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## The Current Global Financial Crisis: do Asian Stock Markets show Contagious or Interdependency Effects?

Lucia Morales

*Technological University Dublin, lucia.morales@tudublin.ie*

Bernadette Andreosso-O'Callaghan

*University of Limerick, bernadette.andreosso@ul.ie*

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# **The Current Global Financial Crisis: Do Asian Stock Markets Show Contagious or Interdependency Effects?**

**Authors:** Bernadette Andreosso-O'Callaghan, University of Limerick<sup>1</sup>  
Lucía Morales, Dublin Institute of Technology, Dublin<sup>2</sup>.

**Keywords:** Stock Returns, VAR-EGARCH modeling, Contagion, Interdependence,, Volatility Spillovers.

**JEL Codes:** F, G

## **Abstract**

In the framework of the current global economic crisis, a pertinent question is whether the world economies are suffering from contagion or interdependency effects. With its origins in the US sub-prime mortgage market crisis starting at the end of 2007, when a loss of confidence by investors in the value of securitized mortgages resulted in a liquidity crisis, hard-hitting the banking system and rapidly spreading into the financial markets, the effects of the crisis were automatically reflected in the rest of the world economies. These effects that become severe as the rest of the world has been facing its economic and financial system instability. Therefore, the American shock can be seen as the trigger that revealed the other economies' own financial problems. This paper's main finding shows that the US stock markets are not generating contagious effects into the Asian stock markets. However, strong evidence suggesting volatility transmissions derived from these economies interlinkages has been detected.

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<sup>1</sup> Bernadette Andreosso-O'Callaghan: [bernadette.andreosso@ul.ie](mailto:bernadette.andreosso@ul.ie); Department of Economics and Euro-Asia Centre, Kemmy Business School. University of Limerick, Ireland.

<sup>2</sup> Lucía Morales: [lucia.morales@dit.ie](mailto:lucia.morales@dit.ie); Department of Accounting and Finance, Business School, Dublin Institute of Technology, Ireland.

## **1. Introduction**

Since the mid-1990s, international financial markets have experienced several episodes of economic and financial distress. The major financial crises observed in recent years were located in diverse regions, from Mexico in December 1994, to Asia beginning in July 1997 (with the devaluation of the Thai baht), Russia in August 1998, the USA in September 1998 (with the near-collapse of the U.S hedge fund Long-Term Capital Management), Brazil towards the end of 1998 and early 1999, and lately, Turkey, and Argentina in 2001 (Dungey et.al, 2002). During these crises, financial markets' interactions and interlinkages played a crucial role, as the high level of integration between countries, and between their financial markets were a major source of spillover effects, that led to extreme volatility in the world's financial markets. In this regard, financial instability and contagion are typically viewed as a developing country phenomenon; however, the current global financial crisis endured by the world leading economies suggests that this is not necessarily the case, and makes us wonder about the causes that have driven this economic downturn and that may be summarised as follow: i) lack of regulation, ii) lack of transparency, iii) and information asymmetry.

The current economic and financial crisis emerged after the US housing prices dropped moderately in 2006-07, and after the US sub-prime mortgage markets manifested huge losses. In turn, these generated chaotic effects throughout the international financial system. Afterwards, the crisis spread with amazing speed to other markets, and even to financial institutions that had no direct exposure to the subprime mortgage market. The confidence in many financial institutions was strongly damaged and share prices for investment banks dropped significantly at the end of 2007 and early 2008. Taking these facts into consideration, the current analysis will look at contagion effects originating from the United States stock markets and spreading into some selected Asian economies (mature and emerging economies), for, as posited in this paper, the current financial turmoil is affecting Asian economies in a different manner. Indeed, given that the region was heavily affected during the 1997-1998 Asian crisis, several policy instruments such as the Chiang Mai Initiative have enabled the Asian markets to be in a better fashion and to be better prepared for coping with the current situation, than most of the world economies. As a result, our expectation is based on the hypothesis that

no contagion effects would be detected in the Asian region. On the other hand, these markets are not totally immune to the current global crisis, so another a priori expectation is to find strong volatility spillovers effects derived from the high interdependence that exists between the Asian and US markets.

The existing literature presents a number of controversies regarding the identification of financial contagious effects. Considering that these effects tend to be associated with a high level of interdependence among markets, what could simply be emerging is an increase in the interlinkages among those markets, and not necessarily contagion effects per se. This differentiation acquires a great level of importance during times of crises, where markets are characterised by high levels of volatility, and where countries appear to be more vulnerable to contagion or transmission effects, which propagate across regions, with global effects such as in the case of the current crisis. Thus, it is pertinent to wonder whether the US financial system did generate contagious effects to the Asian economies, or whether we are just facing markets' reactions derived from the US and Asian markets interlinkages. Therefore, the main objective of this paper is to look at contagion effects from the U.S stock markets (Dow Jones Industrials, and S&P 500) to the stock markets of some Asian emerging and more mature economies (China, Hong Kong, India, Indonesia, Japan, Malaysia, Singapore, South Korea, Taiwan, and Thailand).

