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Kamil Yılmaz

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# Return and Volatility Spillovers among the East Asian Equity Markets

Kamil Yılmaz
Koç University

**Abstract**

This article examines the extent of contagion and interdependence across the East Asian equity markets since early 1990s and compares the ongoing crisis with earlier episodes. Using the forecast error variance decomposition from a vector autoregression, we derive return and volatility spillover indices over the rolling sub-sample windows. We show that there is substantial difference between the behavior of the East Asian return and volatility spillover indices over time. While the return spillover index reveals increased integration among the East Asian equity markets, the volatility spillover index experiences significant bursts during major market crises, including the East Asian crisis. The fact that both return and volatility spillover indices reached their respective peaks during the current global financial crisis attests to the severity of the current episode.

**Keywords:** Stock returns, Volatility, Spillovers, Vector autoregression, Variance decomposition.
**JEL Codes:** G1, F3

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Correspondence Address: Kamil Yilmaz, Department of Economics, Koç University, Rumelifeneri Yolu, Sariyer, Istanbul 34450, Turkey. email: kyilmaz@ku.edu.tr, Tel: +90 212 338 1458, Fax: +90 212 338 1653

## 1. Introduction

The financial crisis that started in the US sub-prime mortgage market in February 2007 reached its climax in mid-September 2008 with the disastrous collapse of the Lehman Brothers. As the global financial crisis have unfolded in several stages, financial markets all around the world went through wild fluctuations, with volatility spreading across markets at an unprecedented speed.

The current financial crisis is not the first of its kind. Following the globalization wave of the early 1990s, financial market crises have become a more frequently observed phenomena, especially in the emerging market economies. During these crises, volatility in financial markets has increased sharply as the stock returns moved into negative territory. As the initial tremors of each of these crises are not confined to the originator country but spread to other countries as well, it is important to obtain a measure of return and volatility spillovers across countries during financial crises.

Early work on contagion dated back to the aftermath of the October 1987 U.S. stock market crash. However, it was not until after the East Asian and Russian crises of 1997-1998 that financial contagion and spillovers had become a major area of research[1]. From the beginning on, the empirical literature on contagion focused on stock returns, and the possibility of volatility contagion has mostly been ignored in the literature. Departing from the rest of the empirical literature, Edwards (1998), Edwards and Susmel (2001) and Baur (2003) are the only papers on the possibility of contagion taking place through spillovers of volatility across stock markets.

[1] See Claessens and Forbes (2001) for a collection of major contributions on financial contagion after the East Asian crisis.

Recently, there have been scores of new research papers mostly focusing on how the current financial crisis has spread around the globe.[2] Among these Diebold and Yilmaz (2009a) proposed a new approach to the analysis of contagion and interdependence across markets. In this paper, we follow in their footsteps. Using separate vector autoregregression of returns and range-based volatility estimates for 10 East Asian stock markets, we analyze the differences in the dynamics that drive return and volatility spillovers over time. Variance decomposition analysis of the VAR model allows us to identify spillovers of return and volatility shocks from the indigenous shocks. In order to measure volatility we use efficient range-based volatility estimate that was first proposed by Garman and Klass (1980).

In this paper, we focus on major East Asian stock markets only. Over the last two decades, East Asian economies and markets have developed into a powerhouse in the global economy. In addition to attaining a growth rate well above the world average, with their rapidly developing financial markets, the East Asian economies started to play an increasingly influential role in the global financial system. As a consequence, it is interesting to study how the region's markets are affected during different financial crisis episodes since early 1990s and especially during the current global financial crisis.

We apply VAR model and the variance decomposition analysis to 100-week long rolling windows of East Asian stock returns and volatility measures separately. For each window we calculate the contribution of spillovers across markets to the variance of forecast errors. Plotting the total contribution of spillovers in all markets across time we obtain a measure of spillovers across markets. Our approach differs from the main contributions to the literature on financial contagion (such as Forbes and Rigobon, 2002, and papers in Claessens and Forbes, 2001,) in

[2] See for example, Baur and Fry, 2009, Dudley and Hutchison, 2009, Frank and Hesse, 2008, and IMF (2008).

several respects. We do not test for contagion before and/or after major crisis episodes, the beginning and ending dates of which are determined exogenously. Instead, using a rolling window framework enables us to account for major changes in the return and volatility spillovers separately by plotting the return and volatility spillover indices.

Our empirical results show that there is substantial difference between the behavior of the East Asian return and volatility spillover indices over time. While the return spillover index reveals increased integration among the East Asian equity markets, the volatility spillover index experiences significant bursts during major market crises, including the East Asian crisis. The fact that during the current global financial crisis the return spillover index experienced its most significant burst since 1990s along with the volatility spillover index and both indices reached their respective peaks attests to the severity of the current financial crisis episode.

Section 2 briefly motivates and describes the spillover index methodology, which is based on variance decompositions of forecast errors obtained from a vector autoregression. In Section 3 we use the spillover index methodology to assess East Asian stock return and volatility spillovers since 1992. In this section, we showed that our results are robust to alternative orderings and also to the inclusion of Chinese, Indian and American equity markets in the analysis. In Section 4 we summarize our results.

## 2. Measuring Return and Volatility Spillovers

In this section, we describe the spillover index methodology proposed by Diebold and Yilmaz (2009a), which we use to measure return and volatility spillovers in East Asia. [3]

In a nutshell, we model the stock market returns (or volatilities) as an *N*-variable vector autoregression (VAR). For each stock market *i* we add the shares of its forecast error variance due to shocks in other stock market *j*, for all $j \neq i$. Then we sum across all $i = 1,..., N$ to obtain the spillover index. In other words, the spillover index is equal to the sum of all non-diagonal elements in the forecast error variance matrix.

Now let's describe how we obtain the spillover index in some detail. First consider the covariance stationary p$^{th}$-order N-variable VAR,

$$x_t = \sum_{i=1}^{p} \Phi_i x_{t-i} + \varepsilon_t , \tag{1}$$

where $x_t = (x_{1,t},..., x_{N,t})'$, $\Phi$ is a *NxN* parameter matrix and the vector of error terms $\varepsilon$ has zero mean and the covariance matrix $\Sigma$. In our framework, *x* will be either a vector of stock returns or a vector of stock return volatilities. Assuming that VAR system is covariance stationary, its moving average representation exists and is given by

$$x_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i} \tag{2}$$

where the *NxN* coefficient matrices $A_i$ obey the recursion $A_i = \Phi_1 A_{i-1} + \Phi_2 A_{i-2} + ... + \Phi_p A_{i-p}$

[3] Rather than just limiting the analysis to the measurement of total spillovers, Diebold and Yilmaz (2008) use generalized VAR approach proposed by Pesaran and Shin (1998) to obtain measures of directional spillovers across asset markets over time.

with $A_0$ being an *NxN* identity matrix and $A_i = 0$ for i<0.

