departures in the literature, which are not explored in the present paper. One suggests that in periods of crisis the nature of the link between markets is different from that which exists in periods of "normal" market activity. This definition crucially begs the question of what precisely constitutes a "crisis". One suggestion is that proposed by Corsetti, Pesenti and Roubini (1998b). They construct a crisis index in which a country experiences an exchange rate crisis where the rate of depreciation exceeds trend depreciation. The concept extends readily to trend behaviour of other variables such as equity markets, bond markets, and to yields. Such a solution is not without its problems - most obvious of which is that the construction of the crisis index becomes sensitive to the choice of the time window over which trend behaviour is defined. An alternative is that the relevant outcome variable declines by more than a pre-set percentage in a predefined "short" period. The weakness of the definition rests on the susceptibility of the measure to manipulation through the predefined critical values.

[2] See Eichengreen, Rose and Wyplosz (1996), Glick and Rose (1999), and Fratzscher (1999, 2000:3).

[3] See for instance Sachs et al. (1996) Rigobon (1998) and Eichengreen et al (1996). Some authors extend real linkages to political relationships - see De Gregorio and Valdés (2001).

[4] This could take the form of direct financial linkages, financial market institutional practices, foreign investors' liquidity problems, and information asymmetries (Hernandez and

By "pure" contagion we denote crisis propagation that is transferred between markets even in the absence of real links between the markets.[5] Instead, crisis in a progenitor country may spread to countries that are not linked to it by true economic linkage, due to investor perception alone. In effect, the driving force of crisis propagation is investor herding behaviour or sentiment alone.[6]

The corollary here is that transmission of an originator shock between markets via already existing real or financial links is merely the expression of linkages between markets, and the spread of the crisis may well be a necessary component of adjustment in relative prices between markets. Strictly, we might argue, one faces not contagion but a "spillover" of the impact of a shock from one market to another through real and/or financial linkages, in which the nature of the linkages themselves may or may not remain essentially stable through the unfolding crisis.[7]

Policy makers are constrained to be concerned by the propagation of crisis whatever the causal mechanism by which crisis spreads. Yet if policy intervention is to be effective, identifying the mechanism by which the crisis is propagated, is crucial. Whether the 1997-99 financial crisis was spillover, shift- or pure-contagion based thus becomes an important question not when establishing whether crises are propagated from country to country, but for purposes of identifying the appropriate policy intervention in order to minimize the chances for crisis propagation between countries.

We conclude this section by noting that contagion might be measured in a number of distinct dimensions. While some studies concentrate attention on currency markets,[8] or asset markets,[9] a few provide more embracing examinations,[10] as well as a range of additional dimensions. An adequate understanding of contagion requires an awareness of all of these dimensions, particularly if the understanding is to form the basis of policy formulation. Focus of this

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Valdés 2001:6). Financial market regulation and ratings may also play a role (see van Rijckeghem and Wedder 1999:6).

[5] Note that "pure" contagion corresponds substantively to the "restrictive" definition of contagion proposed by World Bank (2003). See also Forbes (2001), Corsetti et al (1998c), Gerlach and Smets (1994), Loisel and Martin (2001), Paasche (2001), Clark and Huang (2001), Pericoli and Sbracia (2001) and Canova (2000).

[6] See for instance Park and Song (2000), Edison et al (1998), Bacchetta and van Wincoop (1998), Pritsker (2000), Agenor and Aizenman (1997), Kyle and Xiong (2000), Calvo (1999), Goldstein and Pauzner (2001), Agenor et al (1998), Caballero and Krishnamurthy (1998), Valdes (1997), Allen and Gale (2000), Allen and Douglas (2000), Huang (2000) Bikhchandani and Sharma (2000), Medvedev (2001), Dungey and Martin (2000), Dooley (1997), Masson (1998, 1999), Aiyagari and Gertler (1998), Schinasi and Smith (2000), Pericoli and Sbracia (2001), Kumar and Persaud (2001), Calvo and Mendoza (2000), Kodres and Pritsker (2000), and Fratzscher (1999). Some authors place further emphasis on the speed of transmission of a crisis - see Kaminsky et al (2003:3).

[7] On this view see also Fratzscher (2000:4), Forbes and Rigobon (2000, 2002), and Masson (1998).

[8] See for instance Corsetti, Pesenti and Roubini (1998b).

[9] See for instance Patel and Sarkar (1998).

[10] See for instance Baig and Goldfajn (1998), Hernandez and Valdés (2001), Eichengreen et al (1996), Kaminsky and Reinhart (1998, 1999), Van Rijckeghem and Wedder (1999) Sachs et al (1996), and Rigobon (1998).

study will be on currency and stock markets.

3. Introducing a New Test for Contagion Effects

We have suggested that traditional tests for the presence of contagion effects cannot distinguish between propagation of crisis through shift contagion, and pure contagion effects. We propose an indirect measure of the plausibility of pure contagion effects. The test is based on the hypothesis that where we have pure contagion effects, spreading from some common original shock to a single financial market, the "ripple" effect should be such that the increase in the variance of the indicator variables of the progenitor country **should be no smaller than the increase in the variance of the indicator variables of countries subsequently affected by the spreading crisis**. The discussion represents an adaptation of Rigobon (1998).

