Market Deregulations, Volatility and Spillover Effects: Evidence from Emerging Stock Markets

Duc Khuong NGUYEN[♣]

CERAG-UMR 5820 CNRS
University of Grenoble II, 150 rue de la Chimie, BP 47, 38040 Grenoble, Cedex 9, France.
E-mail: duc.nguyen@upmf-grenoble.fr.
Tel.: +33 (0)1 40 78 83 76

[♣] I am grateful to the Professor Patrice Fontaine for his helpful comments and guidance throughout this research.

Market Deregulations, Volatility and Spillover Effects: Evidence from Emerging Stock Markets

Abstract. This paper investigates the impact of stock market liberalizations on the volatility of emerging markets and volatility spillover effects between these markets and stock markets of the United Stated and Japan. First, our results reinforce common findings of financial literature in that emerging markets tend to generate higher volatility than developed markets. Moreover, some of the sudden changes in emerging market volatility appeared to be closely coincided with financial liberalizations. However, when we explicitly test the relationships between financial liberalization and volatility using regression analysis, we found conflicting results about the sign of financial liberalization effects. Second, we found that stock volatility is substantially transmitted among sample markets, especially between emerging markets of the same geographical location. It is also demonstrated that the multilateral transmission of volatility only increases slightly after liberalization programs. Finally, it is worth notifying that shock to stock volatility in emerging markets rather than that in the US and Japan is a dominant source of return variability for sample markets.

Key words: International Finance, Financial Liberalizations, Volatility Spillover, Emerging Stock Markets

JEL Classification: F3, G15

1. Introduction

The last two decades have been the period of spectacular development in emerging stock markets. Both the market size and level of sophistication have rapidly increased over time[1]. Most would agree that these developments could not be happen without an intensive course of stock market liberalizations undertaken by developing countries in the late 1980s. However, the arrival of 1990s' financial turbulences in emerging markets (e.g., Latin America in 1994; Asia in 1997; Russia in 1998) suggests that market openings might induce financial instability and strengthen the volatility of stock markets through causing institutional changes, asset price bubbles and irregular shifts in economic activities. Under this context, the question of whether market liberalization affects the return volatility in emerging markets has received much attention from finance literature (e.g., Bekaert and Harvey, 1997; Kim and Singal, 2000; and Miles, 2002). However, to date, the debate on this question is still open to any answers.

Recently, several papers are concerned by the volatility linkages between emerging markets and other markets around the world (e.g., Liu and Pan, 1997; and He, 2001).

[1] As recently as in March 2002, the S&P's Emerging Market Databases covers 34 emerging markets and 20 frontier markets which are one-step before obtaining the emerging status, compared to only 24 emerging markets covered in 1985. During the same period, the importance of emerging markets to the world has rapidly increased as well: by 1982 the ratio of emerging markets capitalization to the world market capitalization was only 2.5%, while it stands to 8.5% at the end of 1999 (see, Emerging Stock Markets Factbook 2000, page 19). Specifically, electronic trading systems are installed in many emerging market countries.

Obviously, they are motivated by the increased integration of these markets with the world markets as documented in Bekaert and Harvey (1995), and Carrieri and al. (2002). The growing interest on spillover effects can be also explained by the creation of new financial instruments (e.g., ADR, and Country Funds) in emerging markets and their instantaneous connection with all world marketplaces given by technological advances communications.

This paper will contribute to the above literature in the sense that it analyzes the induced impact of market deregulations on the conditional variance for six of the largest emerging markets of the world (Argentina, Brazil, Chile, South Korea, Mexico and Thailand). It will also investigate the dynamic linkages of volatility between selected emerging markets and two global markets, the US and Japan stock markets. Further, it examine whether market openings impact this international transmission of volatility.

The study is structured as follows. Section 2 offers a brief review of the related literature. Section 3 describes the data and methodology. Section 4 reports and interprets the obtained empirical results. Section 5 discusses the implications of empirical results for foreign portfolio investments and asset pricing formulations in emerging markets, and concludes the paper.

2. Literature Review

Previous studies are divergent about the expected impacts of stock market liberalizations on emerging market volatility. Theoretically, there are a total of three scenarios. First, stock market liberalization may drive up stock volatility. The reason is that the free circulation of capital flows and the speculative positions of foreign investors in domestic markets lead to increasing price changes in emerging markets. Recent crisis during the 1990s constitute plausible proofs of such scenario. Moreover, informational asymmetry between domestic and foreign investors which leads to excessive trading volume is also a considerable source of growth in domestic market volatility. Second, the view that stock market liberalization reduces emerging market volatility is, not at all, unreasonable. It is widely demonstrated that market openings, through leading to the enhancement of transparency, liquidity and thus informational efficiency in emerging markets (e.g., Levine and Zervos, 1998; Kim and Singal, 2000). An important implication of an efficient market is that asset prices will instantaneously incorporate all new information arrived in the market so that there is no or only a small number of trades on financial assets. If emerging markets become more efficient in the aftermath of liberalizations, stock volatility will decline. Finally, market openings may have insignificant impact on emerging market volatility because one may expected that liberalization effects in different directions as above are perfectly compensated.

Empirically, the findings of previous works seem to confirm theoretical anticipations. Bekaert and Harvey (1997), for example, analyze the impact of market openings on conditional volatility in twenty emerging markets and find that, on average, capital market liberalizations do not drive up local market volatility. The analysis of Kim and Singal (2000) indicates that average volatilities of emerging markets are lower in the post-liberalization period than pre-liberalization period. By contrast, the findings of De Santis and Imrohoroglu (1997), and Bekaert and Harvey (2000) suggest that the impact of market openings on the variability of emerging market returns is statistically insignificant or even worthless. Most recently, Miles (2002) shows that market openings has a statistically significant impact in almost three fifths of sample markets, but in most cases, the effect of liberalizations is to raise rather than lower the variance of stock returns. Finally, in a related study, Aggarwal and al. (1999) note that market liberalizations do not cause sudden shifts in emerging markets volatility.

With the growing market integration, both researchers and practitioners have switched their attention to the international transmission of volatility across capital markets. However, the emphasis was manifestly on developed markets (e.g., Masulis and al., 1990; Karolyi, 1995; Leachman and Francis, 1996; and Kearney, 2000). For example, Masulis and al. (1990) propose to study the daily interdependence of asset returns and volatility for three most developed marketplaces, New York, London and Tokyo. The authors report that return volatility changes in Tokyo are significantly influenced by those of New York and London. The transmission of volatility from New York to London is also significant. Karolyi (1995) also explore daily data to evaluate how conditional mean and volatility are transmitted between the US and Canadian stock markets. Using simultaneously multivariate GARCH and Vector AutoRegression (VAR) models, Karolyi (1995) observes that shocks from the US have larger impact on the variability of non-interlisted stock returns than on the variability of cross-listed stocks. Leachman and Francis (1996) apply a methodology quasi-similar to that of Karolyi (1995) to examine the volatility spillover among the G-7 developed countries. They show evidence that volatility in each market is substantially linked to volatility shocks in other markets. They further study the effect of monetary policy coordination on the dynamic transmission of volatility the group of five markets which have signed the Plaza Accord (G-7 minus Canada and Italy).

A few studies are concerned by emerging markets. To start, Liu and Pan (1997) study the volatility spillover effects in the US and four Asian markets including Hong Kong, Singapore, Taiwan and Thailand and found that rather than the US, the Japanese stock market exerts more important impact on the volatilities of Asian markets. Furthermore, the volatility spillover effects are somewhat reinforced after the stock market crash in 1987. He (2001) highlights the volatility spillover effects among the US, Hong Kong and South Korea. The author shows that

South Korea appears to have fewer responses to the return volatility of the US stock markets while the inverse scenario is, however, applied to Hong Kong stock market.

In this paper, we propose to enhance the above empirical literature by using a bivariate AR(1,1)-GARCH(1,1)-in-Mean model which controls for both local and global risk premiums related respectively to the conditional variance of local market index and to the conditional covariance between local and world market indices. The importance of this specification is that it insures the more general dynamics between local and world market volatilities. We then examine the volatility spillover effects among sample markets by using the VAR methodology as in Karolyi (1995). The impact of market liberalizations on emerging market volatility is carried out by testing the relationships between the fitted volatility series and proxy variables for market liberalizations. On the other hand, splitting the studying periods into two sub-samples allows us to understand the impact of market liberalizations on the spillover effects.

3. Data and Empirical Methodology

3.1 Sample Data

This paper investigates the volatility of emerging stock markets and volatility spillovers between these markets and global markets using stock market indices at monthly level. The population of emerging markets includes Argentina, Brazil, Chile, South Korea, Mexico and Thailand. The global markets are represented by the United States and Japan. The data are S&P/IFCG total return indices for emerging markets and MSCI total return indices for two developed markets. The MSCI World index is used as proxy of world markets in order to estimate our bivariate model for conditional volatility. All the data are expressed in US dollar term and obtained from Datastream over the period from January 1976 to January 2003.

Monthly returns for each market are calculated by taking the difference in the natural log of the total return index. As highlighted by Leachman and Francis (1996), the use of monthly returns permit to avoid some potential biases which are involved with high frequency data such as non-synchronous trading and bid-ask effect. This is quite important in the context of emerging markets because they additionally have very thin trading.

The statistical properties of monthly return series are examined and presented in table 1. The findings are similar to those of previous works and indicate that emerging markets are more volatile than well-established markets (see, Claessens and al., 1995; Harvey, 1995). However, we recognize that high risk is not necessarily associated to high returns.

The high significance of skewness and excess kurtosis coefficients coupled with the significance of Jarque-Bera statistics demonstrates that monthly return series are not normally distributed, except for Japan. The results of the Ljung-Box tests for autocorrelation of return levels show evidence of return predictability in only three emerging markets, Chile, Mexico and Thailand. Without the exception of United Stated and MSCI World index, squared returns are serially correlated, indicating the presence of ARCH effects in the distribution of stock returns. As well as the findings of Ljung-Box test, ARCH effects cannot be rejected using Engle (1982)'s test for conditional heteroscedasticity in most of sample markets. Finally, the Augmented Dickey-Fuller (ADF) test indicates that return series are stationary in all markets while rejecting the existence of unit roots.