Using the Cholesky decomposition of the covariance matrix of $\varepsilon_t$, $PP' = \Sigma$, where $P$ is the unique lower-triangular Cholesky factor of $\Sigma$, we can now write (2) as

$$x_t = \sum_{i=0}^{\infty} (A_i P)(P^{-1}\varepsilon_{t-i}) = \sum_{i=0}^{\infty} (A_i P)(\tilde{\varepsilon}_{t-i}) = \sum_{i=0}^{\infty} \tilde{A}_i \tilde{\varepsilon}_{t-i} \tag{3}$$

such that $\tilde{\varepsilon}_t = P^{-1}\varepsilon_t$ are orthogonalized, with zero mean and a covariance matrix of ones in the diagonal and zeros elsewhere.

Variance decompositions allow us to split the forecast error variances of each variable into parts attributable to the various system shocks. More precisely, for the example at hand, they answer the questions: What fraction of the error variance in forecasting $x_1$ is due to shocks to $x_1$? Shocks to $x_2$? Shocks to $x_3$? And so on. And similarly, what fraction of the error variance in forecasting $x_2$ is due to shocks to $x_1$? Shocks to $x_2$? Shocks to $x_3$? And so on.

Let us define *own variance shares* to be the fractions of the H-step ahead error variances in forecasting $x_i$ due to shocks to $x_i$, for $i$=1, 2,…,N and *cross variance shares, or spillovers*, to be the fractions of the H-step ahead error variances in forecasting $x_i$ due to shocks to $x_j$, for $i \neq j$. In the case of an N-variable model, the number of possible spillovers is equal to N!. When we consider the simple case of two-variable VAR, the number of spillovers is simply two: $x_{1t}$ shocks that affect the forecast error variance of $x_{2t}$, and $x_{2t}$ shocks that affect the forecast error variance of $x_{1t}$.

Using the above definition, we first decompose the covariance matrix of the H-step ahead forecast errors:

$$\theta_{ij}(H) = \frac{\sum_{h=0}^{H-1}(e_i^{'} A_h P e_j)^2}{\sum_{h=0}^{H-1}(e_i^{'} A_h \sum A_h^{'} e_i)} = \frac{\sum_{h=0}^{H-1}(e_i^{'} \tilde{A}_h e_j)^2}{\sum_{h=0}^{H-1}(e_i^{'} \tilde{A}_h \tilde{A}_h^{'} e_i)}, \quad (4)$$

where $e_i$ is an *Nx1* vector with one as its i[th] element and zeros elsewhere. $\theta_{ij}(H)$ is the contribution of a one-standard deviation shock to $x_j$ to the variance of the H-step ahead forecast error of $x_i$. By construction $\sum_{j=1}^{N}\theta_{ij}(H) = 1$ and $\sum_{i,j=1}^{N}\theta_{ij}(H) = N$.

Once we obtain the measure of spillovers from variable *i* to variable *j*, for all *i, j*, we now define the ***Spillover Index*** as the measure of total spillovers in percentage terms:

$$S\ (H) \quad = \quad \frac{\sum_{i,j=1,i\neq j}^{N}\theta_{ij}(H)}{\sum_{i,j=1}^{N}\theta_{ij}(H)} \bullet 100 \quad = \quad \frac{\sum_{i,j=1,i\neq j}^{N}\theta_{ij}(H)}{N} \bullet 100$$

Spillover index is simply the sum of the off-diagonal elements of the matrix obtained from a standard variance decomposition exercise in any VAR system relative to the number of variables. The sum of diagonal elements relative to the number of variables, on the other hand, is a measure of how much of the forecast error variances are explained by own shocks. The generality of our spillover measure is often useful, and we exploit it in our subsequent empirical analysis of return and volatility spillovers in East Asia. [4]

## 3. Empirical Analysis

In this section, we describe the empirical implementation of the spillover index methodology, after providing brief information on the returns and volatilities data used in the analysis.

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[4] Ours is not the first implementation of the spillover index methodology in a regional setting. Diebold and Yilmaz (2009b) implement use the same methodology to analyze the behavior of return and volatility spillovers among the Latin American countries.

Data

Our analysis includes stock market index returns for 10 East Asian countries: Hong Kong (HKG), Indonesia (IDN), Japan (JPN), S. Korea (KOR), Malaysia (MYS), Philippines (PHL), Singapore (SGP), Taiwan (TAI), Thailand (THA) and Australia (AUS) from January 1, 1992 through April 30, 2009. We measure log returns weekly, using underlying stock index levels at the Friday close. We express the weekly returns as annualized percentages, which is calculated as $r_{it} = 52 \bullet 100 \bullet (\Delta \ln P_{it})$ for market $i$.

Following Garman and Klass (1980), we estimate weekly return volatilities using weekly high, low, opening and closing prices obtained from underlying daily high, low, open and close data, from the Monday open to the Friday close:

$$\tilde{\sigma}_{it}^2 = 0.511(H_{it} - L_{it})^2 - 0.019\left[(C_{it} - O_{it})(H_{it} + L_{it} - 2O_{it}) - 2(H_{it} - O_{it})(L_{it} - O_{it})\right] - 0.383(C_{it} - O_{it})^2,$$

where $H$ is the Monday-Friday high, $L$ is the Monday-Friday low, $O$ is the Monday open and $C$ is the Friday close (all in natural logarithms). Given the weekly variance estimator $\tilde{\sigma}_{it}^2$ The corresponding estimate of the annualized weekly percent standard deviation (volatility) is $\hat{\sigma}_{it} = 100\sqrt{52 \bullet \tilde{\sigma}_{it}^2}$ . We do not plot the returns and volatilities for all 10 countries in order to save space. Instead, we provide summary statistics for returns and volatilities in Table 1 and 2.

Empirical Implementation of the Spillover Index

In our empirical model, we use second-order VARs ($p$ = 2), with 10-step ahead forecasts ($h=10$), and $N$ = 10 countries. The idea of time variation in spillovers is captured by the reestimation of the VAR, using a 100-week rolling estimation window. We compute and plot the spillover index only when the parameters of the estimated VAR imply covariance stationarity.

