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ABSTRACT

This paper investigates bi-directional linkages between the stock and foreign exchange markets of a number of emerging economies. A quarto-variate VAR-GARCH model with the BEKK representation is estimated for each of twelve emerging economies to test for spillovers, both in terms of return and volatility, between the emerging stock market, foreign exchange market and global and regional stock markets. We find significant bi-directional spillovers between stock and foreign exchange markets. We also examine the effects of a country's choice of exchange rate regime, on the one hand, and the Asian financial crisis, on the other, on the volatility spillover mechanism.

JEL Classifications: F31, F36, G15

Keywords: Volatility Spillovers, MGARCH, Emerging Economies

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1. Introduction

It is widely acknowledged that international financial markets have become substantially more integrated in recent years. On the one hand, the collapse of the Bretton Woods system was followed by greater exchange rate fluctuations. On the other, the liberalization of stock markets and capital flows in the 1990s was followed by a huge increase in the volume of cross border transactions in both securities and currencies. The interlinkage between the stock and foreign exchange markets has been a topic of interest of academic researchers and practitioners alike.

References in the financial press on the linkage between return in the stock and foreign exchange markets abound. Noting the large inflows of foreign capital to emerging markets and subsequent attempts by these countries to dampen them, the *Financial Times* ("Nations try to Cool Hot Money," November 20, 2009) reports that Brazil's[1] move to impose a 2 per cent tax on foreign capital inflows "…comes amid a flurry of miscellaneous policy changes by emerging markets, designed to slow inflows of foreign money" and "… while most of these moves were modest, they did underline the challenges many emerging markets faced in trying to prevent both rapid appreciation against the dollar and the inflation of asset bubbles." Another article ("Asia Currencies Stay Buoyant Amid Storms," *Financial Times*, August 18, 2011) reports that the traditional correlation between higher equity returns and appreciating currencies appears to have broken down recently in Asia while yet another ("Weakest Currency Areas Give Best Returns," *Financial Times*, March 4, 2012) reports that higher stock returns in

[1] Brazil is one of a number of emerging economies that have implemented similar policies in order to mitigate the effects of foreign capital flows on the value of their currency.

emerging economies are correlated with depreciating currencies. Reports in the financial press on the linkage between stock and foreign exchange market returns present conflicting views. Interest on this issue in the financial press is continuous and to be expected given its implications for international portfolio management.

There is a considerable academic literature examining linkages between stock and foreign exchange markets. The flow and portfolio-balance theories of exchange rate determination posit theoretical links between changes in the value of a country's currency and stock prices. This issue has been examined empirically by a number of studies most of which have focused on advanced economies. In view of the increasing significance of the emerging economies in the global financial system, more recent studies have directed emphasis on these economies. The following section provides a brief review of the literature.

Parallel to the literature on the linkage between the stock and foreign exchange market, another branch of the literature has focused on geographic linkages between stock markets. In particular, the mechanism by which shocks in mature stock markets (stock markets of developed economies) are transmitted to stock markets in emerging economies has been the subject of numerous theoretical and empirical studies. The literature on this issue is large and we provide a very brief review in the next section by way of motivating our inclusion of geographic (global and regional) spillovers between stock markets.

Despite extensive research on these interrelated issues, there has been very little work incorporating all of them within a unified empirical framework. The purpose of this paper is to estimate empirically such a framework in order to examine the link between the stock and foreign exchange market in emerging economies allowing for geographic linkages across stock markets. Based on this framework, we provide evidence on a number of hypotheses and test various facets of stock and foreign exchange market interaction in emerging economies.

The paper is organized as follows. The following section is a brief summary of the literature. Section 3 presents the empirical methodology used to test a number of hypotheses and Section 4 the data. Section 5 discusses the evidence from the estimation and tests of the empirical framework and the final section concludes the paper.

2. Theoretical considerations and a brief literature review of the empirical evidence

Theory suggests two broad channels that link return in the stock and foreign exchange market. The first approach known as the flow or traditional approach (Dornbusch, 1980) focuses on the current account, or more specifically the trade balance. According to this approach, a depreciation in the value of a country's currency affects its external competitiveness and thus its trade balance, and ultimately real output. This will alter the profitability and (expected) cash flows of firms and thus stock returns. According to this approach, improved stock market returns would be associated with a depreciating domestic currency.

The second approach, known as the portfolio balance approach (Frankel, 1983), focuses on the choice between holding assets denominated in domestic and foreign currency. Specifically, it postulates that increases in equity returns increase domestic wealth and this, in turn, will lead to appreciation of the domestic currency. This comes about when domestic residents have a higher propensity to hold wealth in the form of domestic bonds than foreign residents. In this case, the increase in domestic wealth increases the net demand for domestic bonds and the domestic currency appreciates to balance relative (domestic and foreign denominated) bond supplies.

When it comes to considerations of volatility spillovers between stock markets or between the stock and foreign exchange markets there is a large empirical literature. The 1987 stock market crisis in the US and the 1992 ERM crisis in Europe gave rise to one branch of the literature on cross-border volatility spillovers among mature (developed economy) stock markets. Early studies covered mostly the G7 economies, e.g. Hamao *et al.* (1990), King and Wadhwani (1990), Schwert (1990) and Karolyi (1995). Later research expanded the sample to other developed economies. For example, Theodosiou and Lee (1993) examined interlinkages between a larger set of countries and Lin *et al.* (1994) examined differences in the transmission of global and local shocks. Most of these studies found weak evidence in favor of significant stock market volatility transmission among advanced economies.

More recently, cross border linkages of emerging stock markets have been the focus of attention because of the high growth and increasing openness of emerging markets, along with the speed with which a financial crisis spreads. The implications of stock market integration of emerging economies with global markets, emerging equity market volatility, and market integration and contagion were analyzed by Bekaert and Harvey (1995, 1997, and 2000) and Bekaert *et al.* (2005). These studies cover individual emerging economies. Other studies have focused on specific emerging market regions (Asia, Europe, Latin America and Middle East). Chen *et al.* (2002) examined regional stock market linkages in Latin American and Yang *et al.* (2006) integration of Central and Eastern European stock markets. Caporale *et al.* (2006), Engle *et al*. (2008), and Li and Rose (2008) examined interlinkages and spillovers across Asian stock markets. Beirne *et al.* (2009, 2010) examined global and regional volatility spillovers among 41 emerging stock markets. On the whole, these studies find some evidence of either stock return transmission or volatility spillovers among emerging stock markets.

Empirical research supports the existence of spillovers in mean between foreign exchange and stock markets. For example, Phylaktis and Ravazzolo (2005) present evidence of bidirectional spillovers between the foreign exchange and stock market returns in emerging markets. When it comes to spillovers in volatility, Yang and Doong (2004) find no evidence of such a link. Other studies on volatility spillovers between the foreign exchange and stock market focus on a specific country or a specific region (mainly Asia) and yield mixed results. Bodart and Reding (1999) and Karolyi and Stulz (1996) examined return and volatility spillovers indirectly; the former finds no significant linkage between these two markets. Francis *et al.* (2002) find a bi-directional relationship and Evans and Lyons (2002) find the spillover from the foreign exchange to the stock market to be much stronger than the other way around.

On the whole, the literature finds a significant link (both in terms of return and volatility) exists between emerging stock markets, on the one hand, and regional and global stock markets, on the other. When it comes to studies on the link between stock and foreign exchange returns and volatility, there is a general presumption for a bidirectional relationship between them. General conclusions, however, are difficult because methodologies, time periods and frequencies of observations are different. For example, Katechos (2011) investigates the underlying relationship between stock markets and exchange rates with currency pairs for seven major currencies and the FTSE All World stock index and finds strong linkages among exchanges rates and global stock market returns. Ülkü and Demirci (2012) study the joint dynamics of emerging stock and foreign exchange markets of eight European countries and the MSCI Europe Index, and find evidence that global developed and emerging stock market returns account for a large part of the comovement between the MSCI Europe stock index and the value of East European currencies and the Turkish lira. Moreover, after controlling for the global index, residual interaction is small, indicating that a significant portion of the stock market and foreign exchange comovements is mainly due to the returns of the global developed market. Walid *et al.* (2011) investigate the dynamic linkage between stock price volatility and exchange rate changes for four emerging countries and find strong evidence that the relationship between stock and foreign exchange markets depends on the regime for the conditional mean and conditional variance of stock returns and stock price volatility responds asymmetrically to events in the foreign exchange market. It should be noted, that none of these studies has looked at the connection between the local stock market, the foreign exchange market and the global and regional stock markets. They conduct pairwise comparisons, while Beirne *et al.* (2010) look at stock market interactions (local, regional, and global) but do not consider the foreign exchange market.