[INSERT TABLE 1 ABOUT HERE]

Table 2 displays the cross-market unconditional correlation matrix. The results are consistent with the findings of previous studies that emerging markets returns are less correlated among them and with those of developed markets. The highest coefficient of correlation between emerging and developed markets is 0.37 in the case of Mexico and the Unites Stated. Unsurprisingly, stock markets of the US and Japan are the most correlated with the MSCI World index.

[INSERT TABLE 2 ABOUT HERE]

Overall, the diagnostics of monthly data indicate that ARCH effects need to be taken into account in order to capture the leptokurtic distribution and time-varying variances of stock returns. Meanwhile foreign investors may find strong interest of holding emerging market securities based on correlation knowledge, some precautions must be taken because the tradeoffs between risk and returns are not always guaranteed.

3.2 Modeling Stock Market Volatility and Spillover Effects

Financially, stock market volatility refers to the variability of market index prices. It can be unconditionally measured by the variance or standard deviation of market index returns. The evidence that stock market returns exhibit time-varying changes in volatility suggests the usefulness of conditional volatility (e.g., Schwert, 1989). To estimate conditional volatility, some studies based on the Schwert (1989)'s two step procedure while others use various versions of (Generalized) Autoregressive Conditional Heteroscedasticity (ARCH/GARCH) models initially proposed by Engle (1982) and Bollerslev (1986) respectively. A large body of empirical literature (e.g., Bekaert and Harvey, 1997; Aggarwal and al., 1999; Kim and Singal, 2000), pointed out that GARCH type-models successfully characterize stylized empirical regularities of asset returns in emerging markets such as leptokurtic distribution and volatility clustering. Therefore, this study also uses GARCH model for modeling conditional volatility.

Given that returns in stock market index of market i, r_{it}, are generated by an autoregressive process AR(1) as follows:

$$r_{i,t} = \delta_0 + \delta_1 r_{i,t-1} + \varepsilon_{i,t} \qquad (1)$$

Assume in addition that return innovations ε_{it} are normally distributed with a mean of zero and a time-varying variance of h_{it}, a standard GARCH(p,q) can be expressed as:

$$h_{i,t} = \omega + \sum_{j=1}^{p} \alpha_j \varepsilon_{i,t-j}^2 + \sum_{j=1}^{q} \beta_j h_{i,t-j} \qquad (2)$$

Equation 2 suggests that current conditional volatility is a linear function both of the p past innovations (i.e., second term in the right-hand-side) and its own q lagged conditional (i.e., last term in the right-hand-side). Though, we can let the actual conditional volatility to be dependent of the entire history of past return innovations and conditional volatilities, Bollerslev and al. (1992) suggest that a GARCH(1,1) is quite successful in fitting most of financial series.

However, two concerns must be taken into account when modeling conditional volatility of emerging markets returns. First, there is evidence to suggest that emerging equity markets are not fully segmented from the world markets. This implies that domestic market volatility will be affected by world market volatility. A way to achieve this end consists of using a bivariate GARCH(1,1) which allows for both own-market and cross-market dependencies in conditional volatility (see, Engle and Kroner, 1995). This specification is technically advantageous because it guarantees a positive-definite covariance matrix and allows for more general volatility dynamics compared to other alternatives such as Bollerslev (1990)'s constant-correlation model. Second, the theory suggests some kind of relationship between expected returns and risk of financial assets to be guaranteed by financial models. Second, financial theory imposes the condition that, for any particular asset, high risk requires high expected returns must hold. For this purpose, we specify the GARCH-in-mean effects in the return generating equation as in Bollerslev, Engle and Wooldridge (1988). Furthermore, it is reasonable to let the conditional covariance between local and world market indices to enter the mean equation since partially integrated markets will be exposed to world market risk. The coefficients associated with the conditional variance and covariance will have the interpretation of the time-varying local and global risk premiums respectively. Precisely, our empirical model for stock market volatility will be a system of three equations:

$$r_{w,t} = \delta_0 + \delta_1 r_{w,t-1} + \delta_2 h_{w,t} + \varepsilon_{w,t} \quad (3)$$

$$r_{i,t} = \lambda_0 + \lambda_1 r_{i,t-1} + \lambda_2 h_{i,t} + \lambda_3 h_{iw,t} + \varepsilon_{i,t} \quad (4)$$

$$H_t = C_0^{'} C_0 + A_1^{'} \varepsilon_{t-1} \varepsilon_{t-1}^{'} A_1 + B_1^{'} H_{t-1} B_1 \quad (5)$$

Where, $\varepsilon_t = [\varepsilon_{w,t}, \varepsilon_{i,t}]^{'}$, et $\varepsilon_t \sim N(0, H_t)$. Equations 3 and 4 correspond to return generating processes of world and local markets respectively. Equation 5 refers to the conditional volatility process. C_0, A1 and B1 are (2×2) parameter matrices with C_0 upper triangular. $h_{w,t}$ and $h_{i,t}$, respectively the conditional variance of world and local market indices, correspond to the first and second elements in the diagonal of H_t. $h_{iw,t}$ is the element below the diagonal of H_t, expressing the conditional covariance between local and world markets market.

After measuring the stock market volatility, we now turn to study the transmission of volatility across markets. In the literature, the simplest way to achieve this objective consists of adding current and lagged values of volatility series of other countries into volatility equation of the country under consideration as in Liu and Pan (1997). Differently, Karolyi (1995), and Leachman and Francis (1996) employ a VAR model to assess the volatility linkages between the US and Canadian stock markets, and among the G7 markets respectively. In this paper, we apply the later because it permits to handle the mutual effects among sample markets and the part of domestic market volatility that can be attributable other markets included in the system.

In a standard form, a VAR model of order p can be represented by:

$$Y_t = c + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + ... + \beta_p Y_{t-p} + u_t = c + \sum_{s=1}^{p} B_s Y_{t-s} + u_t \quad (6)$$

Where $Y_t = (Y_{1t}, Y_{2t}, ..., Y_{nt})$ is a (n×1) vector of endogenous variables; B_s's are (n×n) matrices of coefficients; c is a (n×1) vector of constants, p is the optimal number of lags, and $u_t = (u_{1t}, u_{2t}, ..., u_{nt})$ is a (n×1) vector of uncorrelated white noises having positive definite covariance matrix $\Sigma = E(u_t u_t^{'})$.

Like a single autoregression model having a moving average representation, a VAR can be written as a vector moving average (VMA) representation. That is, endogenous variables of the VAR model are expressed in term of current and past values of shocks or innovations in each equation (i.e., u_{1t}, u_{2t},…u_{nt}):

$$Y_t = C_t \theta + \sum_{s=0}^{\infty} \Phi_s u_{t-s} \quad (7)$$

Where $C_t\theta$ represents the deterministic part of Y_t. The *i,j*th coefficient of Φ_s indicates the effect of a one unit shock in the *j*th variable on the *i*th variable of Y_t after *s* periods. For example, the instantaneous impact of a one unit shock to Y_{2t} on Y_{1t} is $\Phi_{12}(0)$. After one period, this effect will be $\Phi_{12}(1)$. To obtain the effects of a particular shock to one of the system innovations on the values of the endogenous variables, we need to orthogonalize the innovations in (7) so that they are not correlated. Given that volatility links over sample markets are not governed by any explicit economic theory, the Choleski factorization can be straightforwardly used to get uncorrelated innovations. In this way, the equation (7) can be rewritten in the following form (see, Enders, 1995):

$$Y_t = C_t\theta + \sum_{s=0}^{\infty}\Theta_s v_{t-s} \qquad (8)$$

Where $\Theta_s = \Phi_s G$ and $v_t = G^{-1}u_t$ which satisfy $E(v_t v_t^{'}) = I$. Accordingly, Θ(s) contains the impulse response functions of all endogenous variables when the system is shocked by one variable. It is convenient to note that, from the above equation, we can make further explorations about the dynamic interrelationships among the variables in the system through computing the variance decomposition. The idea is that the movement of a variable in k-step ahead forecast horizon can be decomposed into its own shocks and shocks to the other variables.

It is important to note that, in this paper, endogenous variables Y_1 are monthly stock market volatilities of sample markets which will be obtained from estimating the bivariate AR(1)-GARCH(1,1) model. So that n is set to be equal to eight. In this setting, the mechanism of volatility transmission among markets is effectuated through the presence of past realizations of conditional volatility of all markets in the volatility equation of one particular market.

3.3 Estimation Issues

To obtain the conditional volatility for individual markets included in the sample, we proceed into two steps. First, we estimate the conditional volatility of world market using Equation 3 and a univariate GARCH(1,1) as in Equation 2 and save the results. Second, the system of equations from 3 to 5 is estimated for each of eight markets in the sample imposing the estimated parameters in the first step. This allows us to keep the world market risk to be the same for all markets[2]. The estimation of model parameters is fulfilled by the method of quasi-

[2] The trade-off of using this procedure is between understated standard errors due to the ignorance of the sampling errors in the first estimation step and a large number of markets which can be handled in the study. In fact, a multivariate GARCH is preferred in order to avoid this disadvantage, but the risk is that

maximum likelihood estimation (QMLE) proposed by Bollerslev and Wooldridge (1992). The optimization strategy is based on BFGS algorithm.

The estimated series of conditional volatility for eight markets will serve as inputs for the VAR system. We rely on information criteria such as Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) to determine the optimal number of lags for the VAR model since it is naturally unknown. Accordingly, both the AIC and BIC criterions select the 3-lag model which implies that p is set to three. Hence, the total of free coefficients to be estimated is equal to 200. Since all volatility series are stationary (cf., table 4), we estimate the VAR(3) using OLS method.