East Asian Spillovers

In order to provide a better understanding of how the index is calculated, in Tables 3 and 4 we provide details of the calculation of the return and volatility spillover indices over the full-sample, respectively. The variance decompositions presented in Tables 3 and 4 are calculated using the Cholesky factorization-based variance decompositions, where the markets are ordered as presented. Both tables reveal the order dependence of the variance decompositions. While only 2% of Hong Kong's (which is ordered first) return forecast error variance is explained by other markets, this ratio can go as high as 52% in the case of Singapore (see "Contribution from Others" column). Hong Kong's contributions to other markets add up to 202 points, whereas other countries' contributions are rather small (less than 34 points).

Adding the entries in the "Contribution to Others" row (or for that matter "Contributions from Others" column) we obtain the spillover index: 31.6% of the total 1000 points of forecast error variance for all 10 countries is explained by spillovers across markets. The remaining 68.4% of the total forecast error variance is explained by own shocks rather than spillovers of shocks across markets.

As can be observed in Table 4, with a value of 78%, the volatility spillover index for the full sample period is much higher than the return spillover index. The huge difference between the two indices reveals how fast shocks to return volatility spread across the region's equity markets compared to shocks to returns. Tables 3 and 4 are indeed providing measures of *average* spillovers, over the full sample for returns and volatility, respectively.

As the objective of this paper is to learn more about the behavior of return and volatility spillovers over time, we move beyond the average spillovers for the full sample and calculate spillover indices over rolling 100-week sub-sample windows. Spillover plots for returns and return volatilities are presented in Figures 1 and 2, respectively.

Let us now examine the spillover plots in more detail, starting with the return spillovers first. To start with, in the early 1990s approximately 35% of shocks to stock index returns spilled over across the East Asian stock markets. Following the Mexican Tequila crisis that started in late 1994 and continued in 1995, return spillovers increased slightly towards 45% and fluctuated in the 40-50% band. As the observations for the Mexican crisis period are dropped out of the sub-sample windows, return spillovers declined back to 35% level. However, with the outburst of the East Asian financial crisis, return spillovers increased rather quickly to 50%. Even after the observations for the East Asian crisis are dropped out of the sub-sample window, return spillovers continued to fluctuate in the 40-50% band for almost a decade.

Compared to early 1990s, the return spillover index that fluctuates within the 40-50% band can be interpreted as an indication of the increased integration among the East Asian stock markets. After a decade long fluctuation within the 40-50% band, the spillover index jumped significantly to 60% in August 2007 as the first stage of the US sub-prime crisis affected other major financial markets. A year after, following the Lehman Brothers' bankruptcy, the index jumped up again in September 2008, reaching close to 65%. After hitting a maximum level of 68% in December 2008, the return spillover index started to decline towards 65% in the first 4 months of 2009.

The volatility spillovers plot in Figure 2 is much different from the return spillovers plot in Figure 1. While the return spillovers moved rather smoothly over time with occasional fluctuations during major crises, the volatility spillover index moves up and down as the data pertaining to major financial shocks are included in the 100-week rolling sub-sample window. The most important jump in the volatility spillover plot occurred during the East Asian crisis. The volatility spillover index surged to more than sixty percent in early 1994 following a major policy failure in Japan. After this development, the volatility spillover index stabilized around 40% for almost a year. The impact of the Mexican crisis (late 1994, early 1995) on East Asian volatility spillovers was rather small, raising the index by several percentage points only. As the observations for the early 1994 are dropped out, the index declines down and fluctuates between 30% and 40% until the summer of 1997. However, during the East Asian crisis of 1997 volatility spillovers surged substantially, reaching as high as 75% by the end of 1997. First Thailand suffered a major blow in July, followed by the spread of the virus to Hong Kong in October and then to other countries towards the end of 1997. While the volatility spillover index declined as the sub-sample window is rolled over, its level was still higher compared to the level prior to the East Asian crisis.

The volatility spillover index is also affected by the Russian crisis of September 1998, the Brazilian crisis of January 1999, increased U.S. market tensions due to technology stocks in late 2000 and early 2001, 9/11 terrorist attacks in the U.S. in 2001, global markets chasing US stocks down in mid-2002, the Iraq War of 2003, and the reversal in FED interest rate policy stance in early 2004. However, none of these events and developments had as significant an impact as did the 1997 East Asian crisis.

Between 2004 and mid-2006, East Asian equity markets, along with others around the world, went through a period of tranquility. This period was interrupted by the FED's decision to increase interest rates, which led to the reversal of capital flows away from emerging market economies. These developments caused a significant jump in the index. It turned out that what the emerging markets went through in 2006 was just a hick up, compared to what has happened since then.

The East Asian volatility spillover index increased briefly in March 2007, as the first signs of cracks in the thin ice of sub-prime loan market appeared as several loan providers declared bankruptcy while others stopped providing loans. The situation turned uglier in August 2007. On August 1st two hedge funds managed by Bear Stearns declared bankruptcy. On Thursday August 9th a sudden liquidity squeeze and a resulting spike in the interbank lending rate forced the European Central Bank to inject €94.8 billion into the money markets. Equity markets reacted vehemently, with a jump in the volatility spillovers all around the world. The next major jump in the volatility index took place in the last ten days of January 2008, when the Federal Reserve's Federal open market Committee met on a holiday to lower the Fed Funds target rate by one full point and inject more liquidity in money markets in order to ease the increasing worries about the financial health of the major American banks. Finally, the U.S. financial crisis turned into a global financial crisis as Lehman Brothers declared bankruptcy in mid-September 2008. Following the Lehman Brothers' collapse, the U.S. Treasury decided to prevent the imminent collapse of AIG, the largest insurance group in the world, and a possible financial meltdown. Following these developments by the end of September 2008 the East Asian volatility spillover index reached to 80% level. Since then it declined only slightly to 77% (Figure 2).

So far we have shown that the volatility spillover index displays significant bursts during the major financial crises and jumps during the shocks that may have some brief or lasting impact on equity markets. The return spillovers, on the other hand, displayed significant burst only after the collapse of the Lehman Brothers in mid-September 2008.