The remainder of this paper is organised into the following sections: i) First, a brief review regarding contagion and interdependence studies is presented; ii) second the data and methodology are outlined; iii) third, the empirical findings are presented and discussed, and iv) finally, the paper concludes, and some suggestions for further research are discussed.

## **2. Contagion or Interdependence Effects**

Economic integration of an individual country into the world markets typically involves both trade and financial links. Thus, a financial crisis in one country can lead to direct financial effects, including reductions in trade credits, in foreign direct investment flows, and in other capital flows abroad. As a consequence, the spread of a crisis depends on the degree of financial market integration. The higher the degree of integration, and

the more extensive the contagious effects of a common stock, or a real shock to another country. Thus, financial markets facilitate the transmission of real or common shocks, but they do not cause them. Some observers argue that contagion is a consequence of sudden shifts in market expectations and confidence, a situation that was clearly faced by international markets in late 2007, and early 2009. Empirical examinations of the evidence on contagion have focused mainly on co-movements in asset prices rather than on “excessive” co-movements in capital flows or disturbances in real markets (Calvo and Reinhart, 1996; Frankel and Schumuker, 1998; Valde’s, 1997; Agenor et al. 1999, Baig and Goldfajn, 1999).

When looking for a definition for contagion, the literature shows great disagreement in this regard, but in our opinion the best definition is the one proposed by Dornbusch, Park and Claessens (2000). According to these authors, ‘contagion is a significant increase in cross-market linkages after a shock to an individual country (or group of countries), as measured by the degree to which asset prices or financial flows move together across markets relative to this co-movement in tranquil times’ (*op. cit.*, p. 178). This definition is far from being universally accepted, with some economists arguing that any transmission of a shock constitutes contagion, whether or not correlation increases, with others requiring a demonstration of mechanisms of actions. However, Forbes and Rigobon (2002) make a compelling argument that previous statistical tests for contagion were biased because the correlation coefficients are conditional on volatility (that is, heteroskedastic); and therefore, the crisis simply reflected an interdependence that was present even before the crisis.

Dungey, Fry, and Martin (2003), analyse the linkages between daily Asian and Australian equity markets returns over the period 1995-2001 within the framework of a latent factor model. Their empirical results reveal that co-movements in Asian and Australian equity markets are largely determined by interdependent linkages arising from common systemic factors. There is little significant evidence of contagion, although negative shocks have more effect than positive ones.

Diebold and Yilmaz (2005), analyse volatility spillovers across markets during and after the two major emerging market crises (the East Asian, and the Russian). The major findings show that there was substantial increase in the volatility spillovers across markets, as a result of increased market integration in the nineties; stock markets around

the world had become more interdependent, as captured by the steady increase in return stock spillovers in the mid 1990s. Volatility contagion is important because it means that the risks faced by stock investors will be higher in other markets if there is volatility contagion. If one country is suffering from a financial crisis, this problem may spread to another country because of the presence of underlying conditions that make the other country vulnerable, and as a consequence these economies will be dragged into a downward spiral. Nonetheless, countries with healthy economies are also susceptible to the turmoil, as discussed by Dornbusch, Park and Claessens (2000). This is due to the fact that there are three main channels for financial contagion, namely trade links, financial links and competitive devaluations. Thus, a healthy economy can be affected in any of these ways; therefore, contagious and interdependency analysis is a matter of great importance.

Iwatsubo and Ingaki (2007) investigate stock market contagion between US and Asian markets, using NYSE-traded stocks issued by Asian firms. They find significant bilateral contagion effects in returns and return volatility, and also, that contagion effects from the US market to the Asian markets are stronger than in the reverse direction, indicating that the US market plays a major role in the transmission of information to foreign markets. The intensity of contagion was significantly greater during the Asian financial crisis rather than after the crisis.

There is a reasonable large body of empirical studies testing for the existence of financial contagion during financial crises. Although a range of different methodologies have been presented to analyse contagion effects, there is no theoretical or empirical procedure for indentifying contagion on which researchers agree. Latent factor model, (Bekaert, Harvey and Ng, 2005), correlation analysis (Forbes and Rigobon, 2002), VAR (Fravero and Giovazzi, 2002), and probability theory (Eicheyreen, Rose and Wyplosz, 1995) are different methodologies proposed in the literature.

In the current analysis, we will consider the concept of pure contagion, which is related to changes in international investors' behaviour; it is not caused by systematic or mechanical changes in their portfolio composition, but it is caused by shifts in their perception towards market risk. This group of studies use the following terms: herd behaviour, informational cascades, demonstration effect, wake-up call, etc. Some researchers such as Rigobon (1998) and Masson (1998) define contagion as this channel

only. The basic idea behind all these terms is that a crisis in one country can provide information to investors and change the market sentiments or their interpretation of market situations.