The purpose of this paper is to bring together the various strands of the empirical literature reviewed above within a unified framework. Specifically, we study the linkage between the stock and foreign exchange market of emerging economies both in mean and volatility terms, taking into account spillovers from global and regional stock markets. Our framework combines all four in a Multivariate GARCH (MGARCH) framework and tests the existence of spillovers among them. In addition, we look at the possibility that the Asian financial crisis and the choice of exchange rate regime affects the volatility spillover mechanism between the emerging stock market and the foreign exchange market. The following section describes this framework.

3. Empirical Methodology

As outlined in the previous section, the hypotheses of interest are spillovers between the stock and foreign exchange market of emerging economies taking into account possible interactions between these two markets and the global and regional stock markets. In order to test the various hypotheses, we specify and estimate a quarto-variate VAR(1)–GARCH(1,1) model with the BEKK representation of Engle and Kroner (1995).[2] According to this model, the first moment or mean returns in the emerging stock market, foreign exchange market, global stock market and regional stock market are represented by a VAR(1) (for all countries except Brazil). The choice of order of the VAR is based on the BIC criterion.[3] In its general form it is given by

$$R_{1,t} = \alpha_{10} + \delta_{11} R_{1,t-1} + \delta_{12} R_{2,t-1} + \delta_{13} R_{3,t-1} + \delta_{14} R_{4,t-1} + \varepsilon_{1,t}$$

$$R_{2,t} = \alpha_{20} + \delta_{21} R_{1,t-1} + \delta_{22} R_{2,t-1} + \delta_{23} R_{3,t-1} + \delta_{24} R_{4,t-1} + \varepsilon_{2,t}$$

$$R_{3,t} = \alpha_{30} + \delta_{31} R_{1,t-1} + \delta_{32} R_{2,t-1} + \delta_{33} R_{3,t-1} + \delta_{34} R_{4,t-1} + \varepsilon_{3,t}$$

$$R_{4,t} = \alpha_{40} + \delta_{41} R_{1,t-1} + \delta_{42} R_{2,t-1} + \delta_{43} R_{3,t-1} + \delta_{44} R_{4,t-1} + \varepsilon_{4,t} \quad (1)$$

where $R_{1,t}$ is the emerging (or local) stock market return, $R_{2,t}$ is the rate of appreciation of the emerging (or local) currency vis-à-vis the dollar, $R_{3,t}$ is the global stock market return and $R_{4,t}$ is the regional stock market return.[4]

The specification in (1) allows for mean return spillovers among these four markets. Of specific interest in our work is mean return spillovers from global, regional and foreign exchange markets to the local stock market and from global, regional and local stock markets to the foreign exchange market. In estimating (1) we impose the restrictions $\delta_{31} = 0$, $\delta_{32} = 0$, $\delta_{41} = 0$, $\delta_{42} = 0$ because we do not expect returns in emerging stock

[2] This methodology is reviewed in Bauwens *et al.* (2006). The BEKK representation has been used widely in previous work in financial market linkages by, *inter alia*, Baele (2005), Beirne *et al*. (2010), Bekaert and Harvey (1995), Moskowitz (2003), Scruggs and Glabadanidis (2003) and Shields *et al.* (2005).
[3] For Brazil VAR (2) minimizes the BIC (see Table 1).
[4] We conducted Augmented Dickey Fuller unit root tests and found the series to be stationary.

markets and foreign exchange markets to influence returns in the global or regional stock markets.[5] One may also doubt the validity of including both global and regional stock market returns together in determining stock market returns or foreign exchange returns in (1). We have tested the hypothesis $\delta_{14} = \delta_{24} = 0$ (the regional stock market should not be included in the emerging stock market and foreign exchange mean return equations) and found this hypothesis to be rejected in the majority of cases (results in Table 2).[6]

The restricted version of (1) in matrix form is

$$\mathbf{R}_t = \boldsymbol{\alpha} + \boldsymbol{\delta}\mathbf{R}_{t-1} + \mathbf{e}_t \qquad (2)$$

where $\mathbf{R}_t = (R_{1,t}, R_{2,t}, R_{3,t}, R_{4,t})$, $\mathbf{R}_{t-1} = (R_{1,t-1}, R_{2,t-1}, R_{3,t-1}, R_{4,t-1})$, $\boldsymbol{\alpha} = (\alpha_{10}, \alpha_{20}, \alpha_{30}, \alpha_{40})$ is a vector of constants, $\boldsymbol{\delta} = (\delta_{11}, \delta_{12}, \delta_{13}, \delta_{14} | \delta_{21}, \delta_{22}, \delta_{23}, \delta_{24} | 0, 0, \delta_{33}, 0 | 0, 0, 0, \delta_{44})$ is a vector of parameters to be estimated following the restrictions mentioned in the previous paragraph, and $\mathbf{e}_t = (e_{1t}, e_{2t}, e_{3t}, e_{4t})$ is a tergiversate vector of residuals normally distributed or $\mathbf{e}_t | \boldsymbol{\Omega}_{t-1} \sim (0, \mathbf{H}_t)$. Its conditional variance-covariance matrix, $\mathbf{H}_t$, is

$$H_t = \begin{bmatrix} h_{11} & h_{12} & h_{13} & h_{14} \\ h_{21} & h_{22} & h_{23} & h_{24} \\ h_{31} & h_{32} & h_{33} & h_{34} \\ h_{41} & h_{42} & h_{43} & h_{44} \end{bmatrix} \qquad (3)$$

The BEKK representation guarantees the positive definiteness of $\mathbf{H}_t$ given by a GARCH-type structure or

[5] While these restrictions make intuitive sense, we conducted formal likelihood ratio and *t*-tests on the validity of these restrictions and found them to be valid.
[6] We have also restricted $\delta_{34} = \delta_{43} = 0$ such that the global and regional stock market returns follow AR processes.

$$\mathbf{H_t = C'C + \alpha' e_{t-1} e'_{t-1}\ \alpha + \beta' H_{t-1}\beta} \qquad (4)$$

The BEKK representation in (4) decomposes the conditional variance-covariance matrix $\mathbf{H_t}$ and models it as a function of past values ($\mathbf{H_{t-1}}$) and innovations of past values ($\mathbf{e_{1t}, e_{2t}, e_{3t}, e_{4t}}$). This representation can be used to test volatility spillovers as will be explained below.

Similar to the restrictions imposed on mean return spillovers, we impose restrictions on volatility spillovers. Specifically, volatility in the emerging stock market and foreign exchange market does not affect global or regional stock market volatilities, and the regional stock market volatility does not affect the global market and vice versa.[7] The restricted form of (4) is given by

$$H_t = C'C + \begin{bmatrix} \alpha_{11} & \alpha_{12} & 0 & 0 \\ \alpha_{21} & \alpha_{22} & 0 & 0 \\ \alpha_{31} & \alpha_{32} & \alpha_{33} & 0 \\ \alpha_{41} & \alpha_{42} & 0 & \alpha_{44} \end{bmatrix}' \begin{bmatrix} e_{1,t-1}^2 & e_{1,t-1}e_{2,t-1} & e_{1,t-1}e_{3,t-1} & e_{1,t-1}e_{4,t-1} \\ e_{2,t-2}e_{1,t-1} & e_{2,t-1}^2 & e_{2,t-1}e_{3,t-1} & e_{2,t-1}e_{4,t-1} \\ e_{3,t-1}e_{1,t-1} & e_{3,t-1}e_{2,t-1} & e_{3,t-1}^2 & e_{3,t-1}e_{4,t-1} \\ e_{4,t-1}e_{1,t-1} & e_{4,t-1}e_{2,t-1} & e_{4,t-1}e_{3,t-1} & e_{4,t-1}^2 \end{bmatrix} \begin{bmatrix} \alpha_{11} & \alpha_{12} & 0 & 0 \\ \alpha_{21} & \alpha_{22} & 0 & 0 \\ \alpha_{31} & \alpha_{32} & \alpha_{33} & 0 \\ \alpha_{41} & \alpha_{42} & 0 & \alpha_{44} \end{bmatrix}$$
$$+ \begin{bmatrix} \beta_{11} & \beta_{12} & 0 & 0 \\ \beta_{21} & \beta_{22} & 0 & 0 \\ \beta_{31} & \beta_{32} & \beta_{33} & 0 \\ \beta_{41} & \beta_{42} & 0 & \beta_{44} \end{bmatrix}' H_{t-1} \begin{bmatrix} \beta_{11} & \beta_{12} & 0 & 0 \\ \beta_{21} & \beta_{22} & 0 & 0 \\ \beta_{31} & \beta_{32} & \beta_{33} & 0 \\ \beta_{41} & \beta_{42} & 0 & \beta_{44} \end{bmatrix}$$

(5)

Estimation of (5) focuses on two questions: (i) are there volatility spillovers from the global, regional and foreign exchange market to the emerging stock market and (ii) are there volatility spillovers from the global, regional and local stock markets to the foreign exchange market?