One crucial shortcoming of the Cholesky factorization upon which the variance decomposition analysis stands is that it is not robust to ordering of the markets. For that reason, it is crucial to see whether our spillover index measure is sensitive to the ordering of markets. Unfortunately, since there are 10 markets in our analysis we cannot calculate the spillover index for all possible (which amounts to 10!) orderings of markets. Instead, we consider only 10 rotated orderings of markets. First we obtain the spillover index with the original ordering of markets reported in Tables 3 and 4. Then we move Hong Kong to the end of the list, making Japan the first country followed by Australia, Singapore and so on. Then we move Japan to the end of the market list, making Australia the first and so on. Once we calculate the spillover index for all 10 rotated orderings we calculate the median, maximum and minimum values of the index and plot the range and the median values for return and volatility spillover indices in Figures 3 and 4, respectively. Figures 3 and 4 leave no room to suspect that the ordering of markets makes a big difference. Irrespective of the ordering the return and volatility spillover indices follow the same path as with the original ordering. Therefore, we can easily conclude that our return and volatility spillover indices are robust to the ordering of the East Asian equity markets.

So far we have not included two important Asian countries, China and India, in our analysis. Both markets are important among the Asian financial markets. Nevertheless, in the early 1990s stock markets in both countries were not as open to outside investors as others in our analysis. Furthermore, daily Open-High-Low-Close values for the Shanghai Stock Exchange had become available only after December 1994. As a result, when we include Shanghai SE

Composite Index and Bombay SE Sensex Index, our analysis is confined to December 1994-April 2009.

We present the return and volatility spillover indices for 12 Asian countries in Figures 5 and 6. The inclusion of China and India in the analysis does not lead to a major change in the return spillover index until 2002. The 12-country return spillover index (including India and China) started to occasionally deviate from the original 10-country return spillover index in 2002. The difference between the two indices became more persistent from 2004 until the liquidity crisis in August 2007. The difference between the two indices is directly linked to investors around the world paying more attention to Chinese and Indian stock markets. As the US sub-prime crisis evolved into a global financial crisis the difference between the 10-country and 12-country return spillover indices disappeared since August 2007. This is quite understandable, as the main driving force of the return spillovers in the region as elsewhere in the world since the liquidity crisis of August 2007 has been the news coming out of the U.S. markets.

With the inclusion of China and India the volatility spillover index is 5-to-10 percent higher for most of the period considered. Similar to the return spillovers index, the importance of Chinese and Indian stock markets for volatility spillovers increased slightly since 2001. Before then, the 12-market volatility spillover index did not differ as much from the 10-market volatility spillover index. Both in terms of return and volatility spillovers across markets Chinese and Indian markets have become more important since 2001 and 2002.

Finally, we analyze how important are the spillovers from and to the U.S. for the East Asian markets. We, therefore, include the Dow Jones Industrials Average (DJIA) to represent the U.S. stock markets in our analysis. The resulting 10-country and 11-country return and volatility spillover indices are presented in Figures 7 and 8. The inclusion of the U.S. stock markets has more impact on both return (around 5 percentage points) and volatility (around 10 percentage points) spillover indices than the inclusion of the Shanghai and Bombay stock exchanges. This result clearly shows that the East Asian markets have always looked at U.S. markets for direction, but Chinese and Indian markets were more or less isolated from the East Asian markets throughout the 1990s. They have become more important throughout 2000s, commensurate with the role these economies play in recent years.

## 4. Conclusions

We applied the Diebold-Yilmaz (2009a) spillover index methodology to 10 major East Asian stock markets to study the behavior of return and volatility spillovers across the region over the 1992-2009 period. Using rolling sub-sample windows we show that volatility and return spillovers behave very differently over time, during crisis and non-crisis episodes.
Plots of volatility spillovers leave no doubt that it is the burst in volatility spillovers across markets rather than the return spillovers that takes place during the major crises.

As a result of increased market integration throughout the 1990s East Asian stock markets had become more interdependent as captured by the increase in return spillovers in the mid-1990s. Even after the major emerging market crises the return spillovers had not declined to the levels in the early 1990s. With the global financial crisis of 2008 return spillovers in the East Asia region also reached the highest level. The burst in the return spillover index reflects the systemic nature of the current global financial crisis.

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**Table 1: Summary Statistics, East Asian Stock Market Returns**

| | Australia (AUS) | Hong Kong (HKG) | Indonesia (IDN) | Japan (JPN) | S. Korea (KOR) | Malaysia (MYS) | Philippines (PHL) | Singapore (SGP) | Taiwan (TAI) | Thailand (THA) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Mean** | 2.019 | 5.032 | -0.395 | -5.700 | 0.389 | 0.380 | -3.875 | 1.074 | -0.611 | -5.833 |
| **Median** | 10.042 | 10.702 | 7.533 | 3.413 | 7.559 | 2.862 | -0.857 | 5.912 | 11.031 | 1.163 |
| **Maximum** | 421.86 | 748.28 | 943.40 | 601.06 | 909.26 | 1254.68 | 831.35 | 962.62 | 979.79 | 1124.17 |
| **Minimum** | -919.06 | -1044.09 | -1225.94 | -1446.32 | -1191.44 | -993.31 | -1153.35 | -1255.87 | -736.00 | -1375.55 |
| **Std. Dev.** | 100.41 | 190.19 | 206.32 | 162.33 | 224.09 | 165.84 | 188.58 | 168.05 | 188.32 | 206.91 |
| **Skewness** | -1.146 | -0.440 | -0.514 | -0.785 | -0.404 | 0.099 | -0.424 | -0.650 | -0.044 | -0.163 |
| **Kurtosis** | 12.019 | 5.748 | 7.996 | 10.364 | 6.588 | 10.695 | 7.377 | 11.528 | 4.957 | 6.936 |
| **Jarque-Bera** | 3261.48 | 313.47 | 980.07 | 2135.37 | 509.57 | 2231.88 | 748.75 | 2803.34 | 144.56 | 587.60 |

Notes: Returns are in real terms and measured weekly, Friday-to-Friday. The sample size is 904. See text for details.

**Table 2: Summary Statistics, East Asian Stock Market Volatilities**

| | Australia | Hong Kong | Indonesia | Japan | S. Korea | Malaysia | Philippines | Singapore | Taiwan | Thailand |
|---|---|---|---|---|---|---|---|---|---|---|
| **Mean** | 10.878 | 20.268 | 17.530 | 18.339 | 22.297 | 15.382 | 15.674 | 13.558 | 18.602 | 20.686 |
| **Median** | 9.289 | 17.000 | 14.004 | 16.560 | 18.647 | 11.457 | 13.493 | 10.955 | 16.340 | 17.212 |
| **Maximum** | 73.710 | 140.464 | 103.838 | 117.594 | 108.528 | 154.519 | 96.679 | 99.918 | 84.585 | 110.686 |
| **Minimum** | 2.313 | 2.843 | 0.454 | 3.129 | 0.021 | 1.515 | 1.570 | 0.568 | 2.209 | 4.437 |
| **Std. Dev.** | 7.015 | 13.783 | 14.021 | 10.137 | 14.671 | 13.857 | 10.590 | 11.012 | 10.220 | 12.548 |
| **Skewness** | 3.534 | 3.230 | 2.087 | 2.927 | 1.937 | 4.330 | 2.920 | 2.616 | 1.492 | 2.187 |
| **Kurtosis** | 22.698 | 20.622 | 9.001 | 20.131 | 8.307 | 32.595 | 17.401 | 14.226 | 6.997 | 10.374 |
| **Jarque-Bera** | 16496.4 | 13269.0 | 2012.9 | 12344.9 | 1626.0 | 35815.5 | 9095.9 | 5777.6 | 937.3 | 2769.0 |

Notes: Volatilities are for Monday-to-Friday returns. The sample size is 904. See text for details.