4. Empirical Results

4.1 Dynamics of Conditional Volatility

Table 3 reports the estimation results for the conditional variance of the MSCI World index. Panel A shows that none of the coefficients in mean equation is significant at conventional level, implying that world market index is efficient according to the weak-form efficiency. On the other hand, the insignificance of the 'in-mean' parameter provides evidence of the absence of relationships between risk and returns. It is important to note that the volatility of world market index tends to be persistent over time as β is strongly significant. Panels B and C summarize statistics for conditional volatility series and diagnostics of standardized residuals. Notice that the results from Ljung-Box Q-statistic allow us to claim the persistence of volatility.

[INSERT TABLE 3 ABOUT HERE]

Table 4 illustrates estimated parameters and gives a detailed diagnostic of the estimates of stock market volatility for eight individual markets in the sample and standardized residuals. At sight of estimated parameters in mean equations (panel A), we found strong evidence of return predictability from past returns in three markets including Chile, Mexico and Thailand. Similar to the case of world market index, most of the risk-premium parameters related to both conditional variance of local markets and conditional covariance between local and world markets are negative and statistically insignificant. There is only a little evidence of significant impact of conditional covariance on local market returns at 5% level in Brazilian stock market. However, the negative sign of the associated coefficient is difficult to interpret. These findings are partly supported by those of Fontaine and Nguyen (2003) who did not find any significant relationships between stock returns measured in US dollar and volatility in emerging markets using S&P's IFCG total return indices. Similar results are also reached by Baillie and

the estimation of the model is computationally difficult because of the proliferation of parameters to be estimated.

DeGennaro (1990) for the US value-weighted index, and Mougoue and Whyte (1996) for German and French equity markets. Through estimated coefficients of the bivariate GARCH(1,1) are highly significant, they are not reported here for the parsimony of space. They are, however, available on requests addressed to the author.

[INSERT TABLE 4 ABOUT HERE]

Panel B of table 4 provides summary statistics for monthly stock market volatilities. It appears that stock markets of Argentina and Brazil are the most volatile over the estimation period followed by Mexico, Thailand, South Korea and Chile. It is interesting to remark that, on monthly basis, the level of return variability in the less volatile emerging market (i.e., Chile) is six times the volatility of the US stock market and more than two times that of Japanese stock market. In addition, the Ljung-Box statistic test of order twelfth supports the hypothesis of linear dependency in all volatility series, and thus indicates the time-varying persistence of volatility. The stationarity of volatility indices is also examined by the ADF test with intercept and four lags. The results point to the acceptance of stationary series to the detriment of integrated series, implying that there is no need to differentiate them when studying the cross-market volatility relations.

[INSERT FIGURE 1 ABOUT HERE]

Figure 1 depicts the time paths of monthly conditional volatility series. This plot shows that, except for the last three months of 1987, stock markets in the sample are not so volatile during the 1980s. Markets which are the most respondent to the market crash of October 1987 include stock markets of the US, Japan, Thailand, Mexico and Brazil. For example, the typical value of the US conditional variance in November 1987 was about 3.25 percent compared to the mean of only 0.2 percent per month. In the case of Thais stock market, these values are 5.42 percent and 1.5 percent respectively. The Latin American debt crisis of 1982-1983 seems not to generate extreme volatility for emerging markets in the region. The volatility of stock markets in Thailand and South Korea, while appearing to be less affected by the Latin American crisis, was remarkably raised around the Asian financial crisis. Apart from some periods of financial turbulences as above, we found that the increase of stock market volatility seems to be associated with country specific events. Argentina is an interesting case. Indeed, the volatility of this stock market seems to correspond with financial liberalization events as it has been intensified when the exchange rate structure was unified into the Official Fluctuating Free Market Rate, and also when credit controls were abolished at the end of 1976. This market also become greatly volatile prior to its official liberalization dates as presented in column 2 of annex 1. Figure 2 gives a picture of monthly conditional standard deviations (i.e., square root of conditional variance) 5 years before and 5 years after liberalizations for sample emerging markets. As can be observed, Thailand is the only one market that experiences an increase of volatility after liberalizations.

[INSERT FIGURE 2 ABOUT HERE]

The examination of standardized residuals in panel C points out that the specified model is appropriate to fit financial data of sample stock markets. Effectively, the estimated residuals are less correlated than the raw returns both in term of level and squared series (cf., Ljung-Box tests). Only a little evidence of correlation in squared residuals at 5 percent level is found in Argentina. Next, the coefficients of skewness and excess kurtosis are, albeit significant, substantially declined. This indicates that empirical model helps to reduce the departure from normal distribution of monthly returns. The final and most important point to be cited here is the satisfactory feature of bivariate GARCH(1,1) model in capturing volatility dynamics of stock returns as the results show no evidence of ARCH effects in fitted residual series.

4.2 Cross-market Volatility Dependency

Table 5 presents the estimates of model coefficients, $\overline{R}^2$, block F-tests of VAR lags, and the Granger-causality tests for estimated coefficients. An inside view of estimations results brings out that the VAR system allows to satisfactorily explain the dependency of stock market volatility indices. Taking a close look to the adjusted $\overline{R}^2$ statistics, we acknowledge that return volatility in Argentina, Brazil, South Korea, Thailand and Japan are well explained by volatilities in other markets. For these markets, the explanatory power is generally high and ranges from 6.2 percent (Chile) to 52.5 percent (South Korea). The results of block F-tests for causality effects indicate the presence of multilateral spillover effects among sample markets. Consider for example equation corresponding to the volatility of Argentinean stock market. The results indicate that the volatility of this market is Granger-caused by the volatility in Brazilian and Japanese stock markets at conventional levels, but not by other markets. We also found that the conditional volatility of the US stock market significantly causes return volatilities in only one market, Mexico. On the other hand, there is strong evidence of volatility spillovers from Japan to Argentina, Brazil and South Korea, and marginal evidence for Chile. It is worthwhile noting a regional perspective of volatility linkages. In Latin America, we recognize spillover effects from Argentina to Chile, Brazil to Argentina, Brazil to Mexico, and Chile to Mexico while the direction of impact is from Thailand to Korea in Asian pacific-basin region. The geographical proximity might be, in this case, a highly accepted explanation.

One of the most intriguing questions which emerged from the above analysis is whether global markets have significant impacts on emerging markets volatility. For this purpose, we successively interrogate if the US and Japan can be excluded from the VAR system. The null hypothesis considered is that the lags of the US or Japanese volatility series do not enter in the equations for the remaining variables. Since testing this null implies the cross-equation restrictions, the likelihood ratio test is then used. The results indicate that the restrictions are clearly binding because the Chi-squared statistics are highly significant at 1 percent level (cf. table 5). We henceforth conclude that lags of the US and Japan are not block exogenous and play a crucial role in explaining conditional volatilities in emerging markets. The results are in agreement with the findings of several asset pricing frameworks suggesting that emerging markets exhibit some degrees of integration with world markets (see, for example, Bekaert and Harvey, 1995; and Carrieri and al., 2003).

[INSERT TABLE 5 ABOUT HERE]

[INSERT TABLE 6 ABOUT HERE]

Further information about the effect of foreign market volatility on each national stock market is also given by analyzing impulse response functions (IRF). While we have computed the impulse responses from period 1 through 24, only three impulse responses of the periods 1, 6 and 12 are reported in table 6. In effect, each market reacts markedly to the volatility shock in remaining markets of the system. The spillover effect leads to increased volatility for some markets and decreased volatility in others following an original shock to return volatility of one market in the system. The results also indicate that the cross-market volatility responses seem to be very persistent until period 24 (i.e., two years after the beginning of a shock). Emerging market volatility starts to apparently respond to volatility shock in developed markets since the second period. An obvious tendency is that the impulse responses are higher between emerging markets located in the same region, than between emerging markets with geographical distance, and between emerging and developed markets. Looking closely to the developed markets reactions, the results accentuate the fact that they are reasonably sensible to changes in volatility of emerging markets.

[INSERT FIGURES 3, 4 AND 5 ABOUT HERE]

To get a clear picture of these volatility transmissions, we trace the impulse responses of all markets to the volatility shock in the US, Japan and Brazil and present results in figures from 3 to 5. All other graphs are, however, available on request. The figure 3 shows that the responses of sample markets to volatility shocks in the United States are generally small. For example, a one standard deviation shock to the US stock market of about 0.008% at the period 6 implies only a little reaction from foreign markets such as Chile (-0.001%), South Korea (-0.002%), Thailand (-0.003%), and Japan (0.002%). We remark that Argentina and Mexico appear to be the most affected by the stock price changes in the US stock markets, with 0.328% and 0.050% respectively. This evidence shows that the US stock market might not be a dominant source of volatility in emerging markets.

Figure 4 depicts the impulse responses to shocks in stock volatility of Japan. As can be observed, shock to the volatility of Japanese stock market seems result in significant responses of emerging markets, which are apparently more important than that to the US stock market volatility. This typical spillover effect lasts until about 11 periods. From the period 12 (i.e., after one year), the impulse responses tend to decrease and to be comparable to the levels of IRF of emerging markets to the variability of the US stock market. In general, the volatility of most emerging markets moves together with that of Japan. At the period 6 for example, a negative shock to Japanese market generates, except for Mexico, a contemporaneous decline of volatility in all other emerging markets. Argentina is also recognized as the most impacted by the volatility of Japanese market.

Figure 5 depicts the volatility behavior of foreign markets when a shock to volatility occurred in Brazilian stock market. Surprisingly, we found that not only emerging markets, but also the US and Japanese markets have displayed substantial volatility linkages with the Brazilian market. In most markets, the spillover effect from Brazil to sample markets is characterized by reactions in the same direction with original shocks. The volatility of Argentinean stock market, albeit reacts dramatically to volatility shock in Brazil, moves in the opposite direction with the later from period 8. The interregional connection of volatility is clearly illustrated by the extensive reactions of South Korean volatility to volatility shock in Brazil. Within the Latin America region, Mexico shows strong dependence on the volatility of Brazilian market.