### **3. Empirical Framework**

#### *3.1 Data*

This analysis uses daily data on the Asian major stock markets: China (Shenzhen Se and Shanghai Se), Hong Kong (Hang Seng), India (Sensex 30), Indonesia (Jakarta Se composite), Japan (Nikkei 225), Malaysia (KLCI composite), Singapore (STI), South Korea (Korea Se composite), Taiwan (Taiwan Se Weighted), and Thailand (Bangkok SET), and the US market (Dow Jones Industrials, and S&P 500). The sample period covers 2003 through 2009, which is divided in two subsamples in order to analyse how the markets were reacting during a tranquil time period (from the 1<sup>st</sup> of January, 2003 to the 15<sup>th</sup> of October, 2007), and what happened after the financial system entered into times of difficulties; this latter period is identified as the crisis period (16<sup>th</sup> of October, 2007 to 30<sup>th</sup> of May 2009)<sup>3</sup>. All data are taken from DataStream. The analysis focuses on the stock market assessment of volatility effects captured by daily stock returns movements for the countries included in the study.

#### *3.2 Methodology*

The main objective of this research is to identify whether or not there is a substantial increase in cross-market linkages, following a shock from the American stock markets to a group of Asian countries. Thus, our main goal is to test whether there is a rise in correlations between markets after the shock took place. Considering that stock markets are one of the main channels for shock transmission, we consider appropriate to start the analysis looking at the major reactions generated from this channel.

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<sup>3</sup> The Chow test was employed to detect structural instabilities in the markets. For more details see Figure 1 in the appendix.

We obtain two different measures of correlation for the US stock returns and the Asian nations. First, we compute and compare cross-market correlations for the stock returns, during both the crisis and the tranquil periods. The methodology under use is the one developed by Forbes and Rigobon (1999) and Baig and Goldfajn (1999). Thus, we divide our original sample into two subsamples, in order to check whether correlations are significantly different during the two sub-periods.

Forbes and Rigobon (2002) define contagion as the increase in correlation between two variables during a crisis period. In performing their test, the correlation between the two asset returns during the crisis period is adjusted to overcome the problem that correlations are a positive function of volatility. As crisis periods are typically characterised by an increase in volatility, a test based on the (conditional) correlation is biased upwards resulting in evidence of spurious contagion. The correlation coefficients proposed by Forbes and Rigobon (2002) can be placed conveniently within a bivariate regression framework whereby the underlying variables are scaled appropriately.

To demonstrate the steps needed to implement the Forbes and Ribogon (2002) approach, we test for contagion from country 1<sup>4</sup> to country 2. The correlation between the asset returns of the two asset markets during the crisis period (high volatility period) is:

$$\rho_y = \frac{Cov(y_{1,t}, y_{2,t})}{\sqrt{Var(y_{1,t})Var(y_{2,t})}} = \frac{\sigma_{y,1,2}}{\sqrt{\sigma_{y,1}^2 \sigma_{y,2}^2}} \quad (1)$$

whilst,

$$\rho_x = \frac{Cov(x_{1,t}, x_{2,t})}{\sqrt{Var(x_{1,t})Var(x_{2,t})}} = \frac{\sigma_{x,1,2}}{\sqrt{\sigma_{x,1}^2 \sigma_{x,2}^2}} \quad (2)$$

represents the corresponding correlation in the pre-crisis or tranquil period (low volatility period). If there is an increase in the volatility in the asset return of country 1,  $\sigma_{y,1}^2 > \sigma_{x,1}^2$ ,

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<sup>4</sup> Country one represents the country where the shock originates, and country two represent the country that suffers the effects from the shock.



without there being any change to the fundamental relationship between the asset returns in the two markets, then  $\rho_y > \rho_x$ , giving the false appearance of contagion. To adjust for this bias, Forbes and Rigobon show that the adjusted (unconditional) correlation is given by:

$$\nu_y = \frac{\rho_y}{\sqrt{1 + \left( \frac{\sigma_{y,1}^2 - \sigma_{x,1}^2}{\sigma_{x,1}^2} \right) (1 - \rho_y^2)}} \quad (3)$$

This is the unconditional correlation ( $\nu_y$ ) which is the conditional correlation ( $\rho_y$ ) scaled by a nonlinear function of the percentage change in volatility in the asset return of the source country ( $(\sigma_{y,1}^2 - \sigma_{x,1}^2) / \sigma_{x,1}^2$ ), country 1<sup>5</sup> in this case, over the high and low volatility periods. This adjustment allows for a levels shift in the volatility of asset 1, whereby  $\nu_y = \rho_x$  if there is no fundamental change in the relationship between two asset markets. To test that there is a significant change in correlation, the null hypothesis is,  $H_0 : \nu_y = \rho_y$ , where  $\rho_x$  and  $\nu_y$  are defined as in the previous equations.

Another way to implement the Forbes and Rigobon test of contagion is to scale the asset returns and perform the contagion test within a regression framework. This approach not only provides insights into ways in which the testing framework can be generalized, but also, it offers insights into its relationships with other contagion testing procedures. Continuing with the example of testing for contagion from the asset market of country 1 to the asset market of country 2<sup>6</sup>, consider scaling the asset returns during the pre-crisis period by their respective standard deviations. We can then define the following regression equation in terms of the scaled asset returns:

$$\left( \frac{x_{2,t}}{\sigma_{x,2}} \right) = \alpha_0 + \alpha_1 \left( \frac{x_{1,t}}{\sigma_{x,1}} \right) + \eta_{x,t} \quad (4)$$

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<sup>5</sup> In our case, country one is identified as the US stock markets: the Dow Jones Industrials, and the S&P 500.