One difficulty with correlation-based tests of crisis propagation is that correlation coefficients are subject to bias in conditions where the variance of variables is subject to change (for instance at the point of crisis). Consider the case of two variables, y_t and x_t, to represent say stock market indexes, or exchange rates of two countries. Let them be associated by:

$$y_t = \beta x_t + \varepsilon_t \tag{1}$$

where ε_t represents country-y's specific shocks, and let $x_t = \eta_t$, with η_t representing country-x's country specific shocks. We add the standard assumptions that, $E[\eta_t \varepsilon_t] = 0, E[\varepsilon_t \varepsilon_t'] = \sigma_\varepsilon^2, E[\eta_t \eta_t'] = \sigma_\eta^2$. Now if the sample is split, with the variance of η_t increasing, such that $var(\eta_t^h) > var(\eta_t^l)$, given the assumptions concerning the country specific shocks, β-estimates in the two samples should be consistent:

$$y_t^h = \beta^h x_t^h + \varepsilon_t \tag{2}$$
$$y_t^l = \beta^l x_t^l + \varepsilon_t \tag{3}$$

with $plim\beta^h = plim\beta^l$. Since $var(x_t^h) > var(x_t^l)$, it follows that for consistent $\beta's$, $cov(x_t^h, y_t^h) > cov(x_t^l, y_t^l)$, and the increase in the covariance is by the same proportion as for x_t. Since the variance of y_t is homogeneous of degree one on the variance of x_t and ε_t, the variance of x_t increases while the estimate of β^i and $var(\varepsilon_t)$ are the same over the two samples, the variance of y_t will increase by less than that of x_t and the covariance, such that the correlation coefficient must increase, with $\rho^h > \rho^l$, since the noise/signal ratio in equation 1 is reduced.[11]

We can correct for the resultant bias in the correlation. Define:

$$var(x_t^h) = (1 + \delta_t)\sigma_x^2 \tag{4}$$

where $var(x_t^h)$ is the (conditional) variance of x_t during the course of the period of increased variance, while σ_x^2 is the (unconditional) variance of x_t

[11] The result depends only on the lack of correlation between x_t and ε_t, and the independence of their variances, not on the distribution of ε_t.

over the whole sample. This requires that $cov\left(x_t^h, y_t^h\right) = (1+\delta_t)\,\sigma_{xy}$ where σ_{xy} is the unconditional covariance. It can now be shown that:

$$var\left(y_t^h\right) = \left(1+\delta_t\rho^2\right)\sigma_y^2 \tag{5}$$

with ρ the unconditional correlation, and σ_y^2 the unconditional variance of y_t, and that:

$$\rho_t^h = \rho\left[\frac{1+\delta_t}{1+\delta_t\rho^2}\right]^{\frac{1}{2}} \tag{6}$$

It requires only simple substitution to obtain a solution for the unconditional, unbiased correlation coefficient:

$$\rho = \rho_t^h \cdot \left[\frac{var\left(x_t^h\right)}{\sigma_x^2} \cdot \frac{\sigma_y^2}{var\left(y_t^h\right)}\right]^{-\frac{1}{2}} \tag{7}$$

It is this which allows for the generation of corrected correlation coefficients as proposed by Rigobon (1998).

We note that the adjustment depends crucially on $\frac{var\left(x_t^h\right)}{\sigma_x^2} > \frac{var\left(y_t^h\right)}{\sigma_y^2}$. In effect, the supposition is that the country that serves as the progenitor of the crisis, will have the strongest increase in the variance of its indicator variables, and that subsequently infected countries will have proportionately smaller impacts on their variances. This condition is satisfied where $\left[\frac{var\left(x_t^h\right)}{\sigma_x^2} \cdot \frac{\sigma_y^2}{var\left(y_t^h\right)}\right]^{-\frac{1}{2}} < 1$, and violated where $\left[\frac{var\left(x_t^h\right)}{\sigma_x^2} \cdot \frac{\sigma_y^2}{var\left(y_t^h\right)}\right]^{-\frac{1}{2}} > 1$. It is this that forms the basis of the first test of the non-fundamentals (pure contagion) led explanation of contagion.

A limitation of the test described above is that it is premised on the absence of simultaneity between market indicator variables, and would cease to be valid in the presence of simultaneity. We therefore propose a modification to the test outlined above to account for the possibility of simultaneity. Consider the case where:

$$y_t = \beta z_t + \varepsilon_t \tag{8}$$
$$x_t = z_t + \eta_t \tag{9}$$

where z_t denotes either an aggregate unobservable variable, or the impact of endogenous variables, with the coefficient of z_t in equation 9 normalized on unity, and where only y_t and x_t are observables. Under such assumptions the $E\left[\eta_t\varepsilon_t\right] = 0, E\left[\varepsilon_t\varepsilon_t'\right] = \sigma_\varepsilon^2, E\left[\eta_t\eta_t'\right] = \sigma_\eta^2$ condition is violated. We will consider the case where the variance of x_t is increased either by a shock to z_t or to η_t. In particular, assume that:

$$var\left(x_t^h\right) = (1+\delta_z)\,\sigma_z^2 + (1+\delta_\eta)\,\sigma_\eta^2 \tag{10}$$