As noted early, the forecast error variance (FEV) in one market can be decomposed in parts attributable to the variation of its own shocks and shocks in remaining stock market volatility series. Table 7 presents summarized results. The variance decompositions are provided from column 3 to column 7, and add up to 100 percent in each row. Obviously, there is a rich interaction and causality among the system volatility series. The more interesting information is obtained at the longer steps where the interactions between volatility series start to become felt. In all cases, national market exhibits some degrees of volatility dependence with foreign markets. This may be indication that sample markets are fairly integrated among them.

Below, we offer a country by country detailed discussion about the relative importance of foreign markets in the variability of stock returns in national stock markets:

Argentina: The results from variance decompositions show that the variation of domestic volatility shocks is the main source of volatility in this market. Through the impact from foreign market volatility tends to increase with the length of forecast horizon, it remains quite small. Mexico is the most important contributor to the volatility of Argentina with an explanatory power of about 4.60 percent in the 12-step ahead forecast error variance. Among two mature markets, Japan has greater impact on volatility of Argentina.

Brazil: The own innovations of this market count for about 99.44 and 87.98 percent of its FEV in the one-step and one year ahead horizon respectively. The influence of foreign markets volatility on Brazilian market is in general small, and only becomes sizable from 2-step forecast horizon. At the end of the forecast horizon, foreign markets totalize approximately 12.19 percent of the global return variance in Brazilian stock markets, coming mostly from Mexico with 3.84 percent and Japan with 3.33 percent.

Chile: The FEV of Chilean stock market is substantially impacted by that of Brazil, Mexico and Japan. These three markets help to explain a total of about 15.17 percent of the forecast error variance in Chile, of which about 7.70 percent is originated from Brazil, 2.19 percent from Mexico, and 2.50 percent from Japan. All other markets have negligible effects on the variance of stock returns in the market under consideration.

South Korea: It appears that the FEV of South Korean market volatility is for the most part affected by shock to the innovations of volatility in Brazil which counts for about 14.82 percent in the 1-step ahead forecast. This indicates that the volatility transmission between two markets is quite immediate. In addition, the effect from Brazil increases largely at the longer lags and remains stable around 34 percent since the 9-step ahead forecast horizon. Foreign markets including Thailand, Mexico and Japan are also responsible for the volatility of South Korea. About 16.60 percent of the movement of domestic market volatility is due to these markets.

Mexico: Nearly a half of domestic market volatility is explained by the variation of volatility innovations in foreign markets. Since the 6-step ahead forecast, the most significant impacts in descending order are from Brazil, the US, South Korea and Chile. Variance of Japanese stock market volatility has very limited effect in this case. It must wait until the 12-step ahead forecast to have a contribution of 1.08 percent to the FEV of Mexico.

Thailand: Whereas all other foreign markets have very low or negligibly explanatory power with respect to return volatility in Thailand, shock to volatility of South Korea and Brazil experiences a significant effect on the FEV of Thais stock market. The total part of domestic market volatility explained by oversea markets stands at 26.09 percent in the 12-step ahead forecast. It is interesting to note that South Korea, as geographical neighbor, exerts most impacts on Thais market volatility.

United Stated: The estimate of FEV attributable to domestic markets is, except for the first 6-step ahead forecast, steadily close to 55 percent. This indicates that variations of stock volatility in the US market are widely affected by volatility shock to foreign markets. We note, however that the impact of foreign markets comes essentially from the variability of innovations in Brazilian and Mexican markets. For example, in the 12-step ahead forecast, they explain a largest fraction of about 37.61 percent of the domestic market variance. Each of all other markets has a negligible contribution which does not exceed 3 percent to the FEV of the US.

Japan: Without the exception of the 1-step and 2-step horizons, the stock market of Japan takes only about 18 percent of responsibility for its volatility. The remaining fraction of volatility is due to innovations in foreign markets. In particular, more than a half of the FEV in Japanese market volatility is explained by volatility shock to Brazil, followed by that of Mexico, South Korea, the US and Chile.

To summarize, global markets as presented by the US and Japan do not appear, on the contrary to usual beliefs, to be dominant and robust to emerging markets volatility. In all cases, their impact is lower than 10 percent. Stock markets of the US, Japan, Mexico, South Korea and Thailand receive most of volatility spillover effects from shock to foreign markets. This can be potentially explained by the increasing integration of these markets into the world financial system. It is, in addition, worth noting that Brazil is considered as the most relevant sources of volatility for sample markets because its volatility is largely transmitted to all other markets. We are, however, unable to find a satisfactory explanation behind the dominant role of Brazilian stock market volatility.

4.3 Liberalizations, Volatility and Spillover Effects

In examining emerging markets volatility, two following questions are of strong interests for market participants: Do stock market openings strengthen emerging market volatility? And is the transmission of volatility between emerging and global markets increased after market openings?

Here, we apply the simplest approach commonly used in empirical literature to examine the first issue. It consists of regressing the fitted stock market volatility series on four dummy variables of market liberalization. BEFORE refers to 36 months prior to the official dates of market openings. PRE is 30 months to 6 months prior to official dates of liberalization. DURING corresponds to 6 months prior to 3 months after official liberalizations. POST is 4 months after official liberalizations to the end of estimation period. The dates of market openings for selected emerging markets are official dates provided by Bekaert and Harvey (2000). Table 8 reports obtained results. Globally, the findings suggest a strong relationship between stock market liberalization and market volatility. First, it is observed that conditional volatility significantly increases in Brazil and South Korea by 2.8% and 0.2% per month respectively before liberalizations, while decreases by 2.1% per month in Thailand. Second, the pre-liberalization period is characterized by the rising of volatility in two markets, Thailand and Mexico. Next, the evidence from DURING coefficients indicates that volatility is raised in four markets including Argentina, Brazil, Chile and Thailand. Finally, the results for post-liberalization period are mixed according to POST coefficients. We recognize a monthly increase of about 0.9% in Thais stock market volatility. Specifically, market openings significantly lead to a monthly diminution of 3.9% and 0.1% in the volatility of Argentina and Chile. In three remaining markets, stock volatility does not increase neither decrease in the aftermath of liberalizations. The conflicting findings are, in our opinion, due to country specific liberalization strategies and market microstructure. The results from cross-market regression analysis of all markets provide evidence that, on average, emerging market volatility remains unaffected following stock market liberalizations. In this case, it is likely that liberalization effects are compensated across markets.

To reach an answer to the second question, the VAR model is re-estimated over the pre- and post-liberalization periods. Since most of sample stock markets have been liberalized at the end of 1980s, the pre-liberalization period is chosen to be the sub-period from March 1976 to September 1989, while the post-liberalization refer to the sub-period from October 1989 to January 2003. Table 9 reports the block F-tests and adjusted $\overline{R}^2$ statistics for pre- versus post-liberalization samples. The results indicate that return volatility is largely transmitted among markets in both sample periods. Compared to the pre-liberalization period, there is ample evidence of increased volatility transmission after liberalizations in three emerging markets comprising Argentina, Chile, and Thailand, and both mature markets. In other emerging markets, the explanatory power of the corresponding equations is slightly reduced.

5. Conclusion

In summary, the objective of this paper was to examine the level of volatility in 6 emerging stock markets and volatility dependencies between these markets and two global markets, the US and Japan. We also attempt to relate both issues to stock market liberalizations which have been embarked in emerging countries during the last two decades. The rationale behind this phenomenon is that empirical results of such studies will allow investors to determine the appropriate asset pricing rules in emerging markets, and thus to make optimal portfolio allocations. On the other hand, policymakers can learn more about the effect of their political changes on stock markets, and therefore adopt additional measures in order to insure financial stability if necessary. The most interesting results are the followings:

First, our empirical findings indicate that emerging market volatility is substantially affected by the stock market volatility in the US and Japan as shown by the Granger-causality test and the likelihood ratio test for block exogeneity. This may be indicative of the view that financial liberalization process helps to further integrate emerging markets into the global financial system. Unfortunately, this hypothesis appears to be unverified based on our pre- and post-liberalization analysis because there is no obvious tendency of increasing international linkages between emerging and mature markets in the aftermath of financial liberalizations.

Second, results from impulse response analysis are very intriguing in the sense that emerging markets volatility tends to react more importantly to the structural shocks from other emerging markets, especially emerging markets of the same region than to the structural shocks originated in two developed markets. As a result, we think that geographical proximity and market nature similarities are of paramount importance for volatility spillovers.

Finally, over the six emerging markets examined in this study, we found that market deregulations significantly led to less volatile markets in two cases, and contributed to an increase of stock market volatility in only one case. For the remaining emerging markets, it is shown that the variability of stock market returns was not impacted by the actual financial liberalizations. These country-specific evidences concerning the effect of financial liberalization can be reasonably explained, if not certainly for the most part, by the differences in the liberalization strategies which have been used to liberalize emerging markets, and in the domestic market infrastructure. In addition, our bivariate GARCH-M model for stock market volatility whose goal is to incorporate the influence of global markets on the domestic market volatility can be applied to other emerging markets in order to obtain an categorical answer regarding how market deregulations impact stock market volatility.

References

Aggarwal, R., Inclan, C., and Leal, R., "Volatility in Emerging Stock Markets", Journal of Financial and Quantitative Analysis 34, 33-55, 1999.

Baillie, R., and DeGennaro, R.P., "Stock Returns and Volatility", Journal of Financial and Quantitative Analysis 25, 203-214, 1990.

Bekaert, G. and Harvey, C.R., "Time-Varying World Market Integration", Journal of Finance 50, 403-444, 1995.

Bekaert, G. and Harvey, C.R., "Emerging Equity Market Volatility", Journal of Financial Economics 43, 29-78, 1997.

Bekaert, G. and Harvey, C.R., "Foreign Speculators and Emerging Equity Markets", Journal of Finance 55, 565-613, 2000.