[7] Specifically, we restrict the parameters capturing these (α_{13}, α_{14}, α_{23}, α_{24}, α_{34}, α_{43}, β_{13}, β_{14}, β_{23}, β_{24}, β_{34}, and β_{43}) to be jointly equal to zero. A likelihood ratio test for the validity of the joint restrictions supports this hypothesis. Results are available on request.

Given a sample of $t = 1,\ldots,T$ observations of the vector $\mathbf{R_t}$, the vector of unknown parameters (θ) is obtained from the conditional density function

$$f(R_t \mid \Omega_{t-1};\theta) = (2\pi)^{-1} \mid H_t \mid^{-1/2} \exp(-[e_t'(H_t^{-1})e_t]/2) \tag{6}$$

The log likelihood function is:

$$L = \sum_{t=1}^{T} \log f(R_t \mid \Omega_{t-1}, \theta) \tag{7}$$

We obtain Quasi-Maximum Likelihood estimates of the parameters and standard errors assuming the log likelihood function to be conditional normal (Bollerslev and Wooldridge (1992) and Gourieroux (1997)). The various hypotheses concerning volatility spillovers are tested by estimating the conditional variances of: (i) local stock market returns ($h_{11,t}$); (ii) foreign exchange market returns ($h_{22,t}$); (iii) global market returns ($h_{33,t}$); and (iv) regional market returns ($h_{44,t}$). The exact form of these conditional variances is in equations A1, A2, A3 and A4 of the Appendix.

4. Data

In order to compute stock market and exchange rate returns, we use weekly data from the *Emerging Markets Database* (EMDB) of Standard and Poor's that cover the period 06/01/1989-15/08/2008 (1024 observations) for twelve emerging economies in Asia (India, Korea, Malaysia, Pakistan, Philippines and Thailand) and Latin America (Argentina, Brazil, Chile, Colombia, Mexico and Venezuela).[8] The choice of these emerging economies is dictated by data availability in terms of length of coverage: these

[8] Venezuela and Pakistan have 953 (06/01/1989-06/04/2007) and 907 (05/04/1991-15/08/2008) observations, respectively.

are the emerging economies for which sufficiently lengthy and continuous weekly data are available to enable estimating long run links between the foreign exchange and stock market. Moreover, these are some of the most economically important countries in the emerging world.

Stock market return for country *j* is computed as $R_{j,t}=\ln(P_{j,t}/P_{j,t-1})*100$ where $P_{j,t}$ is the stock market index for country *j* and is denominated in local currency. The global market is approximated by the S&P500 stock index from *DataStream*. The global stock return is calculated the same way. The exchange rate for currency *j,* $S_{j,t}$, is defined in dollars per local currency at time *t* and, therefore exchange rate return or $\ln(S_{j,t}/S_{j,t-1})*100$ is the rate of appreciation of local currency *j* at time *t* relative to the US dollar.

To measure a regional stock market return we construct a weighted average return of each emerging economy's local region (or neighborhood), be it in Latin America or Asia. We refer to this as the Neighborhood Trade Weighted Return or *NTWR*. For each Asian or Latin American economy it is the trade weighted sum of stock returns of the other five countries in the region or

$$NTWR_{j,t} = (\sum_{i=1}^{5} w_{ji,t}\ R_{i,t}) \tag{8}$$

where i =1....5 ($i \neq j$) are all other countries in the region (Asia or Latin America) except *j,* $w_{ji,t}$ are trade weights based on total (exports plus imports) trade between countries *i* and *j* and $\sum_{i}^{5} w_{ij} = 1$. Tables 3 and 4 provide descriptive statistics.

5. Empirical Analysis

5.1 Hypothesis Testing

We test a variety of hypotheses concerning mean return spillovers (causality-in-mean) and volatility spillovers (causality-in-variance) between the emerging stock market, the foreign exchange market, and the global and regional stock markets.

First, we test the presence of various conditional mean or return spillovers as follows:

Hypothesis 1: Ho: $\delta_{12}=0$ H_1: $\delta_{12}\neq0$

existence of mean spillover from the foreign exchange to the emerging stock market.

Hypothesis 2: Ho: $\delta_{13}=0$ H_1: $\delta_{13}\neq0$

existence of mean spillover from the global to the emerging stock market.

Hypothesis 3: Ho: $\delta_{14}=0$ H_1: $\delta_{14}\neq0$

existence of mean spillover from the regional to the emerging stock market.

Hypothesis 4: Ho: $\delta_{21}=0$ H_1: $\delta_{21}\neq0$

existence of mean spillover from the emerging stock market to the foreign exchange market.

Hypothesis 5: Ho: $\delta_{23}=0$ H_1: $\delta_{23}\neq0$

existence of mean spillover from the global stock market to the foreign exchange market.

Hypothesis 6: Ho: $\delta_{24}=0$ H_1: $\delta_{24}\neq0$

existence of mean spillover from the regional stock market to the foreign exchange market.

Second, we test the presence of conditional variance or volatility spillover as follows:

Hypothesis 7: Ho: $\alpha_{21}=\beta_{21}=0$ H_1: $\alpha_{21}\neq0$ or $\beta_{21}\neq0$

existence of volatility spillovers from the foreign exchange market to the emerging stock market.

Hypothesis 8: Ho: $\alpha_{12}=\beta_{12}=0$ H_1: $\alpha_{12}\neq0$ or $\beta_{12}\neq0$

existence of volatility spillovers from the emerging stock market to the foreign exchange market.

Hypothesis 9: Ho: $\alpha_{31}=\beta_{31}=0$ H_1: $\alpha_{31}\neq0$ or $\beta_{31}\neq0$

existence of volatility spillovers from the global to the emerging stock market.

Hypothesis 10: Ho: $\alpha_{32}=\beta_{32}=0$ H_1: $\alpha_{32}\neq0$ or $\beta_{32}\neq0$

existence of volatility spillovers from the global to the foreign exchange market.

Hypothesis 11: Ho: $\alpha_{41}=\beta_{41}=0$ H_1: $\alpha_{41}\neq0$ or $\beta_{41}\neq0$

existence of volatility spillovers from the regional stock market to the emerging stock market.

Hypothesis 12: Ho: $\alpha_{42}=\beta_{42}=0$ H_1: $\alpha_{42}\neq0$ or $\beta_{42}\neq0$

existence of volatility spillovers from the regional stock market to the foreign exchange market.

A likelihood ratio test is performed to test each hypothesis of the general form $LR = -2(L_R - L_U) \sim \chi^2 (2)$, where L_R and L_U are the values of the restricted and unrestricted (equation 7) likelihood function.

5.2 Discussion

Regarding hypotheses 1 and 4 we find mixed evidence for conditional mean causality or return spillovers between the foreign exchange and emerging stock markets (see Table 5 – Panel A). In five countries there is no evidence of causality in mean, in six countries there is unidirectional spillover and only in one country there is bidirectional spillover (Brazil). In four countries (Venezuela, Korea, Philippines and Thailand) there is evidence that foreign exchange market returns Granger cause emerging stock market returns while in two cases (Mexico and Pakistan) Granger causality is in the opposite direction. In all (but one) cases of significant Granger causality, stock returns and domestic currency appreciation are inversely related. Regarding the hypothesis of conditional mean spillovers from the global/regional stock market to the emerging stock market and from the global/regional stock market to the foreign exchange market (hypotheses 2-3 and 5-6 respectively) the evidence is also mixed. Relatively more significant effects are found for hypothesis 3, namely positive conditional mean spillovers from regional market returns to local stock markets returns for six emerging countries.

When it comes to volatility spillovers, on the other hand, we find strong evidence in favour of causality-in-variance (hypotheses 7 and 8) between foreign exchange and emerging stock markets volatilities in almost all countries, and especially Asian countries (Table 5 - Panel B). Bidirectional volatility spillovers are evident between the emerging stock market and the foreign exchange market for nine of the twelve economies (Argentina, Brazil, Mexico, India, Korea, Malaysia, Pakistan, Philippines and Thailand) and unidirectional volatility spillover for two others (Venezuela and Chile).

Furthermore, there is strong evidence of volatility spillovers from global/regional stock markets to the foreign exchange and emerging stock markets. Table 6 summarizes the results from various causality-in-variance tests. Regarding volatility spillovers from the global stock market to the emerging stock market and from the global stock market to the foreign exchange market (hypotheses 9 and 10), there is evidence for nine of twelve countries. Regarding spillovers from the regional stock market to the emerging stock market (hypothesis 11) there is evidence for all countries except Colombia. As far as spillovers from the regional stock market to the foreign exchange market (hypothesis 12) there is evidence for nine countries. Volatility spillovers exist from both global and regional stock markets to the stock and foreign exchange market in Argentina, Brazil, Korea, Malaysia, Pakistan, Philippines and Thailand; in Chile and Mexico only regional spillovers are present. In Colombia there is no evidence of volatility spillovers, either global or regional.[9] In conclusion, there is strong evidence of transmission of volatility from regional stock markets to emerging stock markets. This is also true, but to a somewhat lesser extent, for volatility transmission from the global to the emerging stock markets. Volatility from both global and regional stock markets is transmitted to the stock and foreign exchange markets of emerging Asia. In Latin America, regional volatility transmission predominates: global volatility transmission is significant in only three of six economies. Beirne *et al.* (2010) reach similar conclusions.

