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Volatility contagion across the equity markets of developed and emerging market economies

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Volatility Contagion across the Equity Markets of Developed and Emerging Market Economies

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Abstract

Using variance risk premiums (VRPs) nonparametrically calculated from equity markets in selected major developed economies and emerging market economies (EMEs) over 2007–2015, we document the correlation of VRPs across the markets and examine whether equity fund flows work as a path through which VRPs spill over globally. First, we find that VRPs tend to spike up during market turmoil such as the peak of the global financial crisis and the European debt crisis. Second, we find that all cross-equity market correlations of VRPs are positive, and that some economy pairs exhibit high levels of the correlation. In terms of volatility contagion, we find that an increase in VRPs in the United States significantly reduces equity fund flows to other developed economies, but not those to EMEs, in the period after the global financial crisis. Two-stage least squares estimation results show that equity fund flows are a channel for spillover of VRPs in the United States to VRPs in other developed economies.

JEL Classification: F32, G12, G15, G23

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1. INTRODUCTION

The recent global financial crisis of 2007–2009 has prompted renewed academic interest in financial market volatility. In particular, many researchers have found that fluctuations in a measure of volatility such as the Chicago Board Options Exchange Market Volatility Index (in short, the VIX index) are strongly associated with variations in asset prices, leverage, credit provision, capital flows, and, more generally, financial conditions. At the same time, more attention has been given to the pricing and volatility of the VIX index, which has been traded at the Chicago Board Options Exchange since 2004 as a financial product.

Since the variance of asset returns fluctuates over time (that is, volatility itself is volatile), variance is accompanied by risk premium, namely variance risk premium (VRP). VRP is a natural extension of the general risk premium required for return risk, and is defined as the difference between variance, or more formally quadratic variations, under the real probability measure and that under the risk-neutral measure. The estimator of the former is known as realized variance (RV) computed from intra-day price data. The estimator of the latter is known as the model-free implied volatility (IV) or the VIX index, which has been established and widely used in the financial industry. Among several methods of deriving VRPs that have been proposed, we employ the simplest nonparametric one, in which VRP is defined as the difference between ex-post 1-month RV and 1-month IV measured on the same trading day. Nonparametric VRP is one of the well-known concepts for estimating VRPs. After we derive VRPs for each equity market for the economies in our sample, we calculate VRP correlations across markets and investigate the impact of investor flows to equity funds based in the United States (US) on the correlations.

In recent years, both academics and practitioners have paid growing attention to VRP and volatility contagion. Central bank researchers started to pay attention to VRP as a proxy for market risk aversion. Raczko (2015) investigates cross-border contagion of crash and non-crash risks using VRPs. Barras and Malkhozov (2015) discuss the difference between VRPs embedded in equity portfolios and those implied in option prices. Feunou, Jahan-Parvary, and Okou (2015) show that the term structure of variances reveals two important drivers of the bond premium, that is, the equity premium and the variance premium.

Among academics, Aït-Sahalia, Cacho-Diaz, and Laeven (2015) develop a jump contagion model using mutually exciting jump processes. Bekaert et al. (2014) analyze transmission of a financial crisis across 415 economy–industry equity portfolios and find that economy-specific factors have a larger impact than US-related and global factors. Maneesoonthorn et al. (2012) measure premiums for variance-jump and variance-diffusive risks, assuming variance itself jumps. Bollerslev and Todorov (2011) develop a method to measure risk premium for price jumps and highlight the time-varying nature of investors' fear. Many other papers in the literature have also addressed VRPs, such as Broadie, Chernov, and Johannes (2007), Carr and Wu (2009), Bollerslev, Tauchen, and Zhou (2009), and Bollerslev et al. (2011).

The aforementioned papers have deepened our understanding of the methods to estimate VRP and of its features such as cross-equity market correlations among developed economies. This paper extends the cross-equity market correlations of VRP to include several emerging market economies (EMEs).