Bekaert, G. and Harvey, C.R., "Emerging Markets Finance", Journal of Empirical Finance 10, 3-55, 2003.

Bekaert, G., Harvey, C.R. and Lundblad, C., "Emerging Equity Markets and Economic Growth", Journal of Development Economics 66, 465-504, 2001.

Bollerslev, T., "Generalized Autoregressive Conditional Heteroscedasticity", Journal of Econometrics 31, 307-327, 1986.

Bollerslev, T., "Modelling the Coherence in Short-run Nominal Exchange Rates: A Multivariate Generalized ARCH Model", Review of Economics and Statistics 72, 498-505, 1990.

Bollerslev, T., and Wooldridge, J., "Quasi-Maximum Likelihood Estimations and Inferences in Dynamic Models with Time-Varying Covariances", Econometric Reviews 11, 143-172, 1992.

Bollerslev, T., Engle, R.F., and Wooldridge, J., "A Capital Asset Pricing Model with Time-Varying Covariances", Journal of Political Economy 96, 116-131, 1988.

Carrieri, F., Errunza, V., and Hogan, K., "Characterizing World Market Integration through Time", McGill University Working Paper, 2003.

Claessens, S., Dasgupta, S., and Glen, J., "Return Behavior in Emerging Stock Markets", World Bank Economic Review 9, 131-151, 1995.

DeSantis, G., and Imrohoroglu, S., "Stock Returns and Volatility in Emerging Financial Markets", Journal of International Money and Finance 16, 561-579, 1997.

Enders, W. Applied Econometric Time Series. Wiley Series in Probability and Mathematical Statistics, 1995.

Engle, R.F., "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of UK Inflation", Econometrica 50, 987-1008, 1982.

Engle, R.F., and Kroner, K.F., "Multivariate Simultaneous Generalized ARCH", Working Paper, University of California, San Diego, 1993.

Engle, R.F., Chou, R.Y, and Kroner, K.F., "ARCH Modeling in Finance", Journal of Econometrics 52, 5-59, 1992.

Fontaine, P., and Nguyen, D.K., "The Effect of Capital Market Liberalization on Weak Form Efficiency in Emerging Markets", CERAG Working Paper, University of Grenoble II, 2003.

Hamao, Y., Masulis, R.W., and Ng, V., "Correlations in Price Changes and Volatility Across International Stock Markets", Review of Financial Studies 3, 281-307, 1990.

Harvey, C. R., "Predictable Risk and Returns in Emerging Markets", Review of Financial Studies 8, 773-816, 1995.

He, L.T., "Time Variation Paths of International Transmission of Stock Volatility – US vs. Hong Kong and South Korea", Global Finance Journal 12, 79-93, 2001.

Karolyi, G.A., "A Multivariate GARCH Model of International Transmission of Stock Returns and Volatility: The Case of the United States and Canada", Journal of Business and Economic Statistics 13, 11-25, 1995.

Kearney, C., "The Determination and International Transmission of Stock Market Volatility", Global Finance Journal 11, 31-52, 2000.

Kim, E. H. and Singal, V., "Stock Market Openings: Experience of Emerging Economies", Journal of Business 73, 25-66, 2000.

Leachman, L., and Francis, B., "Equity Market Return Volatility: Dynamics and Transmission among the G-7 Countries", Global Finance Journal 7, 27-52, 1996.

Levich, R.M., "The Importance of Emerging Capital Markets", Working Paper, New York University, 2001.

Liu, Y.A., and Pan, M.S., "Mean and Volatility Spillover Effects in the US and Pacific-Basin Stock Markets", Multinational Finance Journal 1, 47-62, 1997.

Miles, W., "Financial Deregulation and Volatility in Emerging Equity Markets", Journal of Economic Development 27, 113-126, 2002.

Mougoué, M., and Whyte, A.M., "Stock Returns and Volatility: An empirical Investigation of the German and French Equity Markets", Global Finance Journal 7, 253-263, 1996.

Schwert, G.M., "Why Does Stock Volatility Change Over Time", Journal of Finance 44, 1115-1153, 1989.

Standard & Poor's. Emerging Stock Markets Factbook 2000. NewYork, Standard & Poor's 2000.

Table 1. Basic statistics for monthly stock returns

	Mean	Std. Dev.	Skewness	Kurtosis	Q(6)	Q(12)	$Q^2(6)$	$Q^2(12)$	JB	ARCH(4)	ADF test
Argentina	1.150	21.884	0.115**	5.401**	5.629	10.992	49.197**	56.320**	395.762**	25.864**	-9.007
Brazil	0.522	15.795	-0.436**	2.856**	2.835	11.002	9.443	51.587**	120.845**	7.238	-8.835
Chile	1.619	9.694	0.334**	2.035**	19.599**	51.999**	14.166*	56.726**	62.147**	10.877*	-7.170
South Korea	0.794	10.731	0.396**	2.846**	4.153	8.404	94.360**	127.652**	118.200**	51.017**	-7.296
Mexico	0.998	12.924	-2.028**	10.279**	23.527**	31.962**	35.062**	36.561**	1653.747**	38.678**	-7.461
Thailand	0.622	10.348	-0.461**	3.052**	15.721*	45.377**	113.331**	186.793**	137.748**	46.609**	-8.454
United States	0.952	4.463	-0.742*	2.894**	7.422	12.011	1.927	6.812	143.320**	2.444	-7.291
Japan	0.709	6.560	0.086	0.493	7.045	19.895	10.997	31.499**	3.705	10.921*	-6.821
World	0.868	4.179	-0.679**	1.745**	8.355	16.583	3.940	9.720	66.294**	1.983	-7.028

Notes: Monthly returns are analyzed over the period from January 1976 through January 2003. The columns from 1 to 4 report sample mean (in percentage), standard deviations (in percentage), skewness and excess kurtosis. Q(6), Q(12), $Q^2(6)$ and $Q^2(12)$ are Q-statistics of the Ljung-Box test for the serial correlation of returns and squared returns up to 6 and 12 lags respectively. JB are statistics of Jarque-Bera (1980)'s test for Gaussian distribution. ARCH (4) are the Chi-squared statistics of Engle (1982)'s tests for conditional heteroscedasticity in returns using residuals from an AR (1) process. ADF test is the augmented Dickey-Fuller test for unit roots (i.e., stationarity test). The critical value for ADF test at 5% is -2.86. Notice that if series are normally distributed, skewness is equal to zero and excess kurtosis is three. The superscripts *, ** indicate that coefficients are significant at 5% and 1% level of significance respectively.

Table 2. Unconditional correlation between sample markets

	Argentina	Brazil	Chile	South Korea	Mexico	Thailand	United Stated	Japan
Brazil	0.05							
Chile	0.19	0.14						
South Korea	-0.01	0.11	0.16					
Mexico	0.20	0.14	0.25	0.17				
Thailand	0.08	0.12	0.25	0.39	0.27			
United Stated	0.12	0.21	0.19	0.28	0.37	0.31		
Japan	0.03	0.14	0.14	0.37	0.15	0.24	0.31	
World	0.09	0.25	0.21	0.35	0.34	0.34	0.85	0.70

Table 3. Estimation results of world market volatility

Panel A: estimated coefficients						
δ_0 ($\times 10^2$)	δ_1 ($\times 10^2$)	δ_2	ω ($\times 10^2$)	α	β	Log-likelihood
0.833 (1.22)	0.655 (6.637)	0.033 (6.989)	0.008 (0.008)	0.048 (0.034)	0.908** (0.071)	-868.337

Panel B: Summary statistics for volatility series						
Mean ($\times 10^{-2}$)	Std. Deviation ($\times 10^{-2}$)	Minimum ($\times 10^{-2}$)	Maximum ($\times 10^{-2}$)	Skewness	Kurtosis	Q(12)
0.178	0.044	0.011	0.353	1.073	1.191	1665.857** (0.000)

Panel C: diagnostics of standardized residuals						
Mean	Std. Deviation	Skewness	Kurtosis	Q(12)	$Q^2(12)$	ARCH(4)
0.003	0.992	-0.767**	1.882**	16.661 (0.162)	6.196 (0.906)	1.458 (0.834)

Notes: Panel A contains estimated coefficients for conditional mean and variance equations. Bollerslev and Wooldridge (1992)'s robust standard errors for non-normality are given in parentheses. Panels B and C report summary statistics for conditional volatility series and diagnostics of standardized residuals. Q(12) and $Q^2(12)$ are Q-statistics of the Ljung-Box test for serial correlation of returns and squared returns up to 12 lags respectively. ARCH (4) is the Chi-squared statistics of Engle (1982)'s tests for conditional heteroscedasticity of the standardized residuals. The p-values of both statistical tests are reported in parentheses. The superscripts *, ** indicate that coefficients are significant at 5% and 1% level of significance respectively.