Following on these findings, an interesting hypothesis arises: which of the two effects, global or regional, is larger in magnitude? Previous studies have not tested this

[9] Colombia's trade is heavily oriented towards Venezuela with a share of around half at the end of the sample period.

hypothesis formally. In Table 7 we perform a Wald test for the equality of coefficients of the spillover parameters in the volatility equation (5) (or equations (A1)-(A2) in the Appendix). The general conclusions are, first, that the transmission effects from regional and global stock markets to emerging stock markets are significantly different for ten of the twelve countries. Second, for these ten countries, the regional effect is larger in magnitude for seven and the global effect is larger for the other three. Third, the results for the transmission of volatility from regional and global stock markets to foreign exchange markets are mixed. The effects are significantly different for seven countries; of these, the regional effect is larger than the global effect in four cases. In sum, spillovers from regional stock markets to emerging stock and foreign exchange markets are larger in magnitude than global spillovers for the majority of emerging economies considered.

Finally, we test the robustness of the results to a different measure of regional market returns, by computing a more naïve measure namely the Neighborhood Average Returns (*NAR*) index. This is similar to the *NTWR* index but we calculate this as the simple (not the trade weighted) average of returns of markets within a region. Results using the *NAR* as a measure of regional market returns are similar to those presented above.

5.3 The effects of the Asian financial crisis on the linkage between the stock and foreign exchange market of emerging economies

The Asian crisis began in early summer of 1997 bringing financial distress as it spread quickly from Thailand to other emerging economies within and outside Asia. The crisis resulted in a plunge in asset prices, speculation and capital flight and instability in the whole region. It has been suggested that longer term the crisis brought about loss of investor confidence and likely a shift in their behavior towards portfolio investment.[10]

One way to study the effects of the Asian crisis on return and volatility spillovers is to use a binary variable that is equal to 1 for the post Asian crisis period and 0 zero otherwise. This is the approach of Chiang *et al*. (2007) who investigate financial contagion following the Asian crisis. We adopt this approach and incorporate such a binary variable in the context of a BEKK model. Our testable hypotheses concerning stock market and foreign exchange spillovers, however, are different compared to the approach in Chiang *et al*. (2007) or Sander and Kleimeier (2003).

To examine whether, following the onset of the Asian financial crisis, there was a change in the volatility spillover mechanism, we modify the model in (5) by adding a dummy variable (denoted *AD*) which is equal to 1 after July 4 1997, and is zero otherwise. This allows us to examine shifts in the parameters that capture the transmission mechanism, so that the parameters shift from α_{21}, β_{21}, α_{12} and β_{12} before the crisis to $\alpha_{21}+\alpha_{21\alpha d}$, $\beta_{21}+\beta_{21\alpha d}$, $\alpha_{12}+\alpha_{12\alpha d}$ and $\beta_{12}+\beta_{12\alpha d}$ after the crisis. In this respect, we follow Forbes and Rigobon (2002) and Beirne *et al.* (2009) and examine the 'shift contagion' volatility concept. This is defined as a shift in volatility transmission from the local stock market to the foreign exchange market and vice versa before and after the crisis. The model in (5) is modified as follows:

$$\mathbf{H_t = C'C + \alpha' e_{t-1}\, e'_{t-1}\, \alpha + \beta' H_{t-1} \beta + \alpha_{\alpha d}' AD e_{t-1}\, e'_{t-1}\, AD \alpha_{\alpha d} + \beta_{\alpha d}'\, AD H_{t-1} AD \beta_{\alpha d}} \qquad (9)$$

[10] For a discussion of the crisis and repercussions on portfolio investment sentiment see Edwards (2000).

The variable *AD* in (9) controls the parameter volatility spillovers before and after the Asian crisis as described above. Before discussing estimation results, we test the significance of including *AD* in (9). The likelihood ratio results are in Table 8; the null hypothesis (i.e. exclusion of *AD*) is rejected in all cases.

The volatility causality results from the estimation of the model in equation (9) are in Table 9. Column 1 tests for shift contagion from the foreign exchange to the stock market after the Asian crisis by testing the hypothesis $\alpha_{21\alpha d}=\beta_{21\alpha d}=0$ (see equations A21 and A22 in the Appendix for the exact formulation of the conditional variance equation). Column 3 tests for spillovers, in general, from the foreign exchange to the stock market over the complete sample period by testing jointly whether $\alpha_{21\alpha d}=\beta_{21\alpha d}=0$ and $\alpha_{21}=\beta_{21}=0$. Columns 2 and 4 repeat these tests to examine volatility causality in the opposite direction, i.e. from the stock market to the foreign exchange market. Results show evidence of shift contagion from the foreign exchange market to the stock market in all countries (except Colombia) and from the stock market to the foreign exchange market in all countries. Moreover, volatility spillovers from the foreign exchange to the stock market and vice versa are significant before and after the Asian crisis in all emerging markets (except Colombia).

The question then becomes whether following the onset of the Asian crisis volatility spillovers increased or decreased. This can be addressed by comparing and testing the differences in the estimated coefficients on volatility transmission before and after the Asian crisis. The difference in coefficients capturing volatility transmission from the stock market to the foreign exchange market before and after the crisis is $[\alpha_{12}+\alpha_{12\alpha d}]^2 + [\beta_{12}+\beta_{12\alpha d}]^2 - \alpha_{12}^2 - \beta_{12}^2$. The difference in volatility transmission in the opposite direction (from the foreign exchange to the stock market) is $[\alpha_{21}+\alpha_{21\alpha d}]^2+[\beta_{21}+\beta_{21\alpha d}]^2 - \alpha_{21}^2 - \beta_{21}^2$. A positive difference implies that after the Asian crisis the coefficients capturing volatility spillovers are bigger. Specifically, a positive difference means that, following the onset of the Asian crisis, there is an increase in volatility spillovers among the two markets (stock and foreign exchange) and a negative difference implies a decrease in volatility spillovers. Table 10 reports differences in the estimated coefficients capturing volatility transmission in both directions. Our general conclusion is that, following the onset of the Asian financial crisis, the experience of the Asian emerging economies is quite different from that of Latin America as regards the volatility transmission mechanism. In most cases, volatility spillovers between the foreign exchange and stock market decreased in Asia (eight of the twelve differences are negative) while the opposite (they increased) is the case for Latin America (nine of the twelve differences are positive). In the years following the Asian financial crisis, the central banks of many Asian nations built up substantial foreign exchange reserves with the aim of cushioning the domestic impact of disturbances in international financial markets. This accumulation of foreign reserves may have served to dampen the volatility transmission mechanism between the foreign exchange and stock markets of Asian emerging economies.

5.4 The effects of the choice of exchange rate regime on the linkage between the stock and foreign exchange market of emerging economies

Recently, an important debate has centered on whether a country's official choice of exchange rate regime is meaningful in terms of determining the value of its currency and the performance of the main macroeconomic aggregates. The debate has taken on importance because countries that purport to maintain fixed exchange rate regimes allow substantial variation in the value of their currency and those that claim to maintain flexible exchange rates are frequently reluctant to allow exchange rate fluctuations in practice ("fear of floating"). Klein and Shambaugh (2008) argue that, in practice, a country's choice of exchange regime is important insofar as how exchange rates behave and their macroeconomic implications. Various issues relevant to the choice of exchange rate regime are discussed in Ghosh *et al.* (2003).

Our purpose in this paper is not to contribute directly to this debate. Rather, we focus on how the choice of exchange regime affects the transmission mechanism between the stock and foreign exchange market of emerging economies. Specifically, we address two questions: (i) does the choice of exchange rate regime shift the level (or constant) in the stock market's return and volatility equations? (ii) does the choice of exchange rate regime have an effect on the transmission mechanism or dynamics between foreign exchange and stock market volatilities?

In order to answer these questions, a scheme for classifying exchange rate regimes is necessary. We resort to the large literature on this issue and employ an existing (and widely used) classification scheme by Ilzetzki *et al.* (2011) to the question at hand. This scheme distinguishes between fifteen categories of exchange rate regime. Following much of the literature in this area, we aggregate the fifteen classifications into three categories (fixed, intermediate and flexible exchange rate regimes) and construct a dummy variable (*RD*) that assumes three values: *RD*=1 for a fixed exchange rate regime, *RD*=2 for an intermediate regime and *RD*=3 for a flexible exchange rate regime. The Ilzetzki *et al.* (2011) scheme and aggregation are shown in Table 11. The actual exchange regime based on this classification for the emerging economies in our sample is in Table 12.