$\delta_z, \delta_\eta \geq 0$, and $\sigma_z^2, \sigma_\eta^2$ denoting the relevant unconditional variances. This implies:

$$var\left(y_t^h\right) = \beta^2(1+\delta_z)\,\sigma_z^2 + \sigma_\varepsilon^2 \tag{11}$$
$$cov\left(x_t^h, y_t^h\right) = \beta(1+\delta_z)\,\sigma_z^2 \tag{12}$$

Hence the unconditional and conditional correlation coefficients are now given by:

$$\rho = \frac{\beta\sigma_z^2}{\left[\left(\beta^2\sigma_z^2+\sigma_\varepsilon^2\right)\left(\sigma_z^2+\sigma_\eta^2\right)\right]^{\frac{1}{2}}} \tag{13}$$

$$\rho^h = \frac{\beta\left(1+\delta_z\right)\sigma_z^2}{\left[\left(\beta^2\left(1+\delta_z\right)\sigma_z^2+\sigma_\varepsilon^2\right)\left(\left(1+\delta_z\right)\sigma_z^2+\left(1+\delta_\eta\right)\sigma_\eta^2\right)\right]^{\frac{1}{2}}} \tag{14}$$

Note that:[12]

$$\delta_z \rightarrow 0, \rho^h < \rho \tag{15}$$

$$\delta_\eta \rightarrow 0, \rho^h > \rho \tag{16}$$

By defining $\lambda = \frac{\rho}{\rho^h}$, and by virtue of simple substitution, it follows trivially that:

$$\lambda < 1\; iff\; \frac{cov\left(x_t, y_t\right)}{cov\left(x_t^h, y_t^h\right)} < \left(\frac{var\left(x_t^h\right)}{\sigma_x^2}\cdot\frac{var\left(y_t^h\right)}{\sigma_y^2}\right) \tag{17}$$

$$\lambda > 1\; iff\; \frac{cov\left(x_t, y_t\right)}{cov\left(x_t^h, y_t^h\right)} > \left(\frac{var\left(x_t^h\right)}{\sigma_x^2}\cdot\frac{var\left(y_t^h\right)}{\sigma_y^2}\right) \tag{18}$$

By virtue of 15 and 16, we know that $\lambda > 1 \Rightarrow \delta_z \rightarrow 0$, such that the shock to the system emerges through η_t not z_t. By contrast, again by virtue of 15 and 16, we know that $\lambda < 1 \Rightarrow \delta_\eta \rightarrow 0$, such that the shock to the system emerges through z_t not η_t.

This suggests an alternative test on the nature of the propagation mechanism of financial crises. Where $\frac{cov(x_t,y_t)}{cov\left(x_t^h,y_t^h\right)} < \left(\frac{var\left(x_t^h\right)}{\sigma_x^2}\cdot\frac{var\left(y_t^h\right)}{\sigma_y^2}\right)$, the implication is that the crisis is being propagated through the interdependence of markets (through common "fundamentals", or through simultaneity), increasing the comovement of market indicators. Where instead $\frac{cov(x_t,y_t)}{cov\left(x_t^h,y_t^h\right)} > \left(\frac{var\left(x_t^h\right)}{\sigma_x^2}\cdot\frac{var\left(y_t^h\right)}{\sigma_y^2}\right)$, the implication is that the crisis has its source in a shock to a single "originator" country, decreasing the comovement of markets. In the former case, in the presence of simultaneity between markets, the implication is that the crisis is being transmitted due to "fundamentals" or real linkages that exist between markets. In the second, the implication is that contagion effects may be present.

This is the basis of the second test presented. We let $\phi = \frac{cov(x_t,y_t)}{cov\left(x_t^h,y_t^h\right)}$, and $\theta = \left(\frac{var\left(x_t^h\right)}{\sigma_x^2}\cdot\frac{var\left(y_t^h\right)}{\sigma_y^2}\right)$. The test is thus which of $\phi \lesseqgtr \theta$ applies. In the light of the above discussion $\phi < \theta$ implies propagation by shift contagion, $\phi > \theta$ propagation by pure contagion.

[12] The explanation is that the increase in x_t's volatility is due to noise, the comovement between country indicator variables should decrease, since noise is drowning out signal.

3.1. The empirical evidence: in the absence of simultaneity

In Table 5 we present the ratio defined by the $\left[\frac{var\left(x_t^h\right)}{\sigma_x^2} \cdot \frac{\sigma_y^2}{var\left(y_t^h\right)}\right]^{-\frac{1}{2}} \begin{smallmatrix} > \\ < \end{smallmatrix} 1$ relation for exchange rates. We examine the possibility of contagion over the sequence of the exchange rate crisis (as defined in Figure 2).[13] Two features of the evidence are striking. The first, is that for the East Asian countries the variance ratio is almost uniformly >1, suggesting that the crisis gained in volatility as it propagated across markets. For the Asian markets our test therefore fails to confirm the "pure" contagion case, and favours the "shift" contagion case instead. The only exception is the impact of the Indonesian currency crisis, which had a less than proportional impact on the variances of the exchange rates of countries to have encountered pressure on their currencies subsequently. The second striking feature of the evidence is the case of South Africa. With the exception of Taiwan, for every potential progenitor country, the propagation of the crisis to South Africa had a less than proportional impact on the variance of the South African exchange rate. To the extent that the test here presented is reliable therefore, for East Asia little evidence in favour of true (non-fundamentals led) contagion emerges, and only for South Africa does the evidence support the presence of a panic-type financial crisis.