Table 4. Conditional volatility of sample stock markets

	Argentina	Brazil	Chile	South Korea	Mexico	Thailand	United Stated	Japan
Panel A: Estimated parameters								
λ_0	0.008	-0.0247	0.069	0.009	0.062	0.015	0.014^{**}	0.015
	(0.015)	(0.029)	(0.096)	(0.006)	(0.047)	(0.014)	(0.003)	(0.017)
λ_1	0.019	0.106	0.244^{**}	0.105	0.206^{**}	0.314^{**}	-0.036	0.058
	(0.085)	(0.056)	(0.050)	(0.057)	(0.043)	(0.058)	(0.031)	(0.040)
λ_2	0.314	-6.199^{*}	3.205	0.641	6.015	-1.895	1.825	3.048
	(1.787)	(2.607)	(7.998)	(1.210)	(6.502)	(2.701)	(3.110)	(7.444)
λ_3	-0.135	1.648	-5.914	-0.426	-4.406	-0.907	-2.280	-3.220
	(0.387)	(1.201)	(10.408)	(0.730)	(3.831)	(1.522)	(3.253)	(7.286)
Log-likelihood	1157.02	1292.15	1431.33	1436.99	1374.59	1445.83	1901.43	1668.24
Panel B: Statistics for monthly stock market volatility series								
Mean	0.077	0.035	0.012	0.014	0.019	0.015	0.002	0.005
Std. dev.	0.083	0.023	0.003	0.009	0.007	0.015	0.002	0.003
Min.[a]	0.122	0.140	0.092	0.058	0.124	0.056	0.010	0.023
Max.[a]	5.709	1.764	0.373	0.715	0.698	1.166	0.325	0.249
Skewness	3.418^{**}	3.102^{**}	3.827^{**}	2.893^{**}	3.111^{**}	3.460^{**}	6.687^{**}	2.760^{**}
Kurtosis	14.054^{**}	12.817^{**}	22.326^{**}	11.410^{**}	14.406^{**}	14.525^{**}	70.974^{**}	10.733^{**}
Q(12)	302.024^{**}	208.637^{**}	29.283^{**}	301.726^{**}	85.544^{**}	671.719^{**}	88.354^{**}	282.223^{**}
	(0.000)	(0.000)	(0.004)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ADF(4)	-5.355	-4.896	-6.019	-5.156	-6.668	-3.593	-5.824	-4.462
Panel C: Diagnostics of standardized residuals								
Mean[b]	0.855	-0.030	-0.013	-0.059	-0.142	0.136	0.934	0.444
Std. dev.	0.193	0.238	0.388	0.372	0.315	0.391	0.879	0.616
Skewness	-0.584^{**}	-0.795^{**}	-0.665^{**}	-0.709^{**}	-0.763^{**}	-0.393^{**}	-0.685^{**}	-0.661^{**}
Kurtosis	2.916^{**}	2.449^{**}	1.777^{**}	2.343^{**}	2.143^{**}	1.228^{**}	2.300^{**}	2.184^{**}
Q(12)	12.033	16.191	15.931	12.766	15.046	18.571	13.589	14.432
	(0.443)	(0.182)	(0.194)	(0.386)	(0.238)	(0.099)	(0.327)	(0.274)
$Q^2(12)$	21.107^{*}	14.431	18.229	9.178	8.227	20.306	55.640	19.720
	(0.048)	(0.273)	(0.108)	(0.687)	(0.767)	(0.061)	(0.936)	(0.072)
JB	128.909^{**}	111.586^{**}	64.538^{**}	103.703^{**}	90.574^{**}	27.837^{**}	93.663^{**}	85.230^{**}
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ARCH(4)	1.089	2.226	1.915	0.905	2.362	0.569	1.723	2.391
	(0.895)	(0.694)	(0.751)	(0.924)	(0.669)	(0.966)	(0.786)	(0.664)

Notes: Panel A contains estimated coefficients of conditional mean equation and maximum values of log-likelihood functions. Bollerslev and Wooldridge (1992)'s robust standard errors for non-normality are given in parentheses. Panels B and C provide summary statistics for conditional volatility series and diagnostics of standardized residuals. Q(12) and $Q^2(12)$ are Q-statistics of the Ljung-Box test for serial correlation of returns and squared returns up to 12 lags respectively. ADF test is the augmented Dickey-Fuller test for unit roots (i.e., stationarity test). The critical value for ADF test at 5% is -2.86. JB are statistics of Jarque-Bera (1980)'s test for Gaussian distribution of standardized residuals. ARCH (4) is the Chi-squared statistics of Engle (1982)'s tests for conditional heteroscedasticity of the standardized residuals. The p-values of all statistical tests are reported in parentheses. The superscripts *, ** indicate that coefficients are significant at 5% and 1% level of significance respectively. [a] indicates that coefficient are multiplied by 10^1 while [b] indicates that coefficients are multiplied by 10^2.

Table 5. Causal relationships of conditional volatility across stock markets

	Endogenous variables							
Exogenous variables	Argentina	Brazil	Chile	South Korea	Mexico	Thailand	United States	Japan
Argentina								
β_{t-1}	0.161 (0.057)*	0.008 (0.018)	0.006 (0.003)*	0.001 (0.006)	0.009 (0.005)	0.002 (0.010)	0.002 (0.002)	0.003 (0.002)
β_{t-2}	0.588 (0.004)**	0.019 (0.014)	0.001 (0.002)	-0.003 (0.004)	-0.001 (0.004)	-0.004 (0.008)	-0.000 (0.001)	0.000 (0.001)
β_{t-3}	0.056 (0.056)	-0.015 (0.017)	-0.007 (0.003)	0.001 (0.005)	-0.006 (0.005)	-0.013 (0.010)	-0.002 (0.002)	-0.004 (0.000)*
F-statistic	70.605**	0.766	2.183^{c}	0.170	0.982	0.972	0.626	1.402
Brazil								
β_{t-1}	0.844 (0.275)**	0.103 (0.086)	0.022 (0.014)	0.017 (0.029)	0.064 (0.027)*	0.032 (0.051)	0.006 (0.010)	0.013 (0.009)
β_{t-2}	-0.017 (0.274)	0.164 (0.086)^{c}	0.008 (0.014)	0.057 (0.029)*	-0.027 (0.027)	0.000 (0.051)	-0.017 (0.010)^{c}	0.003 (0.009)
β_{t-3}	0.413 (0.276)	0.102 (0.086)	0.011 (0.014)	0.027 (0.029)	0.022 (0.027)	0.015 (0.051)	0.010 (0.010)	0.015 (0.009)
F-statistic	4.459**	2.317^{c}	1.379	1.780	2.662*	0.186	1.571	1.805
Chile								
β_{t-1}	-0.000 (0.221)	0.151 (0.382)	0.044 (0.061)	0.079 (0.129)	0.261 (0.121)*	-0.158 (0.227)	-0.036 (0.045)	0.025 (0.043)
β_{t-2}	-0.405 (1.228)	0.338 (0.384)	0.055 (0.061)	-0.124 (0.129)	-0.161 (0.122)	-0.037 (0.228)	-0.023 (0.045)	-0.058 (0.043)
β_{t-3}	-1.082 (1.239)	0.294 (0.387)	0.047 (0.062)	-0.022 (0.131)	-0.063 (0.123)	-0.054 (0.231)	-0.003 (0.045)	0.021 (0.044)
F-statistic	0.300	0.551	0.713	0.428	2.114^{c}	1.100	0.324	0.782
South Korea								
β_{t-1}	-0.245 (0.687)	-0.040 (0.215)	0.009 (0.034)	0.084 (0.072)	-0.014 (0.068)	0.302 (0.127)*	-0.016 (0.025)	-0.000 (0.024)
β_{t-2}	-0.247 (0.656)	-0.393 (0.205)^{c}	0.016 (0.033)	0.101 (0.069)	-0.023 (0.065)	0.002 (0.122)	-0.019 (0.024)	-0.014 (0.823)
β_{t-3}	0.629 (0.661)	0.351 (207)^{c}	0.044 (0.033)	0.104 (0.069)	0.059 (0.065)	0.028 (0.123)	0.016 (0.024)	0.053 (0.023)*
F-statistic	0.362	2.100	0.076	2.226	0.308	1.973	0.484	1.805
Mexico								
β_{t-1}	-0.439 (0.917)	-0.182 (0.287)	-0.009 (0.046)	-0.124 (0.096)	0.056 (0.091)	-0.215 (0.170)	0.020 (0.033)	0.013 (0.032)
β_{t-2}	-0.439 (0.075)	0.272 (0.221)	0.067 (0.035)^{c}	0.081 (0.074)	0.582 (0.070)**	0.059 (0.130)	0.025 (0.026)	0.010 (0.025)
β_{t-3}	-1.188 (0.852)	-0.061 (0.267)	0.019(0.042)	0.050 (0.090)	-0.122 (0.084)	0.068 (0.158)	-0.033 (0.031)	-0.029 (0.030)
F-statistic	1.481	1.001	1.272	1.112	25.449**	0.713	0.756	0.431
Thailand								
β_{t-1}	0.032 (0.334)	-0.114 (0.104)	-0.006 (0.016)	0.050 (0.035)	0.038 (0.033)	0.185 (0.062)**	0.022 (0.012)^{c}	0.026 (0.011)*
β_{t-3}	-0.150 (0.323)	-0.070 (0.101)	-0.043 (0.016)	0.025 (0.034)	-0.006 (0.032)	0.333 (0.062)**	-0.013 (0.011)	-0.010 (0.011)
β_{t-3}	-0.095 (0.335)	-0.090 (0.105)	-0.015 (0.016)	0.114 (0.035)**	-0.035 (0.033)	0.122 (0.062)^{c}	-0.003 (0.012)	-0.018 (0.011)

F-statistic	0.125	0.638	0.622	7.278**	0.631	23.619**	1.350	2.110^{c}
United States								
β_{t-1}	-0.227 (0.656)	-0.452 (0.652)	0.023 (0.104)	-0.123 (0.220)	-0.178 (0.207)	0.453 (0.388)	0.031 (0.077)	-0.059 (0.071)
β_{t-2}	-1.171 (1.956)	0.286 (0.612)	-0.030 (0.098)	0.281 (0.206)	-0.584 (0.190)**	0.107 (0.364)	0.311 (0.069)**	0.111 (0.069)
β_{t-3}	3.727 (2.162)^{c}	0.545 (0.676)	0.115 (0.108)	-0.036 (0.228)	0.552 (0.214)*	-0.438 (0.402)	0.040 (0.079)	0.091 (0.074)
F-statistic	1.127	0.358	0.499	0.719	4.971**	0.638	6.650**	1.428
Japan								
β_{t-1}	-5.543 (3.474)	0.630 (1.087)	-0.239 (0.174)	0.088 (0.367)	-0.538 (0.345)	-0.054 (0.647)	0.027 (0.128)	-0.075 (0.123)
β_{t-2}	1.957 (3.001)	2.979 (0.930)**	0.067 (0.150)	1.086 (0.317)**	0.229 (0.298)	0.415 (0.559)	0.198 (0.110)^{c}	0.651 (0.107)**
β_{t-3}	-4.444 (3.323)	-1.681 (1.039)	-0.253 (0.167)	-0.782 (0.351)*	0.063 (0.330)	-1.035 (0.619)^{c}	-0.053 (0.122)	-0.224 (0.118)^{c}
F-statistic	2.775*	4.756**	2.556^{c}	6.676**	1.198	1.512	1.212	16.413**
Constant	0.066 (0.024)**	0.002 (0.007)	0.008 (0.001)**	0.002 (0.002)	0.008 (0.002)**	0.011 (0.004)**	0.001 (0.000)^{c}	0.001 (0.000)^{c}
$\overline{R}^2$	0.447	0.290	0.062	0.525	0.247	0.415	0.144	0.477