In the first place, the regime variable (*RD)* is inserted as an intercept shift in the stock market return equation (1) and the stock market volatility equation (4). This is because we want to test whether regime choice has a significant shift effect on average return and volatility in emerging stock markets. In addition, *RD* is interacted with the parameters that capture volatility (α_{21} and β_{21}) in order to check whether exchange rate regime changes affect the transmission mechanism of volatility. Specifically we estimate the following model

$$R_{1,t} = \alpha_{10} + \delta_{11} R_{1,t-1} + \delta_{12} R_{2,t-1} + \delta_{13} R_{3,t-1} + \delta_{14} R_{4,t-1} + w_1 RD_t + \varepsilon_{1,t} \quad (10)$$

and

$$\mathbf{H_t} = \mathbf{C'C} + \Xi'\Xi RD + \boldsymbol{\alpha}'\mathbf{e_{t-1}}\,\mathbf{e'_{t-1}}\,\boldsymbol{\alpha} + \boldsymbol{\beta}'\mathbf{H_{t-1}}\boldsymbol{\beta} + \boldsymbol{\alpha_{rd}}'\mathbf{RDe_{t-1}e'_{t-1}}\,\mathbf{RD}\boldsymbol{\alpha_{rd}} + \boldsymbol{\beta_{rd}}'\mathbf{RDH_{t-1}RD}\boldsymbol{\beta_{rd}} \quad (11)$$

where w_1 is a parameter that tests for shift in the constant of the return equation and Ξ is a zero matrix with a single non-zero element ξ_{11} that is the first element of the first row that captures a constant shift in the variance equation of emerging stock market returns, as shown analytically in equation (A31) in the Appendix.

First, we test whether regime choice has a significant shift effect on the constant of the equations for the mean and volatility of emerging stock market returns, or a test of the null hypothesis $w_1=0$ in (10) and $\xi_{11}=0$ in (11), respectively. Table 13 reports the estimate of w_1 and ξ_{11} and the corresponding *p*–value for the test of the null.[11] In general, the choice of exchange rate regime does not have a significant effect on the constant (or level shift) of stock market returns. The estimate of w_1 is significant in two of the ten countries: for Brazil greater exchange rate flexibility is associated with a higher level of average stock returns while in Venezuela with lower stock returns. Exchange regime choice has a significant shift level effect on stock market volatility in five of the ten countries. Our general conclusion is that greater exchange rate flexibility is associated with greater volatility of stock market returns: this is the case for four of the five countries (Brazil, India, Pakistan and Philippines), while only for Thailand is greater exchange rate flexibility associated with lower stock volatility.

Next we examine if exchange regime classification has a significant effect on the dynamics of stock market volatility transmission by focusing on the parameters capturing

[11] Estimation was not carried out for Chile or Colombia because there was no change in regime classification throughout the sample period: both countries were classified in the intermediate regime category throughout (see Table 12).

volatility transmission from the foreign exchange to the stock market (α_{21rd} and β_{21rd}) in equation (11). Exchange rate regime is significant in the transmission volatility mechanism from the foreign exchange market to the local stock market volatility in all cases except India (Likelihood ratio test results are in Table 14). The difference in coefficients capturing volatility transmission from the foreign exchange to the stock market including *RD* ($\alpha_{21}+\alpha_{21rd}$, $\beta_{21}+\beta_{21rd}$) and excluding *RD* (α_{21},β_{21}), is in Table 15. A positive difference, or $[\alpha_{21}+\alpha_{21rd}]^2+[\beta_{21}+\beta_{21rd}]^2 > \alpha_{21}^2+\beta_{21}^2$, implies that higher volatility spillovers are associated with more flexible exchange rate regimes and a negative difference the opposite. For the majority of countries in our sample, more flexible exchange rate regimes are associated with higher volatility spillovers between the foreign exchange and stock market: this is the case for six of ten emerging economies (Brazil, Venezuela, India, Korea, Pakistan and Thailand).

6. Conclusion

The aim of this paper is to investigate bi-directional return and volatility spillovers between the stock market and the foreign exchange market of twelve emerging economies. In addition to the emerging stock and foreign exchange markets, the model incorporates spillovers from the global and regional stock market.

Our analysis shows that there is strong evidence of bidirectional causality in variance between the foreign exchange market and stock market in all emerging economies but Colombia. Global and regional stock markets also contribute significantly to volatility spillovers.

Using the notion of shift contagion, the Asian crisis has had a significant effect on the volatility transmission mechanism between the foreign exchange market and the emerging stock market (in both directions). In addition, more flexible exchange rate regimes are associated with higher volatility spillovers between the foreign exchange and stock market for the majority of emerging economies in our sample.

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APPENDIX

Conditional Variance Equations

The conditional variance equation of local stock market returns ($h_{11,t}$) is

$$\begin{aligned} h_{11,t} &= c_{11}^2 + a_{11}^2 e_{1,t-1}^2 + a_{21}^2 e_{2,t-1}^2 + a_{31}^2 e_{3,t-1}^2 + a_{41}^2 e_{4,t-1}^2 \\ &+ 2a_{11}a_{21}e_{1,t-1}e_{2,t-1} + 2a_{11}a_{31}e_{1,t-1}e_{3,t-1} + 2a_{21}a_{31}e_{2,t-1}e_{3,t-1} \\ &+ 2a_{11}a_{41}e_{1,t-1}e_{4,t-1} + 2a_{21}a_{41}e_{2,t-1}e_{4,t-1} + \beta_{11}^2 h_{11,t-1} + \beta_{21}^2 h_{22,t-1} \\ &+ \beta_{31}^2 h_{33,t-1} + \beta_{41}^2 h_{44,t-1} + 2\beta_{11}\beta_{21}h_{12,t-1} + 2\beta_{11}\beta_{31}h_{13,t-1} \\ &+ 2\beta_{21}\beta_{31}h_{23,t-1} + 2\beta_{11}\beta_{41}h_{14,t-1} + 2\beta_{21}\beta_{41}h_{24,t-1} \end{aligned} \tag{A1}$$

The conditional variance equation of foreign exchange market returns ($h_{22,t}$) is

$$\begin{aligned} h_{22,t} &= (c_{12}^2 + c_{22}^2) + a_{22}^2 e_{2,t-1}^2 + a_{12}^2 e_{1,t-1}^2 + a_{32}^2 e_{3,t-1}^2 + a_{42}^2 e_{4,t-1}^2 \\ &+ 2a_{12}a_{22}e_{1,t-1}e_{2,t-1} + 2a_{22}a_{32}e_{2,t-1}e_{3,t-1} + 2a_{12}a_{32}e_{1,t-1}e_{3,t-1} \\ &+ 2a_{22}a_{42}e_{2,t-1}e_{4,t-1} + 2a_{12}a_{42}e_{1,t-1}e_{4,t-1} + \beta_{12}^2 h_{11,t-1} + \beta_{22}^2 h_{22,t-1} \\ &+ \beta_{32}^2 h_{33,t-1} + \beta_{42}^2 h_{44,t-1} + 2\beta_{12}\beta_{22}h_{12,t-1} + 2\beta_{22}\beta_{32}h_{23,t-1} \\ &+ 2\beta_{12}\beta_{32}h_{13,t-1} + 2\beta_{22}\beta_{42}h_{24,t-1} + 2\beta_{12}\beta_{42}h_{14,t-1} \end{aligned} \tag{A2}$$

The conditional variance equation of global market returns ($h_{33,t}$) is

$$h_{33,t} = (c_{13}^2 + c_{23}^2 + c_{33}^2) + a_{33}^2 e_{3,t-1}^2 + \beta_{33}^2 h_{33,t-1}$$

(A3)

The conditional variance equation of regional market returns ($h_{44,t}$) is

$$h_{44,t} = (c_{14}^2 + c_{24}^2 + c_{34}^2 + c_{44}^2) + a_{44}^2 e_{4,t-1}^2 + \beta_{44}^2 h_{44,t-1}$$

(A4)

In Section 5.3, we considered a model that incorporates a dummy variable *AD* to capture possible shifts in the volatility transmission mechanism, following the onset of the Asian financial crisis. In this case, the conditional variance equation of local stock market returns ($h_{11,t}$) changes to

$$\begin{aligned}
h_{11,t} &= c_{11}^2 + a_{11}^2 e_{1,t-1}^2 + (a_{21} + a_{21ad}.AD)^2 e_{2,t-1}^2 + a_{31}^2 e_{3,t-1}^2 + a_{41}^2 e_{4,t-1}^2 \\
&+ 2a_{11}(a_{21} + a_{21ad}.AD) e_{1,t-1} e_{2,t-1} + 2a_{11} a_{31} e_{1,t-1} e_{3,t-1} \\
&+ 2(a_{21} + a_{21ad}.AD) a_{31} e_{2,t-1} e_{3,t-1} + 2a_{11} a_{41} e_{1,t-1} e_{4,t-1} \\
&+ 2(a_{21} + a_{21ad}.AD) a_{41} e_{2,t-1} e_{4,t-1} + \beta_{11}^2 h_{11,t-1} + (\beta_{21} + \beta_{21ad}.AD)^2 h_{22,t-1} \\
&+ \beta_{31}^2 h_{33,t-1} + \beta_{41}^2 h_{44,t-1} + 2\beta_{11}(\beta_{21} + \beta_{21ad}.AD) h_{12,t-1} + 2\beta_{11}\beta_{31} h_{13,t-1} \\
&+ 2(\beta_{21} + \beta_{21ad}.AD)\beta_{31} h_{23,t-1} + 2\beta_{11}\beta_{41} h_{14,t-1} \\
&+ 2(\beta_{21} + \beta_{21ad}.AD)\beta_{41} h_{24,t-1}
\end{aligned}$$