**Table 3: East Asian Return Spillovers, Full Sample**

| | HKG | JPN | AUS | SGP | IDN | KOR | MYS | PHL | TAI | THA | Contribution From Others |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **HKG** | 98.2 | 0.0 | 0.2 | 0.1 | 0.1 | 0.0 | 0.3 | 0.0 | 0.2 | 0.9 | 1.8 |
| **JPN** | 17.0 | 81.3 | 0.2 | 0.1 | 0.4 | 0.1 | 0.1 | 0.3 | 0.3 | 0.2 | 18.7 |
| **AUS** | 30.5 | 10.6 | 57.7 | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 | 0.5 | 0.1 | 42.3 |
| **SGP** | 44.9 | 3.9 | 1.2 | 47.6 | 0.1 | 0.1 | 0.2 | 0.3 | 0.4 | 1.4 | 52.4 |
| **IDN** | 16.4 | 3.4 | 1.2 | 5.3 | 71.2 | 1.1 | 0.1 | 0.1 | 0.2 | 0.9 | 28.8 |
| **KOR** | 19.8 | 6.9 | 1.6 | 2.7 | 0.6 | 67.0 | 0.0 | 0.1 | 0.0 | 1.3 | 33.0 |
| **MYS** | 19.6 | 1.2 | 0.5 | 7.3 | 4.0 | 0.3 | 65.9 | 0.2 | 0.2 | 0.9 | 34.1 |
| **PHL** | 20.4 | 1.4 | 2.5 | 5.9 | 4.7 | 0.2 | 1.1 | 62.3 | 0.3 | 1.3 | 37.7 |
| **TAI** | 15.1 | 4.6 | 0.5 | 2.1 | 0.5 | 1.7 | 0.5 | 0.7 | 73.9 | 0.5 | 26.1 |
| **THA** | 18.0 | 1.5 | 2.2 | 6.7 | 5.3 | 2.7 | 2.7 | 2.0 | 0.3 | 58.5 | 41.5 |
| **Contribution to Others** | 201.6 | 33.5 | 9.9 | 30.3 | 15.7 | 6.4 | 5.2 | 3.7 | 2.4 | 7.5 | 316.3 |
| **Contribution Including Own** | 299.8 | 114.9 | 67.5 | 77.9 | 87.0 | 73.4 | 71.1 | 66.0 | 76.3 | 66.0 | Index = 31.6% |

Notes: The underlying variance decomposition is based upon a weekly VAR of order 2, identified using a Cholesky factorization with the ordering as shown in the column heading. The (i, j)-th value is the estimated contribution to the variance of the 10-week-ahead stock return forecast error of country i coming from innovations to the stock return of country j. The mnemonics are defined as in Table 1.

## Table 4: East Asian Volatility Spillovers, Full Sample

| | HKG | JPN | AUS | SGP | IDN | KOR | MYS | PHL | TAI | THA | Contribution From Others |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **HKG** | 37.7 | 6.7 | 4.2 | 6.9 | 6.0 | 0.8 | 3.8 | 11.2 | 2.6 | 20.0 | 62.3 |
| **JPN** | 21.9 | 15.2 | 3.5 | 5.3 | 6.2 | 0.7 | 4.9 | 13.7 | 5.3 | 23.5 | 84.8 |
| **AUS** | 23.9 | 6.9 | 33.7 | 2.4 | 4.1 | 2.0 | 2.7 | 9.4 | 1.1 | 13.7 | 66.3 |
| **SGP** | 28.3 | 7.3 | 6.1 | 8.3 | 6.3 | 0.6 | 2.9 | 13.4 | 2.9 | 24.0 | 91.7 |
| **IDN** | 38.8 | 10.1 | 11.6 | 2.4 | 18.0 | 0.5 | 1.6 | 6.3 | 1.0 | 9.8 | 82.0 |
| **KOR** | 17.5 | 12.6 | 3.4 | 3.8 | 6.5 | 4.2 | 4.7 | 15.1 | 5.0 | 27.2 | 95.8 |
| **MYS** | 23.2 | 4.7 | 8.0 | 6.0 | 2.7 | 0.9 | 40.4 | 5.0 | 0.9 | 8.2 | 59.6 |
| **PHL** | 30.9 | 6.6 | 5.0 | 8.0 | 8.1 | 2.9 | 3.8 | 17.4 | 1.5 | 15.7 | 82.6 |
| **TAI** | 28.1 | 12.5 | 5.1 | 7.6 | 3.9 | 2.8 | 3.1 | 7.8 | 12.5 | 16.6 | 87.5 |
| **THA** | 19.3 | 4.5 | 4.8 | 1.8 | 14.5 | 0.6 | 6.0 | 10.8 | 2.3 | 35.3 | 64.7 |
| **Contribution to Others** | 232.0 | 71.9 | 51.6 | 44.2 | 58.1 | 11.9 | 33.3 | 92.7 | 22.8 | 158.7 | 777.1 |
| **Contribution Including Own** | 269.7 | 87.1 | 85.3 | 52.5 | 76.1 | 16.1 | 73.7 | 110.1 | 35.3 | 194.0 | Index = 77.7% |

Notes: The underlying variance decomposition is based upon a weekly VAR of order 2, identified using a Cholesky factorization with the ordering as shown in the column heading. The (i, j)-th value is the estimated contribution to the variance of the 10-week-ahead stock return volatility forecast error of country i coming from innovations to the stock return volatility of country j. The mnemonics are defined as in Table 1.