Block exogeneity test		
H_0: the lags of the US volatility index do not enter in the equations for the remaining variables		
Log det.	Unrestricted model = -69.494	Restricted model = -69.296
$\chi^2_{(21)}$	58.315452 (p-value = 0.00002)	
H_0: the lags of the Japanese volatility index do not enter in the equations for the remaining variables		
Log det.	Unrestricted model = -68.422	Restricted model = -68.250
$\chi^2_{(21)}$	50.900 (p-value = 0.00027)	

Notes: $\beta_{j\ t-i}$ (i=1, 2, 3) is the estimated coefficient of volatility in the j^{th} market at lag t-i. Standard errors of estimated coefficients are put in parentheses. F-statistics are empirical statistics of the Granger-causality tests applied to block of lags of a particular variable in each equation, indicating whether variable j helps to forecast dependent variable. $\chi^2_{(21)}$ is the statistic of the likelihood ratio test for block exogeneity which tests whether the lags of one variable do not enter equations for the remaining variables. This has a Chi-squared distribution with degrees of freedom equal to the number of restrictions. The p-values associated to likelihood ratio tests are reported in parentheses. Log det. is the natural log of the determinant of covariance matrices of the restricted and unrestricted model. The superscripts *, ** indicate that coefficients are significant at 5% and 1% level of significance respectively. ^{c} indicates significance at 10%.

Table 6. IRF of sample stock market volatility series (%)

Endogenous variables	Argentina	Brazil	Chile	South Korea	Mexico	Thailand	United States	Japan
Argentina								
1-step	5.876	0.136	-0.010	0.012	0.022	-0.008	0.002	0.005
6-step	0.773	0.015	-0.003	0.015	0.020	-0.087	-0.004	-0.002
12-step	0.338	0.005	0.000	-0.016	0.009	-0.059	-0.002	-0.003
Brazil								
1-step	0.000	1.833	0.054	0.239	0.339	0.113	0.108	0.152
6-step	0.014	0.242	0.006	0.084	0.074	0.027	0.015	0.025
12-step	-0.181	0.070	0.001	0.036	0.024	0.013	0.005	0.010
Chile								
1-step	0.000	0.000	0.290	0.062	0.105	-0.003	0.018	0.046
6-step	-0.311	0.063	0.008	-0.011	0.029	-0.057	-0.000	0.003
12-step	-0.070	0.021	0.001	-0.001	0.008	-0.017	0.001	0.002
South Korea								
1-step	0.000	0.000	0.000	0.569	0.119	0.359	0.030	0.063
6-step	-0.625	0.000	-0.005	0.067	-0.001	0.123	0.001	0.006
12-step	-0.303	-0.007	-0.002	0.028	0.002	0.064	0.002	0.002
Mexico								
1-step	0.000	0.000	0.000	0.000	0.447	-0.104	0.067	0.068
6-step	-0.867	-0.050	-0.001	-0.045	0.006	-0.072	-0.000	-0.012
12-step	-0.343	-0.001	-0.001	-0.007	0.011	-0.018	0.001	-0.002
Thailand								
1-step	0.000	0.000	0.000	0.000	0.000	1.022	0.022	-0.003
6-step	-0.127	-0.063	-0.004	0.113	-0.019	0.226	0.002	0.005
12-step	-0.180	-0.026	-0.002	0.037	-0.009	0.102	0.000	0.001
United States								
1-step	0.000	0.000	0.000	0.000	0.000	0.000	0.170	0.027
6-step	0.328	0.066	-0.001	-0.002	0.050	-0.003	0.008	0.002
12-step	0.103	0.028	-0.000	0.007	0.017	-0.005	0.002	0.002
Japan								
1-step	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.095
6-step	-0.602	-0.095	-0.018	-0.043	0.001	-0.024	0.002	-0.016
12-step	-0.213	-0.015	-0.004	-0.005	0.012	-0.004	0.002	-0.003

Table 7. Variance decompositions of sample stock market volatility series (%)

Forecast error variance of	Std. error	Argentina	Brazil	Chile	South Korea	Mexico	Thailand	United States	Japan
Argentina									
1-step	0.05876	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6-step	0.07761	89.46	0.63	1.09	1.92	3.74	0.31	0.38	2.43
12-step	0.08144	86.80	0.74	1.11	2.68	4.60	0.31	0.53	2.87
Brazil									
1-step	0.01838	0.55	99.44	0.00	0.00	0.00	0.00	0.00	0.00
6-step	0.02216	1.42	89.24	1.55	0.17	3.39	0.50	0.63	3.06
12-step	0.02272	1.52	87.98	1.64	0.25	3.79	0.62	0.85	3.32
Chile									
1-step	0.00295	0.11	3.40	96.47	0.00	0.00	0.00	0.00	0.00
6-step	0.00314	1.75	7.29	86.15	0.41	1.72	0.40	0.02	2.22
12-step	0.00317	1.79	7.70	84.83	0.44	2.19	0.47	0.03	2.50
South Korea									
1-step	0.00621	0.03	14.82	1.01	84.11	0.00	0.00	0.00	0.00
6-step	0.00879	0.29	32.65	0.78	49.70	3.41	7.48	1.68	3.35
12-step	0.00931	0.37	34.20	0.69	46.22	4.11	8.82	1.88	3.67
Mexico									
1-step	0.00584	0.14	33.78	3.28	4.15	58.61	0.51	0.00	0.00
6-step	0.00686	1.21	31.30	3.36	3.72	54.74	0.51	4.23	0.89
12-step	0.00699	1.29	31.34	3.38	3.61	53.27	0.61	5.37	1.08
Thailand									
1-step	0.01095	0.00	1.07	0.00	10.76	0.91	87.23	0.00	0.00
6-step	0.01379	0.94	3.15	1.32	15.88	1.74	76.05	0.51	0.37
12-step	0.01460	2.07	3.15	1.39	16.78	1.72	73.91	0.47	0.46
United States									
1-step	0.00217	0.01	25.12	0.73	1.96	9.64	1.10	61.41	0.00
6-step	0.00242	0.45	25.47	0.90	2.03	11.91	2.15	56.27	0.77
12-step	0.00244	0.64	25.70	0.90	2.12	11.91	2.12	55.66	0.90
Japan									
1-step	0.00209	0.07	52.75	4.90	9.11	10.53	0.02	1.71	20.87
6-step	0.00287	0.69	54.10	3.01	7.43	10.88	1.13	4.05	18.67
12-step	0.00302	0.67	54.22	2.87	7.29	11.03	1.03	4.48	18.36

Table 8. Stock market liberalizations and conditional volatility

	Liberalization indicators					
	CONST.	BEFORE	PRE	DURING	POST	$\overline{R}^2$
Argentina	0.091** (0.011)	0.096 (0.095)	-0.127 (0.096)	0.158** (0.036)	-0.039** (0.012)	0.297
Brazil	0.033** (0.002)	0.028** (0.006)	-0.011 (0.009)	0.010* (0.004)	-0.002 (0.003)	0.093
Chile	0.012** (0.000)	-0.000 (0.000)	0.001 (0.001)	0.001* (0.000)	-0.001** (0.000)	0.047
South Korea	0.013** (0.000)	0.002** (0.000)	0.001 (0.002)	-0.001 (0.000)	0.002 (0.001)	0.013
Mexico	0.018** (0.000)	-0.001 (0.003)	0.006c (0.003)	0.001 (0.003)	0.000 (0.001)	0.032
Thailand	0.009** (0.000)	-0.021** (0.002)	0.021** (0.002)	0.021** (0.002)	0.009** (0.002)	0.103
All markets	0.029 (0.002)	0.017 (0.050)	-0.017 (0.050)	0.032 (0.031)	-0.004 (0.003)	0.034

Notes: The definition of liberalization indicators are given in annex. The superscripts *, ** indicate that coefficients are significant at 5% and 1% level of significance respectively. c indicates significance at 10%.