(A21)

The conditional variance equation of foreign exchange market returns ($h_{22,t}$) changes to

$$
\begin{aligned}
h_{22,t} &= (c_{12}^2 + c_{22}^2) + a_{22}^2 e_{2,t-1}^2 + (a_{12} + a_{12ad}.AD)^2 e_{1,t-1}^2 + a_{32}^2 e_{3,t-1}^2 \\
&+ a_{42}^2 e_{4,t-1}^2 + 2(a_{12} + a_{12ad}.AD) a_{22} e_{1,t-1} e_{2,t-1} + 2 a_{22} a_{32} e_{2,t-1} e_{3,t-1} \\
&+ 2(a_{12} + a_{12ad}.AD) a_{32} e_{1,t-1} e_{3,t-1} + 2 a_{22} a_{42} e_{2,t-1} e_{4,t-1} \\
&+ 2(a_{12} + a_{12ad}.AD) a_{42} e_{1,t-1} e_{4,t-1} + \beta_{22}^2 h_{22,t-1} \\
&+ (\beta_{12} + \beta_{12ad}.AD)^2 h_{11,t-1} + \beta_{32}^2 h_{33,t-1} + \beta_{42}^2 h_{44,t-1} \\
&+ 2(\beta_{12} + \beta_{12ad}.AD) \beta_{22} h_{12,t-1} + 2 \beta_{22} \beta_{32} h_{23,t-1} \\
&+ 2(\beta_{12} + \beta_{12ad}.AD) \beta_{32} h_{13,t-1} + 2 \beta_{22} \beta_{42} h_{24,t-1} \\
&+ 2(\beta_{12} + \beta_{12ad}.AD) \beta_{42} h_{14,t-1}
\end{aligned}
\tag{A22}
$$

The conditional variance equations for global and regional stock returns remain the same as (A3) and (A4) above.

In Section 5.4, we considered a model that incorporates a dummy variable *RD* to capture possible shifts in the volatility transmission mechanism from the choice of exchange rate regime. In this case, the conditional variance ($h_{11,t}$) equation of emerging stock market returns changes to

$$
\begin{aligned}
h_{11,t} &= (c_{11} + \xi_{11}.RD)^2 + a_{11}^2 e_{1,t-1}^2 + (a_{21} + a_{21rd}.RD)^2 e_{2,t-1}^2 \\
&+ a_{31}^2 e_{3,t-1}^2 + a_{41}^2 e_{4,t-1}^2 + 2 a_{11} (a_{21} + a_{21rd}.RD) e_{1,t-1} e_{2,t-1} + 2 a_{11} a_{31} e_{1,t-1} e_{3,t-1} \\
&+ 2(a_{21} + a_{21rd}.RD) a_{31} e_{2,t-1} e_{3,t-1} + 2 a_{11} a_{41} e_{1,t-1} e_{4,t-1} \\
&+ 2(a_{21} + a_{21rd}.RD) a_{41} e_{2,t-1} e_{4,t-1} + \beta_{11}^2 h_{11,t-1} + (\beta_{21} + \beta_{21rd}.RD)^2 h_{22,t-1} \\
&+ \beta_{31}^2 h_{33,t-1} + \beta_{41}^2 h_{44,t-1} + 2 \beta_{11} (\beta_{21} + \beta_{21rd}.RD) h_{12,t-1} + 2 \beta_{11} \beta_{31} h_{13,t-1} \\
&+ 2(\beta_{21} + \beta_{21rd}.RD) \beta_{31} h_{23,t-1} + 2 \beta_{11} \beta_{41} h_{14,t-1} \\
&+ 2(\beta_{21} + \beta_{21rd}.RD) \beta_{41} h_{24,t-1}
\end{aligned}
\tag{A31}
$$

The return and variance equations for the foreign exchange, global and regional stock returns remain the same as in equation (1) and (A2), (A3) and (A4) above.

Table 1:

Optimal lag order (p*) selection for the quarto VAR(p) model in equation (1)

	Minimum values of the BIC	Optimal order p* for VAR(p)
Argentina	22.79033	1
Brazil	21.04861	2
Chile	17.49199	1
Colombia	17.82509	1
Mexico	18.24711	1
Venezuela	20.73464	1
India	16.83782	1
Korea	18.28559	1
Malaysia	17.24406	1
Pakistan	17.14194	1
Philippines	17.70300	1
Thailand	17.74255	1

Note: Similar results apply to the restricted VAR discussed in Section 3.

Table 2:

Likelihood Ratio test for the significance of the regional market in the mean and variance equations of stock and foreign exchange returns

	Mean Equation $\delta_{14}=\delta_{24}=0$	**Variance Equation** $\alpha_{14}=\alpha_{24}=0$ **and** $\beta_{14}=\beta_{24}=0$
Argentina	245.0*	225.3*
Brazil	8.1**	169.6*
Chile	2.6	53.7*
Colombia	6.6**	0.7
Mexico	6.2**	18.0*
Venezuela	78.3*	14.7*
India	3.4	30.7*
Korea	65.7*	88.6*
Malaysia	189.8*	57.6*
Pakistan	163.7*	8.9*
Philippines	2.8	87.3*
Thailand	0.4	23.9*

Note: LR test is reported on the basic quarto-variate model in equations (1) and (4). Critical values for 1%, 5%, and 10% are 9.210, 5.991 and 4.605 respectively. *, **, and *** denote significance at 1%, 5%, and 10% respectively.

Table 3

Descriptive statistics

	Mean	Median	Max	Min	S.D.	Skew.	Kurt.
Stock Market Return							
Argentina	1.0508	0.6798	76.0548	-40.3150	7.4592	2.5150	22.5360
Brazil	1.8844	1.3216	30.0647	-45.7452	6.3842	0.1715	7.8099
Chile	0.4008	0.3444	11.0873	-9.6232	2.6445	0.0075	4.6003
Colombia	0.5335	0.3983	24.3530	-20.1252	3.3248	0.3972	9.8645
Mexico	0.4692	0.6487	15.5995	-16.1141	3.2421	-0.2862	4.8135
Venezuela	0.6809	0.2957	26.7017	-22.2842	4.7410	0.5516	6.7349
India	0.3178	0.4669	16.4980	-15.7825	3.7120	-0.1224	4.9410
Korea	0.1037	0.0847	18.1568	-19.8756	4.2972	-0.0604	5.3928
Malaysia	0.1372	0.2476	28.0922	-19.5575	3.3718	0.1718	11.7761
Pakistan	0.3574	0.5647	14.6091	-18.2677	4.0937	-0.5359	5.1933
Philippines	0.1403	0.1916	15.5985	-24.0543	3.5362	-0.6089	8.1788
Thailand	0.1207	0.2034	23.8841	-26.7491	4.5247	-0.0431	6.8142
Foreign Exchange Return							
Argentina	-0.7351	0.0000	19.2609	-81.1227	5.1945	-8.0672	91.0087
Brazil	-1.5192	-0.2305	11.2940	-21.4112	3.5555	-1.6421	7.9803
Chile	-0.0708	-0.0930	4.6821	-5.4964	1.1086	-0.1407	6.9086
Colombia	-0.1685	-0.1515	9.1771	-13.1290	1.2541	-0.8686	21.5563
Mexico	-0.1448	-0.0369	7.0982	-30.0383	1.6163	-7.3145	123.3732
Venezuela	-0.4674	-0.1308	18.4483	-71.3371	3.7359	-9.3613	164.9412
India	-0.1027	0.0000	5.0636	-8.4327	0.7818	-3.7244	44.1789
Korea	-0.0408	0.0000	13.5989	-33.0534	1.6812	-7.2133	158.6227
Malaysia	-0.0206	0.0000	10.0095	-14.9639	1.1856	-1.2202	53.0337
Pakistan	-0.1348	-0.0014	4.6305	-8.3536	0.7964	-4.5922	45.0758
Philippines	-0.0765	0.0000	7.6693	-12.7833	1.2766	-1.7758	23.6151
Thailand	-0.0289	0.0000	9.6774	-11.8821	1.3186	-1.4669	27.9442
Global Stock Market Return							
S&P500 returns	0.1506	0.2772	7.4923	-12.3304	2.0770	-0.4834	5.7827