INSERT TABLE 5 ABOUT HERE.

In Table 6 we present the ratio defined in the $\left[\frac{var\left(x_t^h\right)}{\sigma_x^2} \cdot \frac{\sigma_y^2}{var\left(y_t^h\right)}\right]^{-\frac{1}{2}} \begin{smallmatrix} > \\ < \end{smallmatrix} 1$ relation for stock markets. We examine the possibility of contagion over the sequence of the equity market crises (as defined in Figure 1).[14] For stock markets the evidence is more mixed than for exchange rates - with greater evidence favouring the necessary condition for "pure" contagion than for exchange rates. For South Africa, Taiwan and Brazil the variance ratios again suggest that for these countries "pure" contagion on asset markets is at least plausible. For others, notably Malaysia, on the other hand, the implication of the variance ratio is that the crisis merely precipitated adjustment to fundamentals, suggesting "shift" contagion at best. For other countries the evidence is mixed, but with the implication that the cross market propagation of the crisis was at least in some cases an adjustment to fundamentals, rather than contagion.

INSERT TABLE 6 ABOUT HERE.

3.2. The empirical evidence: in the presence of simultaneity

There is one important limitation to the test on the presence of contagion effects outlined above. The test is constructed on the assumption of an absence of simultaneity between the country indicators (either of exchange rates, or of stock market indexes), and/or the absence of common underlying "fundamen-

[13] Note that the emergence of crisis in Thailand and Singapore was virtually simultaneous - hence the presentation of twin ratios in this case.

[14] Note that the emergence of crisis was coincident for South Africa, Brazil, and Indonesia - hence the presentation of multiple ratios.

tals" that act as drivers for both markets. Where this condition is violated, the test loses its validity - for reasons explained above. For this reason we present a second test on the presence of contagion effects, which allows for the possibility of simultaneity between market indicators. Recall that the test depends on which of $\phi \lesseqgtr \theta$ applies, where $\phi = \frac{cov(x_t,y_t)}{cov\left(x_t^h,y_t^h\right)}$, and $\theta = \left(\frac{var\left(x_t^h\right)}{\sigma_x^2} \cdot \frac{var\left(y_t^h\right)}{\sigma_y^2}\right)$. The intuition behind the test is that where $\frac{cov(x_t,y_t)}{cov\left(x_t^h,y_t^h\right)} < \left(\frac{var\left(x_t^h\right)}{\sigma_x^2} \cdot \frac{var\left(y_t^h\right)}{\sigma_y^2}\right)$, the implication is that the crisis is being propagated through the interdependence of markets (through common "fundamentals", or through simultaneity), increasing the comovement of market indicators. Where instead $\frac{cov(x_t,y_t)}{cov\left(x_t^h,y_t^h\right)} > \left(\frac{var\left(x_t^h\right)}{\sigma_x^2} \cdot \frac{var\left(y_t^h\right)}{\sigma_y^2}\right)$, the implication is that the crisis has its source in a shock to a single "originator" country, decreasing the comovement of markets. In the former case, in the presence of simultaneity between markets, the implication is that the crisis is being transmitted due to "fundamental" (real or financial) linkages that exist between markets. In the second, the implication is that contagion effects may be present.

We note that the evidence of section 3 of this paper, presenting evidence on the presence or absence of a long run cross-market equilibrium relationships for exchange rates and stock markets, suggests that simultaneity between markets is perhaps unlikely to be present post-crisis. Nevertheless we present the $\phi - \theta$ test for exchange rates in Tables 7 and 8. Table 7 reports the values of ϕ below, and the values of θ above diagonal. Table 8 summarizes the implication by noting which of $\phi \lesseqgtr \theta$ holds. Bearing in mind the caveat outlined above, the implication of the evidence is unambiguously that "pure" contagion effects between countries were present, except for the transmission of the crisis from Singapore, and from Thailand to Singapore, Indonesia to South Africa, and South Korea to South Africa.

INSERT TABLE 7 ABOUT HERE.

INSERT TABLE 8 ABOUT HERE.

The $\phi - \theta$ test for stock markets is presented in Tables 9 and 10. Table 9 reports the values of ϕ below, and the values of θ above diagonal. Table 10 summarizes the implication by noting which of $\phi \lesseqgtr \theta$ holds. Again bearing in mind the caveat outlined above concerning the likelihood of simultaneity between stock markets, the implication here is the reverse of that obtained for exchange rates. The evidence in general rejects the likelihood of "pure" contagion as the propagation mechanism, and favours "shift" contagion between markets instead. The only exceptions are South Africa, Brazil, and the Hang Seng indexes, for which the evidence suggests that there may have been some "pure" contagion.