<sup>6</sup> In this study, country two will be represented by each Asian stock market under study.

where  $\eta_{x,t}$  is a disturbance term and  $\alpha_0$  and  $\alpha_1$  are regression parameters. The pre-crisis slope regression parameter is related to the pre-crisis correlation coefficient as  $\alpha_1 = \rho_x$ .

We define the following regression equation for the crisis returns, except that the scaling of asset returns is still done by the respective standard deviation from the pre-crisis periods:

$$\left( \frac{y_{2,t}}{\sigma_{x,2}} \right) = \beta_0 + \beta_1 \left( \frac{y_{1,t}}{\sigma_{x,1}} \right) + \eta_{y,t} \quad (5)$$

where  $\eta_{y,t}$  is a disturbance term and  $\beta_0$  and  $\beta_1$  are regression parameters. The crisis regression slope parameter  $\beta_1$  is equivalent to  $\beta_1 = \nu_y$ , which is the Forbes-Rigobon (2002) adjusted correlation coefficient given in the previous equation.

Equations (4) and (5) suggest that another way to implement the Forbes-Rigobon adjusted correlation is to estimate (4) and (5) by OLS and test the equality of the regression slope parameters (this regression approach is the one used to check for contagion effects in this paper). This test is equivalent to a Chow test for a structural break of the regression slope. Implementation of the test can be based on the following pooled regression equation over the entire sample,

$$\left( \frac{z_{2,t}}{\sigma_{x,2}} \right) = \gamma_0 + \gamma_1 d_t + \gamma_2 \left( \frac{z_{1,t}}{\sigma_{x,1}} \right) + \gamma_3 \left( \frac{z_{1,t}}{\sigma_{x,1}} \right) d_t + \eta_t, \quad (6)$$

where,

$z_i = (x_{i,1}, x_{i,2}, \dots, x_{i,T_x}; y_{i,1}, y_{i,2}, \dots, y_{i,T_y})'$ , with  $i$  referring to either country, i.e:  $i = 1, 2$

and  $z_i$  representing the  $(T_x+T_y) \times 1$  scaled pooled data set by stacking the pre-crisis and crisis scaled data;  $dt$  is a slope dummy variable defined as:

$$dt = \begin{cases} 1 & : t > T_x \\ 0 & : \text{otherwise} \end{cases}$$

and  $\eta_t$  is a disturbance term. The parameter  $\gamma_3 = \beta_1 - \alpha_1$  in equation (6), captures the effect of contagion. It represents the additional contribution of information on asset returns in country 2 to the pre-crisis regression; if there is no change in the relationship the dummy variable provides no new additional information during the crisis period, resulting in  $\gamma_3 = 0$ . Thus the Forbes and Rigobon (2002) contagion test can be implemented by estimating equation (6) by OLS and by performing a one-sided t-test of  $H_0 : \gamma_3 = 0$ , in equation (6). This is equivalent to testing  $H_0 : \alpha_1 = \beta_1$  in equations (4) and (5). Of course, the test statistic to perform the contagion test is invariant to scaling transformations of the regressors, such as the use of  $\sigma_{x,1}$ , and  $\sigma_{x,2}$  to standardize  $z_t$ . This would suggest that an even more direct way to test for contagion would have been to implement a standard test of parameter constancy in a regression framework simply based on  $z_t$ , the unscaled data<sup>7</sup>.

We also use a multivariate VAR-EGARCH model specification to investigate market interdependence and volatility transmission effects between the countries under investigation. The VAR-EGARCH model allows the simultaneous estimation of mean and variance equations in both markets. Furthermore, this methodology is free from a priori restrictions on the structure of the relationships among the variables investigated, and it can be viewed as a flexible reduced form approximation of an unknown correctly specified economic structure. The model is expressed as follows,

$$R_{it} = \beta_{i,0} + \sum_{j=1}^n \beta_{ij} R_{j,t-1} + \varepsilon_{it} , \quad (7)$$

$$\sigma_{it} = \exp \left[ \alpha_{i0} + \sum_{j=1}^n \alpha_{ij} f_j(z_{j,t-1}) + \delta_i \ln(\sigma_{i,t-1}^2) \right] \quad (8)$$

$$f_j(z_{j,t-1}) = \left( |z_{j,t-1}| - E(|z_{j,t-1}|) \right) + \gamma_j z_{j,t-1} \quad (9)$$

$$\sigma_{ijt} = \rho_{ij} \sigma_{it} \sigma_{jt} \quad (10)$$

for  $i, j = 1, \dots, n$  and  $i \neq j$

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<sup>7</sup> Our analysis is based on using this model to estimate contagion effects.

Equation (7) describes the returns of equity markets in country 1 and country 2, as a vector autorregression (VAR), where the conditional mean in each market is represented by  $\mu_{it}$ . Equation (8) describes the conditional variance in each market. Under this specification, the estimations of equation (8), (9) and (10) require maximization of the log-likelihood function, which is highly non-linear. In this case, we employ the algorithm proposed by Berndt, Hall, Hall and Hausman (1974).