Table 4

Descriptive statistics for regional market returns (NTWR)

NTWR	Mean	Median	Max	Min	S.D.	Skew.	Kurt.
Argentina	1.4617	1.1466	22.7112	-28.7426	4.7676	0.1696	6.4020
Brazil	0.7169	0.6518	32.9018	-14.6038	4.1864	1.2170	10.9568
Chile	1.2273	1.1389	25.6183	-22.1666	4.2625	0.4553	7.0868
Colombia	0.8983	0.8195	16.6926	-16.2496	3.1655	0.1700	5.8914
Mexico	1.3009	1.0262	23.6797	-19.9142	3.8799	0.7019	7.4905
Venezuela	1.1041	0.9529	20.8108	-14.3073	3.2177	0.3884	6.9215
India	0.1410	0.1896	11.6961	-12.9359	2.7841	-0.4114	5.7469
Korea	0.1643	0.3044	14.7712	-14.2339	2.5797	-0.6107	7.7179
Malaysia	0.1378	0.1257	13.6257	-13.2886	2.8929	-0.1497	5.6810
Pakistan	0.1360	0.1601	15.3255	-12.4684	2.8118	-0.1828	5.4072
Philippines	0.1354	0.1598	11.8721	-13.9792	3.0017	-0.2844	5.8438
Thailand	0.1329	0.1800	12.9019	-11.7614	2.5343	-0.3609	5.6369

Table 5

Causality-in-mean and Causality-in-variance tests

	Panel A: Causality in the mean (spillovers in mean)						Panel B: Causality in variance (spillovers in volatility)					
	Local emerging stock market			Foreign Exchange Market (FX)			Local emerging stock market			Foreign Exchange Market (FX)		
	No return spillovers from FX market	No return spillovers from the global market	No return spillovers from the regional market	No return spillovers from local stock market	No return spillovers from global market	No return spillovers from regional market	No spillovers from FX market	No spillovers from global market	No spillovers from regional market	No spillovers from local stock market	No spillovers from global market	No spillovers from regional market
	δ_{12}= 0	**δ_{13}= 0**	**δ_{14}= 0**	**δ_{21}= 0**	**δ_{23}= 0**	**δ_{24}= 0**	$\alpha_{21}=\beta_{21}=0$	$\alpha_{31}=\beta_{31}=0$	$\alpha_{41}=\beta_{41}=0$	$\alpha_{12}=\beta_{12}=0$	$\alpha_{32}=\beta_{32}=0$	$\alpha_{42}=\beta_{42}=0$
ARG	0.08	-0.06	-0.03	-0.19	0.01	0.01						
	[0.57]	[0.41]	[0.44]	[0.40]	[0.03]**	[0.28]	392.6*	74.7*	16.2*	160.7*	286.7*	7.4**
BRA	-0.54	0.25	0.08	-0.06	-0.04	0.03	222.4*	95.3*	42.1*	90.9*	600.1*	249.5*
	[0.00]*	[0.04]**	[0.19]	[0.03]*	[0.54]	[0.68]						
CHI	0.08	0.02	0.01	0.01	0.01	0.01						
	[0.17]	[0.58]	[0.67]	[0.83]	[0.31]	[0.02]**	0.1	0.7	10.4*	228.9*	0.5	51.1*
COL	-0.10	-0.02	0.07	0.05	0.0003	0.01						
	[0.11]	[0.55]	[0.01]*	[0.34]	[0.98]	[0.55]	3.9	2.4	1.8	2.3	2.0	4.0
MEX	-0.06	-0.03	0.05	-0.10	-0.004	-0.003						
	[0.15]	[0.41]	[0.00]*	[0.02]**	[0.81]	[0.59]	380.9*	5.2***	15.2*	27.4*	0.9	13.5*
VEN	-0.07	-0.12	0.28	-0.11	-0.02	0.05						
	[0.01]*	[0.01]*	[0.00]*	[0.08]	[0.24]	[0.06]	348.4*	19.3*	15.6*	3.2	41.9*	4.0
IND	-0.21	0.05	0.05	-0.01	-0.0004	-0.003						
	[0.33]	[0.32]	[0.26]	[0.86]	[0.95]	[0.72]	19.7*	0.1	7.4**	15.3*	136.1*	0.4
KOR	-0.27	0.05	0.15	0.03	0.005	0.002						
	[0.00]*	[0.38]	[0.00]*	[0.52]	[0.46]	[0.76]	61.0*	29.0*	96.4*	66.9*	26.9*	175.0*
MAL	0.14	0.04	0.10	0.08	-0.002	0.002						
	[0.38]	[0.28]	[0.02]**	[0.28]	[0.00]*	[0.00]*	23.7*	44.0*	118.8*	45.1*	14.2*	18.2*
PAK	-0.18	0.03	0.13	-0.38	-0.04	0.05						
	[0.33]	[0.60]	[0.01]*	[0.00]*	[0.02]**	[0.00]*	90.0*	295.5*	53.0*	28.0*	55.6*	69.1*
PHIL	0.25	0.06	0.06	-0.08	-0.002	0.01						
	[0.03]**	[0.12]	[0.28]	[0.18]	[0.88]	[0.51]	196.1*	39.2*	65.7*	120.0*	91.3*	152.1*
THAI	-0.31	0.21	-0.02	-0.01	0.02	-0.004						
	[0.00]*	[0.00]*	[0.72]	[0.85]	[0.01]*	[0.46]	17.9*	11.3*	78.1*	6.9**	7.8**	17.8*

Note: (Panel A) Robust estimated coefficients and p-values in [ ] of the conditional mean model in equation (1). We reject the null at the 1%, 5%, and 10% denoted by * ,**, and *** respectively. The asymptotic normal distribution critical values are 2.54, 1.96 and 1.64. (Panel B) The Likelihood Ratio test is performed in the conditional variance model in equation (5) and in equations (A1)-(A2) in the Appendix. The critical values of the chi-square distribution with two degrees of freedom are 9.210, 5.991 and 4.605. We reject the null at the 1%, 5%, and 10% denoted by *,**, and *** respectively. Restrictions related to the δ coefficients refer to single parameter tests for all countries except Brazil, given VAR(2) for this country. For Brazil the sum of the two AR(2) coefficients is reported and the corresponding Wald test for their joint significance is performed.

Table 6

Causality in variance tests among the foreign exchange market (FX), the local stock market (ESM), global stock market (MM) and regional stock market (NTWR)

From:	FX & ESM	MM	NTWR
To:	FX & ESM	ESM & FX	ESM & FX
Argentina	Bi-directional	MM to ESM & FX	NTWR to ESM & FX
Brazil	Bi-directional	MM to ESM & FX	NTWR to ESM & FX
Chile	ESM to FX	No relationship	NTWR to ESM & FX
Colombia	No relationship	No relationship	No relationship
Mexico	Bi-directional	No relationship	NTWR to ESM & FX
Venezuela	FX to ESM	MM to ESM & FX	NTWR to ESM
India	Bi-directional	MM to FX	NTWR to ESM
Korea	Bi-directional	MM to ESM & FX	NTWR to ESM & FX
Malaysia	Bi-directional	MM to ESM & FX	NTWR to ESM & FX
Pakistan	Bi-directional	MM to ESM & FX	NTWR to ESM & FX
Philippines	Bi-directional	MM to ESM & FX	NTWR to ESM & FX
Thailand	Bi-directional	MM to ESM & FX	NTWR to ESM & FX

Note: The Likelihood Ratio tests are performed in models in equation (5) and equations (A1)-(A2) in the appendix. The direction of causality is reported.

Table 7

Global vs. Regional Market volatility effects: comparison of coefficients

	Joint tests	
	Effect of global market to local stock market = Effect of regional market to local stock market	**Effect of global market to FX market = Effect of regional market to FX market**
	$\alpha_{31} = \alpha_{41} = \beta_{31} = \beta_{41} = 0$	$\alpha_{32} = \alpha_{42} = \beta_{32} = \beta_{42} = 0$
Argentina	+	+
	[0.00]*	[0.00]*
Brazil	-	+
	[0.00]*	[0.00]*
Chile	-	-
	[0.05]**	[0.73]
Colombia	-	+
	[0.83]	[0.26]
Mexico	-	+
	[0.01]**	[0.00]*
Venezuela	-	-
	[0.02]**	[0.17]
India	-	+
	[0.06]***	[0.77]
Korea	+	-
	[0.00]*	[0.11]
Malaysia	-	-
	[0.00]*	[0.02]**
Pakistan	+	-
	[0.02]**	[0.00]*
Philippines	+	-
	[0.27]	[0.00]*
Thailand	-	-
	[0.00]*	[0.00]*

Note: The reported number in [ ] is the p-value of a Wald test for the null of jointly equal coefficients for the model in equation (5) and (A1)-(A2) in the appendix. "+" means that $\sum((\alpha_{31}-\alpha_{41}) + (\beta_{31}-\beta_{41})) > 0$ i.e. the global effect is larger in magnitude than the regional effect and "–" means that $\sum((\alpha_{31}-\alpha_{41}) + (\beta_{31}-\beta_{41})) < 0$ i.e. the regional effect is larger than the global effect.