INSERT TABLE 9 ABOUT HERE.

INSERT TABLE 10 ABOUT HERE.

4. Conclusions

Traditional tests for contagion effects do not distinguish between different types of transmission mechanisms of crisis. In particular, while they provide some evidence on whether crisis propagation occurs, they are not able to establish whether the transmission of crisis takes place through "fundamental" (real or financial) channels, or whether the transmission occurs through pure panic mechanisms.

In this paper we have examined evidence on contagion effects surrounding the crises of 1997-9 that affected emerging markets. Empirical evidence is presented for a range of emerging markets, including Brazil, Hong Kong, Indonesia, Korea, Malaysia, Philippines, Russia, Singapore, South Africa, Taiwan and Thailand. Data on exchange rate and equity markets forms the basis of the study.

Traditional correlation-based measures presented in this paper confirm the spread of market volatility for the 1997-9 crises for exchange rates, but not for equity markets. However, such evidence does not serve to distinguish between crisis-contingent and non-crisis-contingent contagion, as defined by Forbes & Rigobon (2000), nor does it distinguish between broad (structural) and restrictive (herding) types of contagion, as defined by the World Bank (2003).

Alternative evidence based on testing for breaks in the presence of long-run equilibrium relationships between markets suggests that crisis-contingent propagation of the crisis dominated non-crisis-contingent propagation, and does so for both exchange rates and equity markets. However, such results do not distinguish between what this paper has termed shift and pure contagion.

Evidence on whether the crisis was subject to shift or pure contagion, depends crucially on whether we assume the presence or absence of simultaneity between markets.

Two new tests are introduced in the present paper, based on the work of Rigobon (1998) - which assume either the presence or absence of simultaneity between market indicators. In the absence of simultaneity, the proposed test suggests that over the 1997-9 period East Asia was characterized predominantly by shift contagion for exchange rates and equity markets, while only South Africa faced pure contagion for its exchange rate, and South Africa, Brazil and Taiwan faced pure contagion in their equity markets. Under the assumption of simultaneity, all countries included in the study faced pure contagion for exchange rates, while in equity markets all countries faced shift contagion except South Africa, Brazil and Hong Kong for whom the evidence favours pure contagion. While not definitive, PSS F-tests presented in establishing the presence or absence of long run equilibrium relationships between markets, in general did not support simultaneity between markets.

We conclude by noting that evidence in favour of pure contagion is obtained in the present study. Nevertheless, the ability to distinguish between pure and shift contagion does appear to remain critically dependent on the presence or absence of simultaneity between markets. Repeated calls in the literature for tests that allow for the testing of simultaneity between markets, therefore remain germane.

5. Appendix A

We outline the procedure for testing for the existence of a long run relationship proposed by Pesaran, Shin & Smith (1996, 2001) (PSS). Suppose that the question is whether there exists a long run relationship between three variables, y_t, x_{1t}, x_{2t}. The univariate time series characteristics of the data are not known. The PSS approach to testing for the presence of a long run relationship proceeds by:

1. Estimating the error correction model given by:

$$\begin{aligned} y_t &= \alpha_0 + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \sum_{i=0}^{p} \gamma_{1i} \Delta x_{1,t-i} + \sum_{i=0}^{p} \gamma_{2i} \Delta x_{2,t-i} \\ &\quad + (\delta_1 y_{t-1} + \delta_2 x_{1,t-1} + \delta_3 x_{2,t-1}) + \epsilon_t \end{aligned} \tag{19}$$

   The order of augmentation, p, is determined by the need to render the error term free of systematic variation, in order to extract the "signal", or long run relationship, from the data.

2. Computing the standard F-statistic for the joint significance of:

$$\delta_1 = \delta_2 = \delta_3 = 0 \tag{20}$$

   While the distribution of the test statistic is non-standard[15], the critical values are tabulated by Pesaran, Shin and Smith (1996).

3. The critical values have upper and lower bounds, denoted by F_U and F_L respectively. Where estimated $\widehat{F} > F_U$, we reject $\delta_1 = \delta_2 = \delta_3 = 0$, and conclude that a long run relationship *is present* between the variables included in the model. Where estimated $\widehat{F} < F_L$, we accept $\delta_1 = \delta_2 = \delta_3 = 0$, and conclude that a long run relationship is *not present* between the variables included in the model. Where estimated $F_L < \widehat{F} < F_U$, the test is inconclusive, and more needs to be established concerning the order of integration of the underlying variables, before proceeding with estimation.

4. Repeat the testing procedure with x_{1t} and x_{2t} as dependent variables.

5. Once the existence of a long run relationship has been established, we estimate the long run relationship by means of the ARDL methodology.

We are here concerned only with the presence of a long run relationship between variables, and hence rely only on the F-test of the PSS-approach.

[15] And also influenced by whether the x_i are $I(0)$ or $I(1)$.