#### **4. Findings and analysis**

The major outcomes of this study are presented in two main sections: first we analyse the results obtained from the correlation analysis, and also the major findings after applying the Forbes and Rigobon (2002) methodology<sup>8</sup> to analyse contagious effects in stock markets. Afterwards we discuss the VAR-EGARCH methodology<sup>9</sup> used to detect stock markets interdependencies.

##### *4.1 Contagious Effects*

The current analysis starts by looking at the correlation coefficients between country 1 (country at the origin of a financial crisis, the US) and country 2 (country affected by the financial crisis, the Asian markets). Initially, we have estimated the correlation coefficients for the whole sample, and two subsamples. In doing this, we have implemented the Chow test for structural stability in the whole sample, where the test identifies the 15<sup>th</sup> of October of 2007 as a major breakpoint for all the markets (Figure 1). These two subsamples allow us to identify possible initial signs of contagious effects between the US stock markets and some selected Asian stock markets. The results are outlined in table 1. The results for the whole sample show that overall, there is a high level of correlation between the US and Asian equity markets. The exceptions are the Chinese equity markets (Shenzhen Se composite and Shangai Se composite) for which the lowest coefficients from the whole sample are found, a situation that is repeated when looking at the tranquil and crisis sub periods.

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<sup>8</sup> For more details see equation 6, in page 9.

<sup>9</sup> For more details see equations 7 to 10, in page 10.

Through the correlation analysis, we are interested in knowing whether the correlation coefficients increased during the crisis time from country 1 to country 2. The results show that overall correlation coefficients tend to be slightly higher during the crisis period for almost all the markets with the exceptions of the Jakarta Se composite (Indonesia) KLCI composite (Malaysia) and Taiwan Se Weighted (Taiwan). These three markets behave differently with regard to the rest of the Asian markets, as they are the only ones where the correlations coefficients are slightly smaller during the crisis period than during the tranquil period. Considering that there is no evidence of an important jump among the correlation coefficients for any of the markets under analysis, and taking into account the contagious definitions (outlined in the contagious analysis background), we are not expecting to find empirical evidence that demonstrates that the Asian markets are suffering from contagious effects derived from the US equity markets.

The results from the Forbes and Rigobon (2002) test (table 2) show that there is evidence of contagion effects only for three countries: Hong Kong, India and Thailand, results that are consistent when looking at the influence of the Dow Jones Industrials and also in the case of the S&P 500. The rest of the markets do not show evidence of contagious effects. It is reasonable to think that the Chinese stock market should be the one that has the least chances of suffering from contagious effects, due to the limitations on inward foreign capital. However, the rest of the Asian markets would be more likely to experience contagion, perhaps via herd behaviour or portfolio rebalancing by an international investor base, expectations that are not supported by our empirical results. Therefore, the main conclusion from this section could be summarised as follows: the US equity markets (Dow Jones Industrials, and S&P 500) do not seem to be generating contagious effects in the Asian economies, with the three exceptions mentioned above.

#### *4.2 Asian and US Stock Markets Interdependencies' Effects*

The daily stock returns for each series were calculated as the logarithmic difference in the daily price indices,  $R_{it} = \ln(P_{it} - P_{it-1})$ , where R represents the stock returns, and P the stock prices per market. The Augmented Dickey-Fuller test is used to check if our series are stationary, our findings show that all the variables follow an I(0) process; therefore we proceed to conduct our VAR-EGARCH analysis, where the main

interest is based on the analysis of volatility spillovers effects running from the US stock returns (Dow Jones Industrials, and S&P 500) to the selected Asian stock returns. In order to be consistent with our contagion analysis, our interdependency modeling will be differentiated between the tranquil and crisis period. The analysis starts by selecting the appropriate number of lags that would be used in the mean equation (equation 7). In doing this, a VAR model between stock returns from country 1 to country 2<sup>10</sup> is implemented, where the Hannan Quinn selection criterion is used. Then, we settled the mean equation taking into consideration the optimal number of lags obtained from the VAR, and we run the EGARCH model that provides us with information regarding volatility persistence, volatility spillovers and asymmetric spillovers effects.

#### *4.2.1 Volatility Persistence*

The results obtained show that volatility persistence is a characteristic of all Asian stock returns during the tranquil period (table 3, first and fourth row). When looking at the Dow Jones Industrials and S&P 500, the results show that any shock originating in the US stock markets tend to have a short lasting effect in the Asian markets as the coefficients are very small and in all the cases are far from one. These results are surprising as volatility is distinguished for showing clustering behaviour and therefore, for having lasting effects in the markets. The results are similar when looking at the crisis period (table 4, first and fourth row), where the two indices for China show insignificant coefficients, as well as the indices for Malaysia and Thailand with regard to the Dow Jones Industrials. In relation to the S&P 500, the results are quite consistent, with the only difference being the case of Taiwan which shows insignificant coefficients, while Thailand shows significant coefficients. These results are again quite surprising, as it was expected that these markets would be showing significant volatility persistence during both periods, but in particular during the crisis period, as all the markets would be affected by the economic downturn. But it seems that during the tranquil and crisis periods, volatility is short-lived in the Asian countries.