**Figure 1: East Asian Return Spillovers**

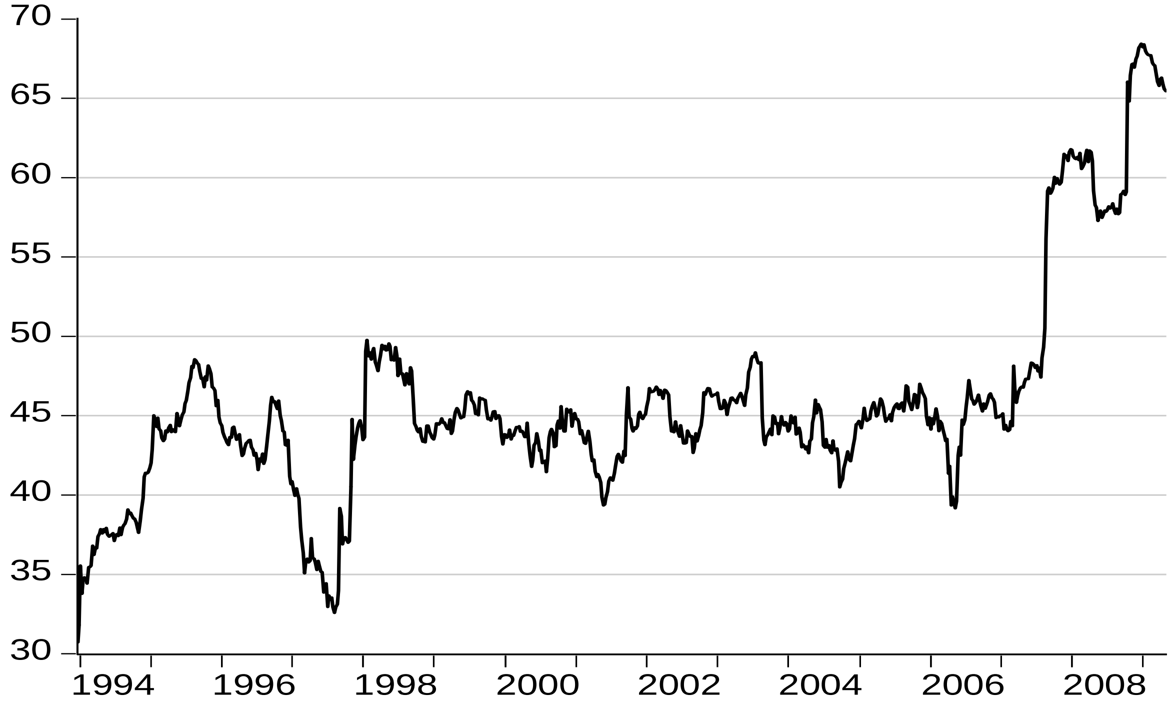


**Figure 2: East Asian Volatility Spillovers**

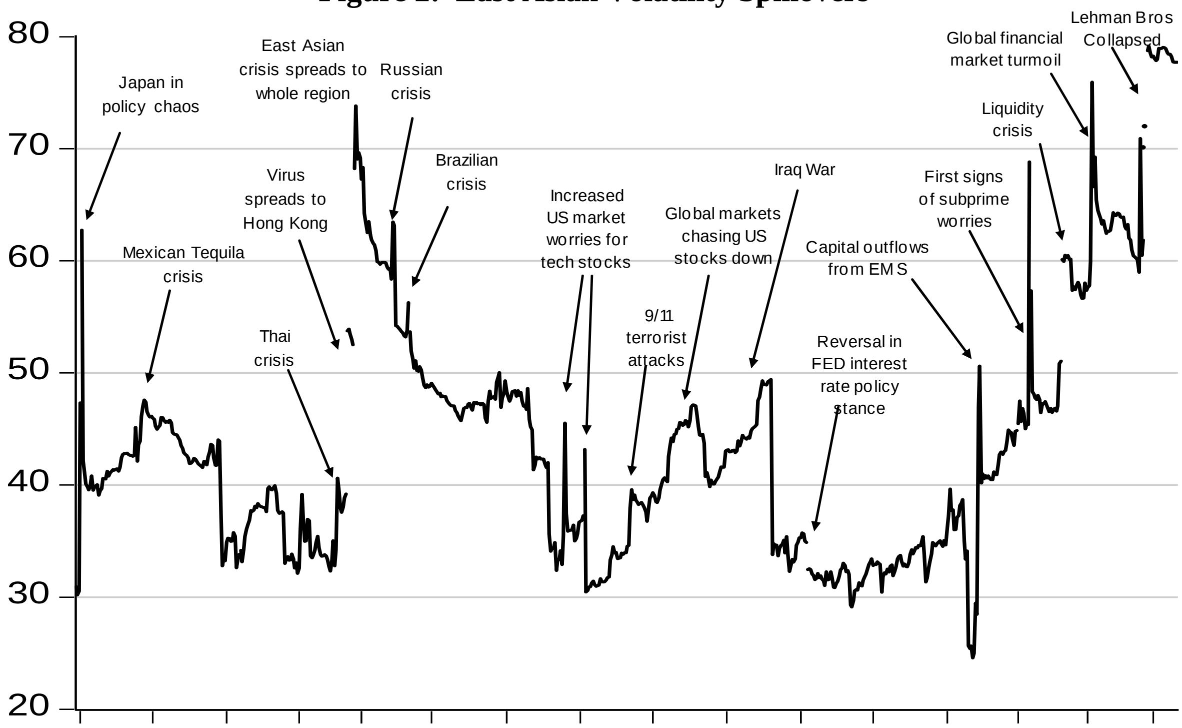

**Figure 3: East Asian Return Spillovers –**
**Median, Maximum and Minimum Values Based on 10 Rotated Orderings**

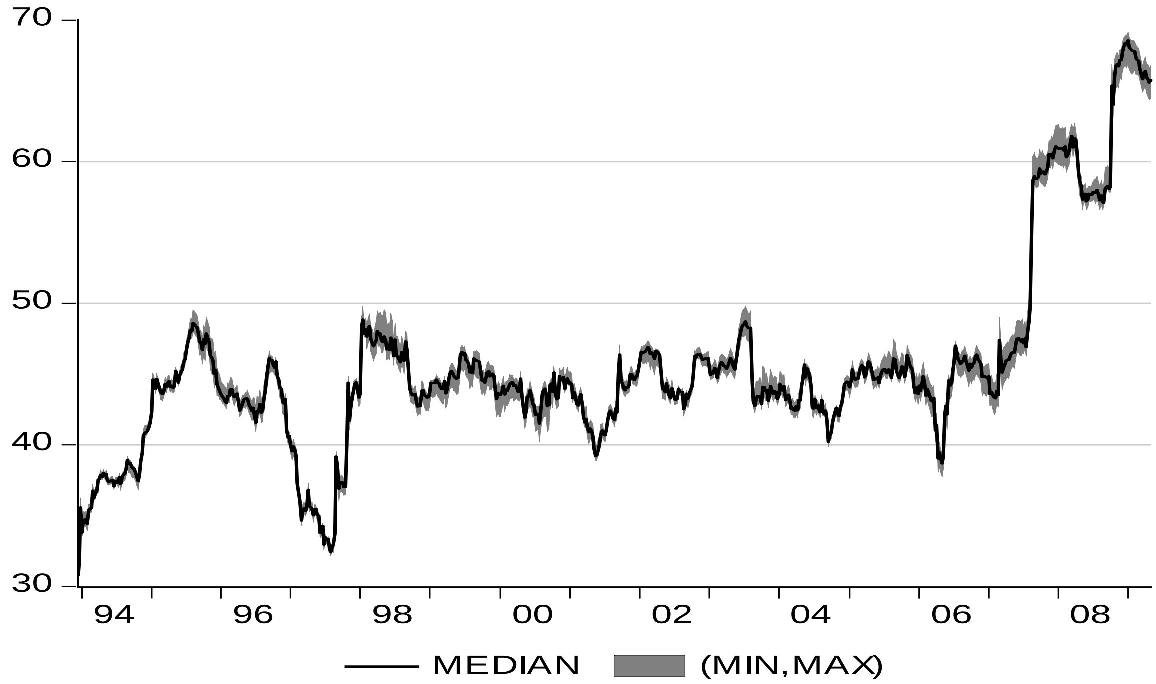