6. Appendix B

Johansen[16] techniques of estimation are now standard, so that the discussion here can be brief. We employ a vector error-correction (VECM) framework, for which in the case of a set of k variables, we may have cointegrating relationships denoted r, such that $0 \leq r \leq k-1$. This gives us a k-dimensional VAR:

$$z_t = A_1 z_{t-1} + ... + A_m z_{t-m} + \mu + \delta_t \tag{21}$$

where m denotes lag length, and δ a Gaussian error term. While in general z_t may contain $I(0)$ elements, given our bivariate association, as long as non-stationary variables are present we are exclusively restricted to $I(1)$ elements. Reparametrization provides the VECM specification:

$$\Delta z_t = \sum_{i=1}^{k-1} \Gamma_i \Delta z_{t-i} + \Pi z_{t-k+1} + \mu + \delta_t \tag{22}$$

The existence of r cointegrating relationships amounts to the hypothesis that:

$$H_1(r) : \Pi = \alpha\beta' \tag{23}$$

where Π is $p \times p$, and α, β are $p \times r$ matrices of full rank. $H_1(r)$ is thus the hypothesis of reduced rank of Π. Where $r > 1$, issues of identification arise[17]. In our case, given the focus on bivariate associations, this case does not arise. Our chief concern here is with the existence of cointegration, hence the possibility of long-run equilibrium relationships contained in $\beta' z_t$. We do not proceed to an estimation of the parameters of the cointegrating vectors.

In all instances we test for the presence of a link by means of the standard reduced rank Johansen procedure.

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[16] See Johansen (1991) and Johansen and Juselius (1990).

[17] See Wickens (1996), Johansen and Juselius (1990, 1992), Pesaran and Shin (1995a, 1995b), Pesaran, Shin and Smith (1996).

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	Thailand	Malaysia	Indones.	HongKong	Singap.	Philipp.	Taiwan	S.Korea	Brazil	S. Africa	Russia
Thailand		0.64	1.30	0.24	81.33*	0.21	4.91	6.15*	3.97	1.53	6.08*
Malaysia	6.52*		1.96	0.13	92.03*	4.59	4.90	8.93*	6.74*	3.01	7.53*
Indonesia	0.82	0.67		0.47	31.92*	0.95	6.61*	0.89	1.51	0.61	5.37
HongKong	3.87	4.01	1.61		63.29*	6.68*	4.74	5.48	6.14*	4.53	5.35
Singapore	0.67	0.62	0.76	0.23		0.25	4.16	2.48	4.67	1.34	5.18
Philipp.	5.65	5.48	1.65	0.12	76.79*		4.95	7.49*	6.35*	2.40	5.94*
Taiwan	0.82	0.76	6.01*	0.62	23.72*	0.92		1.49	0.68	0.83	4.35
S. Korea	0.84	0.63	1.69	0.83	48.03*	0.32	6.52*		1.01	0.97	4.66
Brazil	2.15	0.91	0.94	0.18	37.58*	0.81	5.56	3.53		0.38	4.60
S. Africa	2.03	0.83	1.42	0.14	58.72*	0.74	5.47	3.28	11.94*		5.20
Russia	3.20	2.64	0.61	0.69	0.92	2.26	3.27	1.27	3.47	1.38	

Table 1: Pre 6 February 1996 Stock Market Indexes: PSS F-Tests, tests are bivariate, with column headings indicating the dependent stock market index, and rows the forcing variable stock market index, * denotes that the row variable is a forcing variable of the column head.

	Thailand	Malaysia	Indones.	HongKong	Singap.	Philipp.	Taiwan	S.Korea	Brazil	S. Africa	Russia
Thailand		1.35	0.54	1.33	1.91	1.48	2.66	1.14	1.32	1.54	1.01
Malaysia	11.76*		6.22*	3.43	2.10	2.88	3.24	0.94	2.03	3.16	2.60
Indonesia	15.68*	2.44		2.59	0.97	1.53	4.14	1.00	1.90	2.87	3.96
HongKong	5.66	1.84	0.58		1.17	1.07	2.98	1.18	2.94	3.03	8.93*
Singapore	18.10*	0.69	2.19	1.55		2.04	2.99	0.93	1.93	2.59	2.16
Philipp.	12.20*	0.48	3.72	1.99	1.17		3.07	0.91	1.98	2.41	1.94
Taiwan	7.19*	5.72	1.61	1.33	2.96	3.98		2.34	9.81*	1.40	7.17*
S. Korea	21.37*	2.29	2.08	2.83	5.56	2.28	2.70		1.83	3.01	2.42
Brazil	7.13*	7.20*	1.90	2.47	4.65	5.97*	3.56	2.87		1.10	2.23
S. Africa	5.14	6.51*	1.44	2.60	4.64	5.24	2.55	5.00	1.46		1.09
Russia	7.23*	4.33	2.47	2.91	2.14	2.60	2.21	2.87	1.43	1.25	

Table 2: Post 6 February 1996 Stock Market Index: PSS F-Tests, tests are bivariate, with column headings indicating the dependent stock market index, and rows the forcing variable stock market index, * denotes that the row variable is a forcing variable of the column head.