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<sup>10</sup> The results from this test have not been included in the paper due to space limitations, but they are available upon request.

#### *4.2.2 Volatility Spillovers*

The analysis for volatility spillovers effects during the tranquil period, generated from the Dow Jones to the Asian stock returns (table 3, second and fifth row) shows that, in most cases, the coefficients are insignificant for both Chinese stock returns, and also for Malaysia, Singapore and Thailand. In the rest of the cases, the coefficients are significant, showing that the US financial downturn is transmitted to Hong Kong, India, Indonesia, Japan, South Korea, and Taiwan. In terms of the S&P 500 the results are consistent with the Dow Jones findings. In the case of China, the results are not surprising as they show evidence of independent behaviour of this financial market vis-à-vis the US one, and as mentioned before, this is explained by the limitations on the Chinese stock market to foreign investment. This market is therefore relatively isolated from the global turmoil.

The results for volatility spillovers effects during the crisis period (table 4, second and fifth row) from the Dow Jones show that the coefficients are significant for almost all the markets, with the exception of Shanghai Se composite for China. With regard to the S&P 500, the results are consistent with the ones for the Dow Jones; the exception is the Taiwan Se Weighted that appears as an insignificant coefficient in this case. These results show that the Asian markets are reflecting strong interdependencies with regard to the US stock markets during the crisis period. The minor differences obtained with regard to the S&P 500 and the Dow Jones can be explained by the indices composition, where few Asian countries are affected by the Dow Jones but not much by the S&P 500. Therefore, it is possible to conclude that the current economic crisis is not generating contagious effects in the Asian stock markets; however, strong evidence exists suggesting that the markets are interdependent.

#### *4.2.3 Asymmetric Spillovers*

The results for asymmetric effects during both the tranquil and crisis periods (table 3 and 4, third and sixth row) show that asymmetry is present in almost all the markets, where almost all the coefficients appear to be significant and where the

coefficients magnitude tends to be close to one in most of the cases. Surprisingly, most of the coefficients are showing a positive sign. This means that good news are having a stronger impact in these markets than negative news, results that make sense during the crisis period, as positive news are deemed to have a higher effect in the markets. But during tranquil times, negative news tend to generate stronger impacts in the markets than positive news.

## **5. Conclusions and Remarks**

In general, the results suggest that the American crisis is not generating contagious effects in the Asian economies. These results are quite interesting, as the US equity markets do generate an influence on the Asian economies, but there is a need to consider, that after the American economy slowed down, this was only an event that triggered Asian financial markets own problems. The analysis pertaining to interdependencies between the US and Asian stock returns, shows that there is a strong evidence suggesting that these markets are highly integrated. Therefore, shocks affecting or generated from the US do have a strong effect in the Asian markets. However, interdependency does not necessarily imply contagious effects. As the results show, there is no evidence of a jump or big increase in terms of correlations between these markets. Therefore, we can conclude that US stock markets have not exercised any contagious effects, but they do show interdependencies with Asian markets.

The main limitations of this study are in relation to the methodology used to carry out this analysis. There is a need to perform alternative tests that allow to verify that the results obtained are robust. Future research analysing this issue should be based on analysing the world economies, where a division by region would be appropriate, and where latent factor models for detecting contagion effects should be used as a complement to the Forbes and Rigobon (2002) methodology. This would allow for a comparative analysis.



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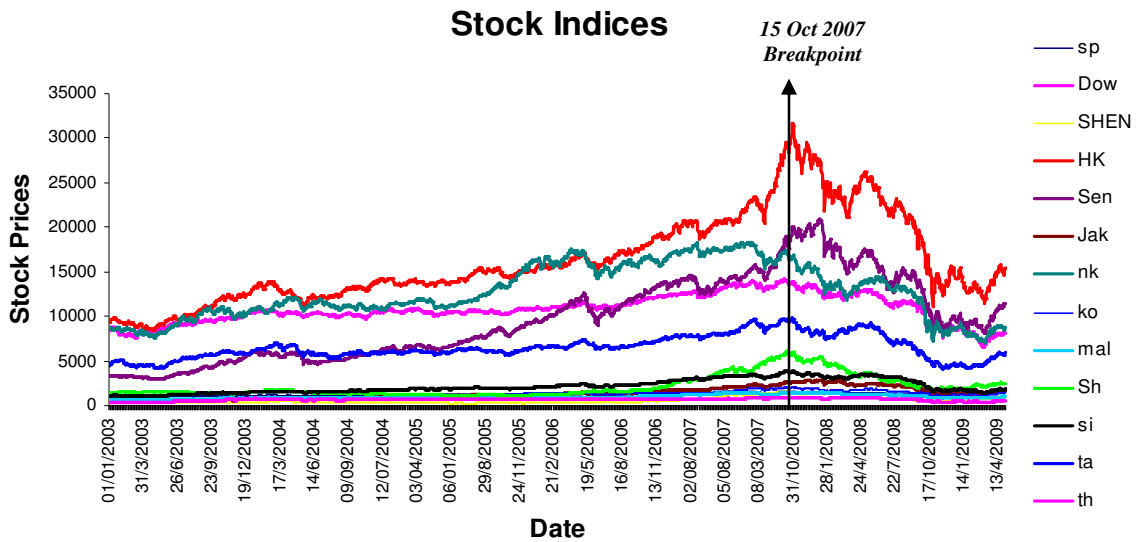
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## 7. Appendix

Figure 1: Stock Price Indices



\* Graph notation: sp: S&P 500; Dow (Dow Jones Industrials), Shen: (Shenzhen Se and Shanghai Se), HK(Hang Seng), Sen (Sensex 30), Jak (Jakarta Se composite), nk (Nikkei 225), Mal (KLCI composite), Si (STI), Ko (Korea Se composite), Ta (Taiwan Se Weighted), and Th (Bangkok SET).