**Figure 4: East Asian Volatility Spillovers –**
**Median, Maximum and Minimum Values Based on 10 Rotated Orderings**

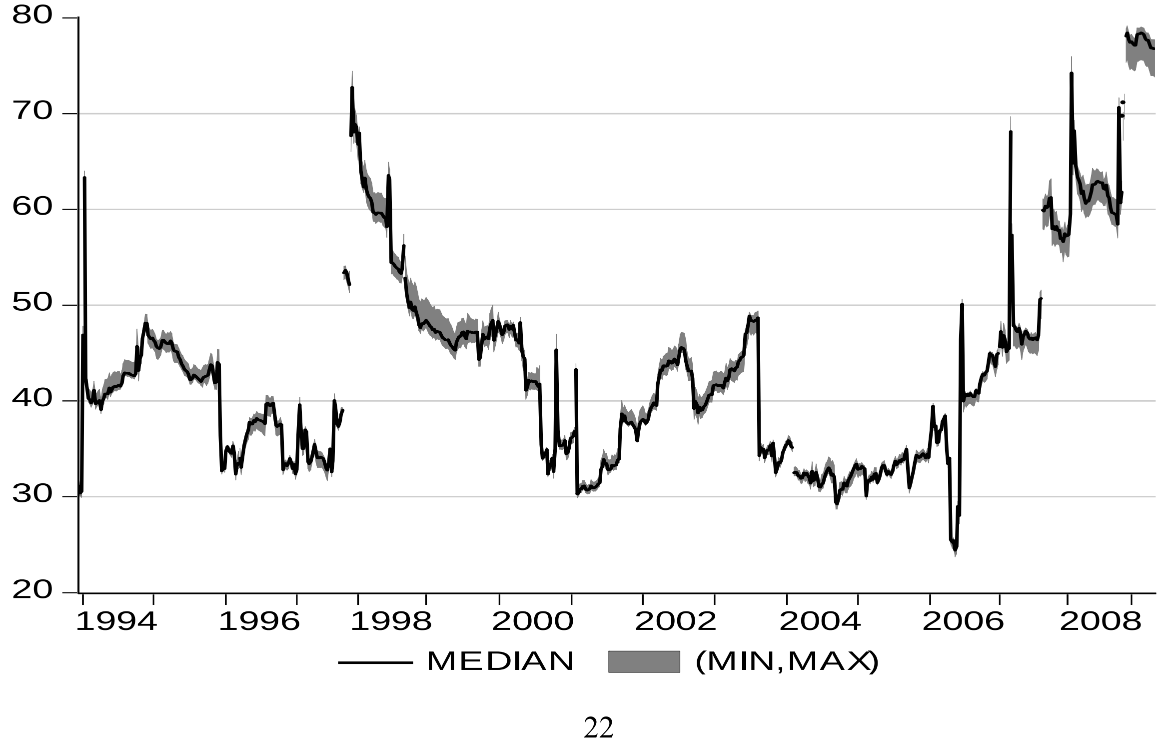

**Figure 5: East Asian Return Spillovers – Including China and India**

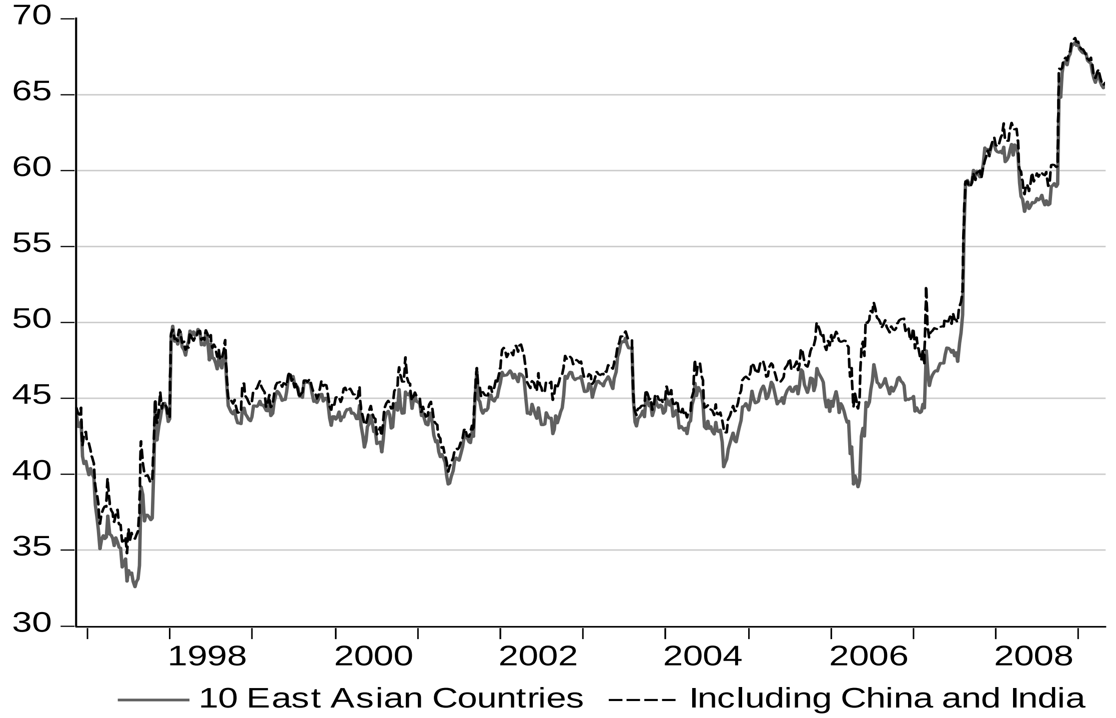