	Thailand	Malaysia	Indones.	HongKong	Singap.	Philipp.	Taiwan	S.Korea	Brazil	S. Africa	Russia
Thailand		16.35	4.72	7.73	45.92*	10.78	29.63*	19.90*	9.58	8.7	15.22
Malaysia	15.81*		4.40	6.56	48.31*	15.59	29.5*	23.50*	9.9	6.17	21.45*
Indonesia	2.99	3.18		3.86	14.14	3.80	37.58*	8.73	4.36	4.34	9.04
HongKong	7.33	6.32	2.8		29.12*	11.12	27.38*	13.85	9.98	8.68	13.05
Singapore	44.55*	47.87*	12.21	28.95*		38.29*	33.92*	28.38*	20.7*	27.68*	12.50
Philipp.	10.36	15.33*	2.56	10.73	37.99*		29.05*	17.55	8.74	4.64	15.51
Taiwan	28.18*	28.58*	33.06*	26.69*	27.55*	27.90*		32.46*	26.49*	27.64*	12.45
S. Korea	18.61*	22.60*	7.63	12.95	26.74*	16.94*	30.24*		10.49	10.28	10.71
Brazil	9.57	8.93	4.18	8.57	20.64*	8.00	26.33*	10.35		9.57	11.42
S. Africa	7.84	6.17	3.41	8.63	26.5*	4.48	26.75*	9.15	9.30		9.55
Russia	10.27	13.90	8.13	12.59	10.35	10.46	10.73	8.35	10.35	8.82	

Table 3: Pre 6 February 19967 Stock Market Indexes: Johansen cointegration tests, tests are bivariate; test statistics below diagonal are the Johansen eigenvalue statistic; test statistics above diagonal are the Johansen trace statistic; * denotes the presence of a cointegrating vector.

	Thailand	Malaysia	Indones.	HongKong	Singap.	Philipp.	Taiwan	S.Korea	Brazil	S. Africa	Russia
Thailand		9.37	9.16	6.74	10.42	10.08	11.53	13.06	9.65	10.23	7.58
Malaysia	8.37		21.21*	7.76	11.56	10.42	15.63	6.25	20.86*	17.85	10.97
Indonesia	5.97	20.25*		9.83	12.48	13.88	11.08	8.63	12.37	11.15	9.15
HongKong	3.84	6.94	7.59		6.04	6.04	10.13	7.96	7.98	12.29	15.65
Singapore	8.14	10.71	9.97	3.76		7.73	13.47	13.78	12.83	17.37	7.40
Philipp.	7.70	9.86	11.32	4.19	5.54		13.99	8.03	14.99	15	6.46
Taiwan	6.29	11.13	6.30	6.22	8.03	9.40		12.37	23.25*	11.07	11.85
S. Korea	10.69	5.28	5.6	4.71	11.60	5.91	7.30		10.78	16.9	12.37
Brazil	6.75	17.67*	9.61	4.47	9.96	12.26	19.14*	7.91		9.24	8.66
S. Africa	6.53	16.64*	7.67	8.47	14.43	12.94	7.3	14.16	5.93		8.67
Russia	5.37	7.01	6.53	11.92	5.31	3.89	8.68	9.28	6.38	6.47	

Table 4: Post 6 February 1996 Stock Market Indexes: Johansen cointegration tests, tests are bivariate; test statistics below diagonal are the Johansen eigenvalue statistic; test statistics above diagonal are the Johansen trace statistic; * denotes the presence of a cointegrating vector.

	Thailand	Malaysia	Indones.	HongKong	Singap.	Philipp.	Taiwan	S.Korea	Brazil	S. Africa	Russia
Thailand		1.17	1.17		0.67	1.01	0.97	1.20		0.61	
Malaysia			1.09			0.85	0.86	1.10		0.57	
Indonesia							0.73	0.99		0.54	
HongKong											
Singapore	1.50	1.76	1.76			1.52	1.45	1.80		0.91	
Philipp.			1.29				1.01	1.30		0.67	
Taiwan								1.73		1.14	
S. Korea										0.81	
Brazil											
S. Africa											
Russia											

Table 5: Exchange Rate: ratio of variances: progenitor country to crisis-affected country: ratios include only country pairs, column headings indicate countries affected by crisis, rows indicate possible progenitor countries, feasible pairings determined by the timing of the unfolding crisis

	Thailand	Malaysia	Indones.	HongKong	Singap.	Philipp.	Taiwan	S.Korea	Brazil	S. Africa	Russia
Thailand		1.20	0.94	0.63		0.79	0.64	1.07	0.59	0.44	0.94
Malaysia			0.98	0.71			0.45	0.83	0.44	0.51	0.72
Indonesia				0.87			0.61		0.58	0.69	0.97
HongKong											1.31
Singapore	0.92	1.08	0.84	0.57		0.71	0.59	0.97	0.53	0.39	0.86
Philipp.		1.60	1.53	1.08			0.68	1.28	0.67	0.77	1.11
Taiwan				1.38							1.71
S. Korea			1.12	0.91			0.63		0.61	0.70	0.98
Brazil			1.73	1.50			1.06			1.19	1.68
S. Africa			1.46	1.27			0.89		0.84		1.41
Russia											