Table 9. Comparison of volatility dependencies before and after financial liberalizations: March 1976-Sept. 1989 versus Oct. 1989-Jan. 2003

	Independent variables								$\overline{R}^2$
Dependent variables	Argentina	Brazil	Chile	South Korea	Mexico	Thailand	United States	Japan	
Argentina									
F-statistic (B)	16.754**	4.451**	0.785	1.311	1.764	0.351	1.258	0.636	0.356
F-statistic (A)	67.479**	1.845	2.492c	0.868	1.078	0.420	1.054	1.101	0.668
Brazil									
F-statistic (B)	0.368	1.484	0.191	1.388	1.163	1.539	1.574	3.999**	0.335
F-statistic (A)	2.802*	0.866	2.991*	0.205	0.769	0.595	0.691	0.724	0.260
Chile									
F-statistic (B)	1.995	1.629	0.128	0.759	1.622	1.836	0.423	0.722	0.016
F-statistic (A)	2.241c	10.276**	2.533c	0.204	5.903**	1.846	1.810	2.722*	0.433
South Korea									
F-statistic (B)	0.770	0.653	0.564	2.594c	1.089	0.451	1.819	5.614**	0.591
F-statistic (A)	0.091	2.229c	0.946	0.329	2.429c	6.084**	1.473	2.340c	0.501
Mexico									
F-statistic (B)	1.435	4.387**	3.047*	0.553	18.574**	2.174c	3.626*	1.191	0.306
F-statistic (A)	1.227	1.515	0.797	0.222	1.166	0.405	2.280c	0.243	0.208
Thailand									
F-statistic (B)	0.250	1.834	0.812	0.949	0.118	5.718**	0.584	1.470	0.288
F-statistic (A)	0.413	0.158	0.855	1.421	0.775	6.796**	1.071	1.264	0.366
United States									
F-statistic (B)	0.564	2.729*	0.297	0.686	0.641	3.669*	2.120	1.257	0.155
F-statistic (A)	0.591	0.353	0.336	0.145	0.486	1.901c	2.544	0.892	0.197
Japan									
F-statistic (B)	1.862	3.696*	0.825	0.180	0.970	2.957*	0.968	10.301**	0.477
F-statistic (A)	1.148	1.852	0.975	0.607	0.572	1.152	2.019	4.395**	0.495

Notes: F-statistics are empirical statistics of the Granger-causality tests applied to block of lags of a particular variable in each equation, indicating whether variable j helps to forecast dependent variable. The superscripts *, ** indicate that coefficients are significant at 5% and 1% level of significance respectively. c indicates significance at 10%. B: before liberalizations. A: after liberalizations.

Figure 1. Conditional variance of sample stock markets

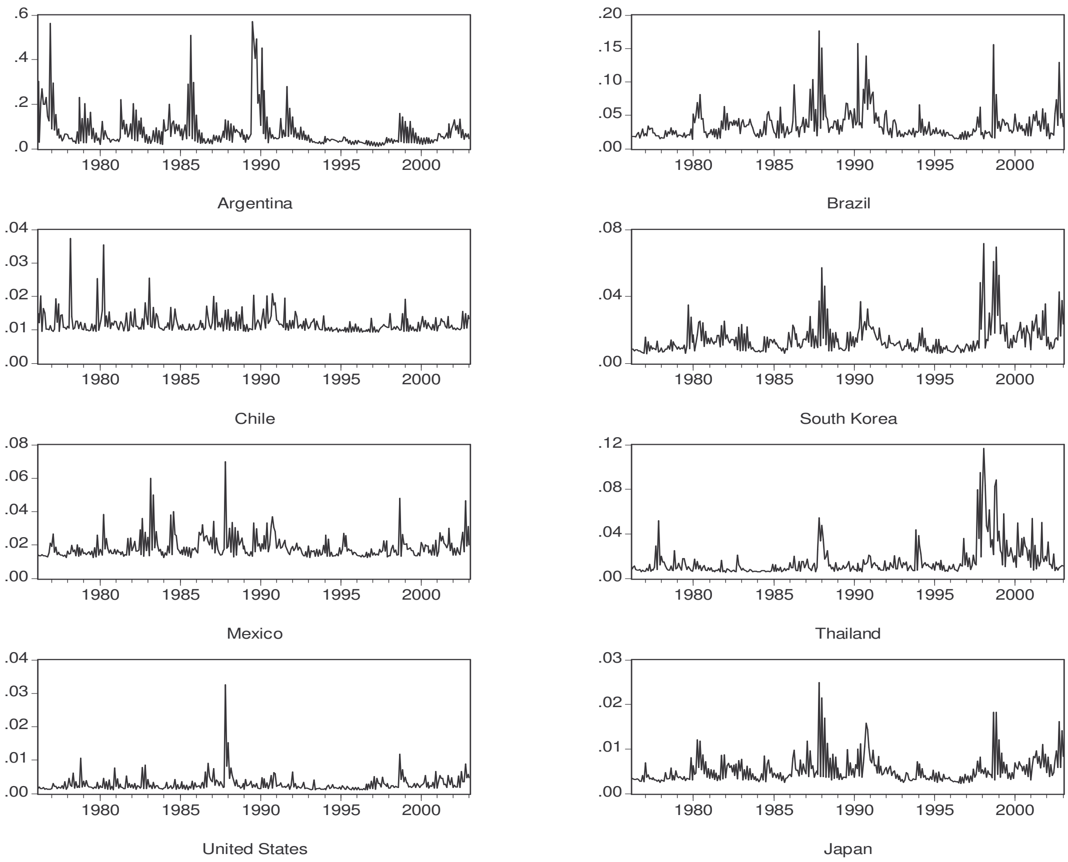

Figure 2. Monthly standard deviations before and after stock market liberalizations

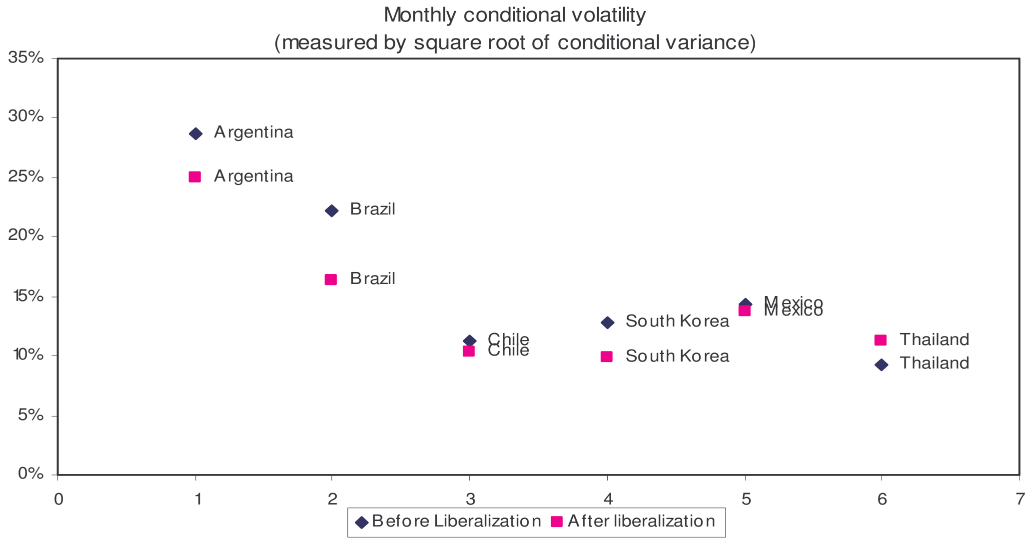

Figure 3. Responses of sample markets to volatility shock in the United States

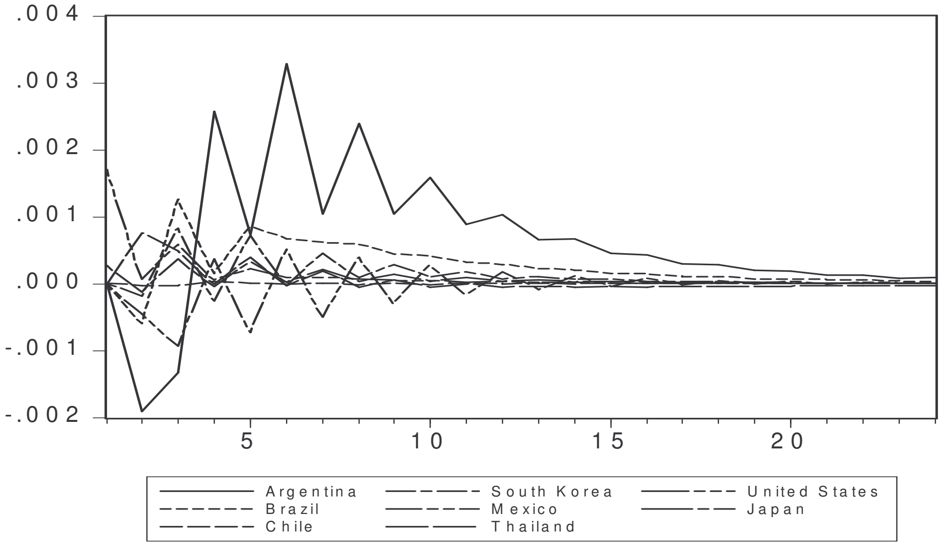

Figure 4. Responses of sample market to volatility shock in Japan

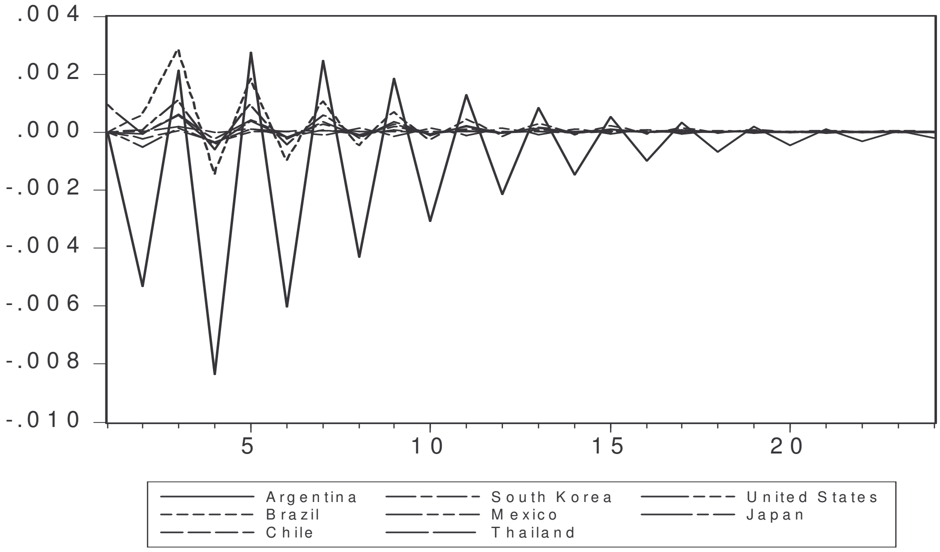

Figure 5. Responses of sample market to volatility shock in Brazil