**Figure 6: East Asian Volatility Spillovers – Including China and India**

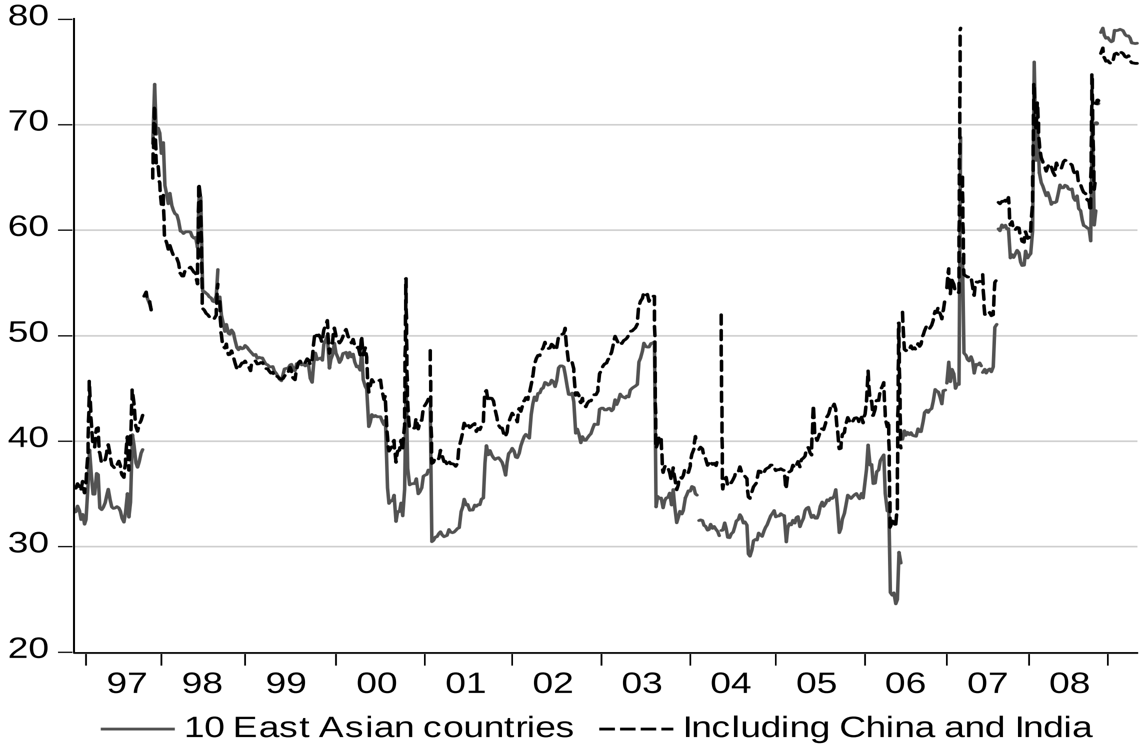

**Figure 7: East Asian Return Spillovers – Including the U.S.**

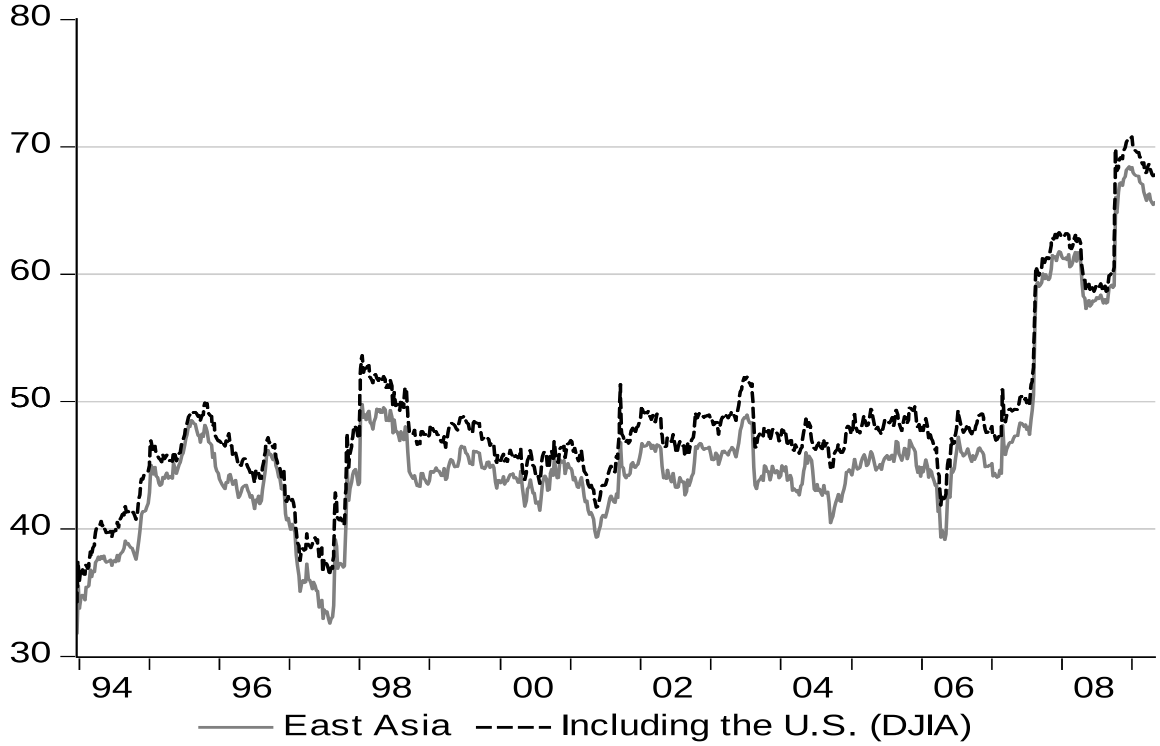


**Figure 8: East Asian Volatility Spillovers – Including the U.S.**