Table 6: Stock Market Indexes: ratio of variances: progenitor country to crisis-affected country: ratios include only country pairs, column headings indicate countries affected by crisis, rows indicate possible progenitor countries, feasible pairings determined by the timing of the unfolding crisis

	Thailand	Singap.	Malaysia	Philipp.	Indones.	Taiwan	S.Korea	S. Africa
Thailand		1.51	0.86	0.99	0.86	1.04	0.84	1.65
Singap.	0.40		1.29	1.49	1.29	1.56	1.26	2.48
Malaysia	0.97	0.50		1.05	0.82	1.047	0.81	1.58
Philipp.	1.23	0.20	1.06		0.98	1.26	0.97	1.88
Indones.	1.64	1.03	1.23	1.33		1.15	0.84	1.55
Taiwan	1.31	0.22	1.050	1.27	1.45		2.26	3.44
S.Korea	0.96	0.09	0.91	1.15	1.53	4.85		2.54
S. Africa	4.40	-1.32	1.59	1.96	1.41	4.14	-4.61	

Table 7: Exchange Rate: phi-theta test: theta values above diagonal: progenitor country to crisis-affected country: ratios include only country pairs, column headings indicate countries affected by crisis, rows indicate possible progenitor countries, feasible pairings determined by the timing of the unfolding crisis; phi values below diagonal: ratios include only country pairs, column headings indicate possible progenitor countries, row labels countries affected by crisis, feasible pairings determined by unfolding of crisis

	Thailand	Malaysia	Indones.	Singap.	Philipp.	Taiwan	S.Korea	S. Africa
Thailand		$\phi > \theta$	$\phi > \theta$	$\phi < \theta$	$\phi > \theta$	$\phi > \theta$	$\phi > \theta$	$\phi > \theta$
Malaysia			$\phi > \theta$		$\phi > \theta$	$\phi > \theta$	$\phi > \theta$	$\phi > \theta$
Indonesia						$\phi > \theta$	$\phi > \theta$	$\phi < \theta$
Singapore	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$		$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$
Philipp.			$\phi > \theta$			$\phi > \theta$	$\phi > \theta$	$\phi > \theta$
Taiwan							$\phi > \theta$	$\phi > \theta$
S. Korea								$\phi < \theta$

Table 8: Exchange Rate: phi-theta test: progenitor country to crisis-affected country: ratios include only country pairs, column headings indicate countries affected by crisis, rows indicate possible progenitor countries, feasible pairings determined by the timing of the unfolding crisis

	Singap.	Thail.	Philipp.	Malay.	S.Korea	S. Africa	Brazil	Indones.	Taiwan	H.Kong
Singap.		0.88	1.14	0.75	0.84	2.07	1.52	0.96	1.38	1.43
Thail.	0.8		1.26	0.83	0.93	2.28	1.7	1.06	1.56	1.58
Philipp.	1.06	0.81		1.33	1.66	2.74	3.15	1.38	3.1	1.96
Malay.	0.75	0.7	1.31		1.08	1.75	2.03	0.91	2	1.26
S.Korea	0.69	0.91	1.03	0.82		2.11	2.43	1.32	2.35	1.62
S. Africa	2.74	0.27	3.66	1.97	0.43		3.54	2.04	3.33	2.35
Brazil	-0.65	0.86	3.99	1.29	-0.76	3.82		2.43	3.96	2.8
Indones.	0.72	0.52	0.97	0.68	0.61	1.76	1.55		2.29	1.62
Taiwan	-0.39	0.73	1.45	0.41	-0.07	2.38	3.12	1.36		3.06
H.Kong	1.38	0.66	2.25	1.09	0.28	4.45	3.47	1.24	1.61	

Table 9: Stock Market: phi-theta test: theta values above diagonal: progenitor country to crisis-affected country: ratios include only country pairs, column headings indicate countries affected by crisis, rows indicate possible progenitor countries, feasible pairings determined by the timing of the unfolding crisis; phi values below diagonal: ratios include only country pairs, column headings indicate possible progenitor countries, row labels countries affected by crisis, feasible pairings determined by unfolding of crisis

	Singap.	Thail.	Philipp.	Malay.	S.Korea	S. Africa	Brazil	Indones.	Taiwan	H.Kong
Singap.		$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi > \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$
Thail.			$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$
Philipp.				$\phi < \theta$	$\phi < \theta$	$\phi > \theta$	$\phi > \theta$	$\phi < \theta$	$\phi < \theta$	$\phi > \theta$
Malay.					$\phi < \theta$	$\phi > \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$
S.Korea						$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$	$\phi < \theta$
S. Africa							$\phi > \theta$	$\phi < \theta$	$\phi < \theta$	$\phi > \theta$
Brazil								$\phi < \theta$	$\phi < \theta$	$\phi > \theta$
Indones.									$\phi < \theta$	$\phi < \theta$
Taiwan										$\phi < \theta$
H.Kong										

Table 10: Stock Market: phi-theta test: progenitor country to crisis-affected country: ratios include only country pairs, column headings indicate countries affected by crisis, rows indicate possible progenitor countries, feasible pairings determined by the timing of the unfolding crisis