Structural breaks for all the markets were identified. The Chow test was applied to each of the stock indices, and a common breakpoint was identified to be the 15<sup>th</sup> October 2007, a time when all the markets started their downturn.

- 1) Firstly, we run the regression using all the data, before and after the structural break we collected  $RSS_c$ .
- 2) Secondly, we run two separate regressions on the data before and after the structural break, collecting the RSS in both cases, giving  $RSS_1$  and  $RSS_2$ .
- 3) Using these three values we calculate the test statistic from the following formula:

$$F = \frac{RSS_c - (RSS_1 + RSS_2) / k}{RSS_1 + RSS_2 / n - 2k}$$

- 4) Then, we find the critical values in the F-test tables, in this case it has  $F(k, n-2k)$  degrees of freedom.
- 5) The null hypothesis is that there is no structural break. We conclude that all the markets suffer from structural break the 15<sup>th</sup> of October of 2007. This information is then used in order to implement our contagion (Forbes and Rigobon, 2002) and VAR-EGARCH interdependency study.

Table 1: Correlation Matrix

Price Index	Whole Period*		Tranquil Period**		Crisis Period**	
	Dow Jones Industrials	S&P 500	Dow Jones Industrials	S&P 500	Dow Jones Industrials	S&P 500
Shenzhen Se Composite	0.61	0.51	0.71	0.61	0.77	0.76
Hang Seng	0.86	0.81	0.97	0.96	0.97	0.97
Sensex 30	0.79	0.75	0.94	0.95	0.95	0.95
Jakarta Se Composite	0.77	0.72	0.96	0.97	0.95	0.96
Nikkei 225	0.88	0.92	0.90	0.93	0.97	0.98
Korea Se Composite	0.81	0.78	0.93	0.95	0.95	0.96
KLCI Composite	0.86	0.82	0.96	0.95	0.93	0.93
Shanghai Se Composite	0.68	0.59	0.75	0.66	0.81	0.80
STI	0.90	0.86	0.97	0.97	0.98	0.99
Taiwan Se Weighted	0.95	0.92	0.96	0.93	0.94	0.94
Bangkok SET	0.88	0.88	0.80	0.82	0.97	0.97

\*The whole period is from January 1, 2003 to May 30, 2009; \*\*The tranquil period is from January 1, 2003 to October 15, 2007;\*\*\*The crisis period is from October 16, 2007 to May 30, 2009.

Table 2: Forbes and Rigobon (2002) test results.

Dow Jones Industrials	$\gamma_3$	t-statistic	Contagion?
Shenzhen Se Composite	-0.05	-0.84	N
Hang Seng	0.18	3.39	Y*
Sensex 30	0.18	3.41	Y*
Jakarta Se Composite	0.03	0.49	N
Nikkei 225	0.04	0.76	N
Korea Se Composite	0.06	1.19	N
KLCI Composite	0.07	1.29	N
Shanghai Se Composite	-0.02	-0.35	N
STI	0.08	1.52	N
Taiwan Se Weighted	-0.01	-0.17	N
Bangkok SET	0.12	2.30	Y**

S&P 500	$\gamma_3$	t-statistic	Contagion?
Shenzhen Se Composite	-0.04	-0.76	N
Hang Seng	0.17	3.05	Y*
Sensex 30	0.16	2.96	Y*
Jakarta Se Composite	0.03	0.55	N
Nikkei 225	0.04	0.71	N
Korea Se Composite	0.06	1.05	N
KLCI Composite	0.07	1.21	N
Shanghai Se Composite	-0.02	-0.31	N
STI	0.07	1.30	N
Taiwan Se Weighted	-0.02	-0.42	N
Bangkok SET	0.13	2.42	Y**

\*1% significance level; \*\* 5% significance level. Augmented Dickey-Fuller tests for all stock returns were implemented; the results obtained showed that the variables are all stationary at levels, therefore they are an I(0) process, so the results from the Forbes and Rigobon test and VAR-EGARCH are reliable. We follow Forbes and Rigobon (2002) methodology to check for contagion effects (see equation 6 in page 7)