Table 8

Significance tests for inclusion of the Asian crisis dummy variable (AD) in the conditional variance equation

	LR test statistic
Argentina	733.7*
Brazil	81.8*
Chile	33.9*
Colombia	93.5*
Mexico	171.4*
Venezuela	34.8*
India	115.1*
Korea	86.5*
Malaysia	214.4*
Pakistan	46.3*
Philippines	348.2*
Thailand	190.3*

Note: Significance at 1%, 5%, and 10% levels is denoted by *, **, and *** respectively.

Table 9
Causality in Variance: The Asian crisis model

	No shift contagion from FX market after Asian crisis $\alpha_{21\alpha d}=\beta_{21\alpha d}=0$	No shift contagion from stock market after Asian crisis $\alpha_{12\alpha d}=\beta_{12\alpha d}=0$	No spillover from FX market $\alpha_{21}=\beta_{21}=\alpha_{21\alpha d}=\beta_{21\alpha d}=0$	No spillover from stock market $\alpha_{12}=\beta_{12}=\alpha_{12\alpha d}=\beta_{12\alpha d}=0$
Argentina	678.2*	147.2*	933.1*	87.7*
Brazil	83.3*	70.8*	172.8*	13.3*
Chile	52.0*	94.4*	27.6*	121.6*
Colombia	2.0	23.3*	0.7	79.5*
Mexico	108.5*	49.3*	446.0*	72.7*
Venezuela	79.6*	9.6*	447.6*	271.7*
India	64.1*	95.3*	55.2*	21.6*
Korea	166.5*	120.4*	63.2*	202.3*
Malaysia	16.9*	84.4*	36.8*	41.2*
Pakistan	79.5*	239.6*	122.2*	250.3*
Philippines	205.7*	151.5*	388.8*	198.6*
Thailand	148.5*	13.0*	21.6*	48.2*

Note: Significance at 1%, 5%, and 10% levels is denoted by *, **, and *** respectively.

Table 10
What is the sign of the difference in the estimated volatility spillovers pre and post Asian crisis?

	$[\alpha_{12}+\alpha_{12\alpha d}]^2+[\beta_{12}+\beta_{12\alpha d}]^2$ minus $\alpha_{12}^2+\beta_{12}^2$	$[\alpha_{21}+\alpha_{21\alpha d}]^2+[\beta_{21}+\beta_{21\alpha d}]^2$ minus $\alpha_{21}^2+\beta_{21}^2$
Argentina	-	+
Brazil	-	+
Chile	+	+
Colombia	+	+
Mexico	+	+
Venezuela	+	-
India	-	-
Korea	-	+
Malaysia	+	+
Pakistan	-	-
Philippines	-	+
Thailand	-	-

Note: +/- denotes the sign of the difference of the estimated coefficients in equations (A1)-(A2) and (A21)-(A22). "+" means that $[\alpha_{12}+\alpha_{12\alpha d}]^2+[\beta_{12}+\beta_{12\alpha d}]^2-\alpha_{12}^2-\beta_{12}^2>0$ or volatility spillovers increased following the onset of the Asian crisis and "–" means $[\alpha_{12}+\alpha_{12\alpha d}]^2+[\beta_{12}+\beta_{12\alpha d}]^2-\alpha_{12}^2-\beta_{12}^2<0$ or volatility spillovers decreased following the onset of the Asian crisis.

Table 11

Exchange Regime Classification Scheme: Fixed/Intermediate/Flexible

The different regime classification codes are:		
1	• No separate legal tender	
1	• Pre announced peg or currency board arrangement	Fixed [RD=1]
1	• Pre announced horizontal band that is narrower than or equal to +/-2%	
1	• De facto peg	
2	• Pre announced crawling peg	
2	• Pre announced crawling band that is narrower than or equal to +/-2%	
2	• De factor crawling peg	
2	• De facto crawling band that is narrower than or equal to +/-2%	Intermediate [RD=2]
3	• Pre announced crawling band that is wider than or equal to +/-2%	
3	• De facto crawling band that is narrower than or equal to +/-5%	
3	• Moving band that is narrower than or equal to +/-2% (i.e., allows for both appreciation and depreciation over time)	
3	• Managed floating	
4	• Freely floating	
5	• Freely falling	Flexible [RD=3]
6	• Dual market in which parallel market data is missing.	

Source: Ilzetzki, Reinhart and Rogoff (2011)

Table 12

Exchange Rate Regime Classification of Various Emerging Economies

Latin America			Asia		
Argentina	1/1989-3/1991	3	India	1/1989-7/1991	2
	4/1991-11/2001	1		8/1991-6/1995	1
	12/2001-1/2003	3		7/1995-8/2008	2
	2/2003-8/2008	2	Korea	1/1989-11/1997	2
Brazil	1/1989-3/1989	1		12/1997-6/1998	3
	4/1989-6/1994	3		7/1998-8/2008	2
	7/1994-1/1999	2	Malaysia	1/1989-7/1997	2
	2/1999-8/1999	3		8/1997-9/1998	3
	9/1999- 8/2008	2		10/1998-2/2008	1
Chile	1/1989-8/2008	2		3/2008-8/2008	2
Colombia	1/1989-8/2008	2	Pakistan	4/1991– 2/2008	2
				3/2008-7/2008	3
				8/2008	2
Mexico	1/1989-4/1992	2	Philippines	1/1989-8/1995	2
	5/1992-1/1994	1		9/1995-6/1997	1
	2/1994-12/1994	2		7/1997-11/1997	3
	1/1995-3/1996	3		12/1997-8/2008	2
	4/1996-8/2008	2	Thailand	1/1989-6/1997	1
Venezuela	1/1989-3/1990	3		7/1997-12/1997	3
	4/1990-9/1992	2		1/1998-8/2008	2
	10/1992-6/1996	3			
	7/1996-1/2003	2			
	2/2003-4/2007	1			

Source: The exchange rate regime data are from Ilzetzki, Reinhart and Rogoff (2011).

Table 13

Exchange rate regime choice as a shift in the constant of the mean return equation and variance of returns equation

	ARG	BRA	MEX	VEN	IND	KOR	MAL	PAK	PHIL	THAI
Mean Returns	0.0691	1.8548	0.4559	-0.9932	0.3283	0.0090	0.0534	-0.2769	0.2158	0.2279
(w_1)	[0.816]	[0.005]*	[0.137]	[0.000]*	[0.209]	[0.994]	[0.702]	[0.719]	[0.380]	[0.300]
Conditional Volatility	0.0421	3.6768	0.0680	0.2525	0.2515	-1.486	0.0645	0.8856	1.0333	-0.6323
(ξ_{11})	[0.834]	[0.000]*	[0.736]	[0.385]	[0.042]*	[0.161]	[0.698]	[0.000]*	[0.000]*	[0.000]*

Note: Reported values are the estimated coefficients and corresponding *p*-values are in [ ] for the model in equations (10)-(11).

Table 14

Testing volatility causality in the presence of Exchange Regime Classification

	Volatility causality from the FX market to the local stock market volatility $\alpha_{21rd}=\beta_{21rd}=0$
Argentina	1705.1*
Brazil	16.3*
Mexico	273.1*
Venezuela	861.7*
India	1.6
Korea	79.9*
Malaysia	4.7***
Philippines	455.4*
Pakistan	240.3*
Thailand	51.2*

Note: The Likelihood Ratio test examines the null of no causality in variance from foreign exchange to stock market volatility in equation (A31) in the Appendix. Significance at the 1%, 5%, and 10% level is denoted by *, **, and *** respectively.

Table 15

The size of the effect of exchange regime classification on the dynamics of volatility

	$[\alpha_{21}+\alpha_{21rd}]^2+[\beta_{21}+\beta_{21rd}]^2$ minus $\alpha_{21}{}^2+\beta_{21}{}^2$
Argentina	-
Brazil	+
Mexico	-
Venezuela	+
India	+
Korea	+
Malaysia	-
Pakistan	+
Philippines	-
Thailand	+

Note: +/- denotes the sign of the difference in estimated coefficients of the model in equation (A31). "+" means that $[\alpha_{21}+\alpha_{21rd}]^2+[\beta_{21}+\beta_{21rd}]^2-\alpha_{21}{}^2-\beta_{21}{}^2>0$ or more flexible exchange regimes are associated with increased volatility spillovers and "–" means $[\alpha_{21}+\alpha_{21rd}]^2+[\beta_{21}+\beta_{21rd}]^2-\alpha_{21}{}^2-\beta_{21}{}^2<0$ i.e. or more flexible exchange regimes are associated with reduced volatility spillovers.