Table 3: VAR-EGARCH Results -Tranquil Period

Estimated Parameters	China	Hong Kong	India	Indonesia	Japan	Korea	Malaysia	China	Singapore	Taiwan	Thailand
<b>Dow Jones Industrials</b>											
Volatility Persistence ( $\sum \alpha_{ij}$ )	0.1084* (0.000)	0.1683* (0.006)	0.3013* (0.000)	0.1898* (0.000)	0.1576* (0.000)	0.2283* (0.000)	0.1178* (0.001)	0.1758* (0.000)	0.1726* (0.000)	0.3573* (0.001)	0.1084* (0.000)
Volatility Spillover( $\sum \gamma_{ij}$ )	0.0161 (0.397)	-0.1279* (0.001)	-0.1789* (0.000)	-0.0869* (0.000)	-0.0883* (0.005)	-0.0302* (0.001)	0.0115 (0.287)	-0.0351 (0.602)	-0.0561 (0.174)	-0.2124** (0.0309)	0.0161 (0.117)
Asymmetric Spillover ( $\sum \delta_{ij}$ )	0.9848* (0.000)	0.7798* (0.000)	0.8004* (0.000)	0.9416* (0.000)	0.9521* (0.000)	0.9441* (0.000)	0.9833* (0.000)	0.9724* (0.000)	0.9474* (0.000)	0.3231* (0.000)	0.9848 (0.254)
<b>S&amp;P 500</b>											
Volatility Persistence ( $\sum \alpha_{ij}$ )	0.1093* (0.000)	0.1673* (0.000)	0.3166* (0.000)	0.1868* (0.000)	0.1683* (0.000)	0.2257* (0.000)	0.1190* (0.000)	0.1774* (0.001)	0.1821* (0.000)	0.2988* (0.000)	0.1093* (0.000)
Volatility Spillover ( $\sum \gamma_{ij}$ )	0.0160 (0.402)	-0.1223* (0.000)	-0.1881* (0.000)	-0.0853* (0.000)	-0.0901* (0.008)	-0.0299* (0.000)	0.0115 (0.296)	-0.0342 (0.604)	-0.0675 (0.183)	-0.2200** (0.012)	0.0160 (0.117)
Asymmetric Spillover ( $\sum \delta_{ij}$ )	0.9845* (0.000)	0.7938* (0.000)	0.7922* (0.000)	0.9489* (0.000)	0.9485* (0.000)	0.9399* (0.000)	0.9828* (0.000)	0.9703* (0.000)	0.9367* (0.000)	0.5085* (0.000)	0.9845** (0.011)

\*1% significance level; \*\* 5% significance level; \*\*\*10% significance level. The VAR-EGARCH methodology used to analyse interdependencies between each Asian Market, and the US most representative equity indices is outlined in page 10, where the mean and variance equation used are presented.

Table 4: VAR-EGARCH Results - Crisis Period

Estimated Parameters	China	Hong Kong	India	Indonesia	Japan	Korea	Malaysia	China	Singapore	Taiwan	Thailand
<b>Dow Jones Industrials</b>											
Volatility Persistence ( $\sum \alpha_{ij}$ )	0.1399 (0.112)	0.2240* (0.000)	0.2549** (0.021)	0.1294* (0.009)	0.1683** (0.018)	-0.0620* (0.000)	0.2020 (0.785)	0.1170 (0.117)	0.1003* (0.010)	-0.0122*** (0.082)	0.1399 (0.632)
Volatility Spillover( $\sum \gamma_{ij}$ )	-0.0882*** (0.084)	-0.1702* (0.000)	-0.2469* (0.005)	-0.1865* (0.000)	-0.1983* (0.000)	-0.1786* (0.000)	0.0908** (0.037)	-0.1825 (0.292)	-0.0893* (0.000)	-0.1369*** (0.070)	-0.0882* (0.000)
Asymmetric Spillover ( $\sum \delta_{ij}$ )	0.8938* (0.000)	0.9512* (0.000)	0.8565* (0.000)	0.9690* (0.000)	0.9691* (0.000)	-0.0733* (0.000)	-0.2294 (0.962)	0.9827 (0.610)	0.8851* (0.000)	0.9816* (0.000)	0.8938* (0.000)
<b>S&amp;P 500</b>											
Volatility Persistence ( $\sum \alpha_{ij}$ )	0.1446 (0.102)	0.2163* (0.000)	0.2741** (0.024)	0.6189* (0.002)	0.1712** (0.023)	0.1941* (0.000)	0.2085 (0.701)	0.1259 (0.112)	0.0811* (0.004)	-0.0428 (0.104)	0.1446** (0.017)
Volatility Spillover ( $\sum \gamma_{ij}$ )	-0.0877*** (0.083)	-0.1773* (0.000)	-0.2424* (0.005)	0.0765* (0.000)	-0.2137* (0.000)	0.0728* (0.000)	0.0951** (0.035)	-0.1870 (0.270)	-0.0352* (0.000)	-0.1412 (0.207)	-0.0877* (0.000)
Asymmetric Spillover ( $\sum \delta_{ij}$ )	0.8976* (0.000)	0.9610* (0.000)	0.8606* (0.000)	0.0241* (0.000)	0.9678* (0.000)	0.0710* (0.000)	-0.1893 (0.880)	0.9845 (0.667)	0.9808* (0.000)	0.9827* (0.000)	0.8976* (0.000)

\*1% significance level; \*\* 5% significance level; \*\*\*10% significance level.