A novel contribution of this paper is that it considers a specific channel of contagion from VRP in the US equity market to VRP in other economies' equity markets via equity fund flows.¹ In particular, we employ a two-step approach: the first step considers the impact of the US VRP on global equity fund flows to other economies; and the second step considers the impact of equity fund flows to the economies on their respective VRPs.

The weekly data on global equity fund flows from EPFR Global are useful for our analysis. This is because the impact of changes in VRP on equity flows is better captured by looking at relatively high frequency data, and equity fund flows are known to be strongly correlated with measures of global investors' risk appetite such as the VIX index.

We first conduct a simple ordinary least squares (OLS) estimation to gauge the impact of the US VRP on global equity fund flows to seven economies—that is, two developed economies (the eurozone and Japan) and five EMEs (the People's Republic of China; Hong Kong, China; India; the Republic of Korea; and Mexico)—as well as to two regional groups—that is, all developed economies (excluding the US) and all EMEs. We split the whole sample period into two subsample periods: one for the turbulent crisis period of 2007–2009 and the other for a relatively stable time after the crisis period. We attempt to detect any qualitative difference between the two periods of distinctive features.

In the global financial crisis period, we find the US VRP is a significant explanatory variable for the equity fund flows to India and Japan, with somewhat weak significance for India. In the post-crisis period, the US VRP is a significant explanatory variable for Japan, as it is in the earlier sample period, and also for developed eurozone economies and Hong Kong, China. As for the equity fund flows to the two distinct regional groups, the US VRP strongly influences equity fund flows to developed economies excluding the US in the post-crisis period in contrast to its insignificance during the global financial crisis period.

Next, we use a standard two-stage least squares (2SLS) estimation method to empirically implement the two-step approach outlined above. In the first stage regression, we find that the estimated effect of the US VRP on the equity fund flows to the developed economies and EMEs differs between the two subsample periods: in the global financial crisis period, the US VRP is generally a significant explanatory variable for the EMEs; but in the post-crisis period, it is significant only for the developed economies. In the second stage regression, the fitted value of the equity fund flows has a significant impact on the VRP only for the eurozone and Japan in both subsample periods. It is also clear that VRP is strongly autoregressive for Hong Kong, China; India; the Republic of Korea; and Mexico. We can conclude that the results of the 2SLS regression analysis point to a spillover path of the US VRP to the equity markets in developed economies via equity fund flows, and that the finding is more robust in the post-crisis period.

The literature on the determinants of equity portfolio flows mainly focuses on global (or push) factors, regional factors, and local (or pull) factors. The VIX index is one of the global factors often used as a measure of global investors' risk appetite, but other

¹ Conceptually, we can think of the following three distinct channels of contagion from the variance risk premium of the US equity market to the variance risk premium of another economy's equity market: (1) direct contagion via changes in the general risk appetite of common investors in both markets, (2) indirect contagion through equity fund flows mainly driven by retail investors, and (3) indirect contagion through other equity flows by institutional investors such as insurance companies and pension funds. This paper tries to show the existence and significance of the second channel.

global factors such as the Treasury and Eurodollar (TED) spread are also used.² In particular, IMF (2015) shows that an increase in the VIX index by one standard deviation tends to be associated with a decline of around 33% in monthly investor flows to equity funds, and that mutual fund investors shift away from equity funds to government bond funds when the VIX index rises.

Lo Duca (2012) considers a model where regression coefficients endogenously change over time to see how the drivers of equity fund flows to EMEs change across different periods. He finds that investors pay more attention to regional developments in EMEs when market tensions are elevated, such as the period before the bankruptcy of Lehman Brothers (between August 2007 and mid-September 2008), the peak of sovereign debt problems in Europe in 2010, and the downgrade of the credit rating of the US in August 2011. In contrast, he finds that in the aftermath of the Lehman Brothers' bankruptcy, a general loss of confidence due to elevated market uncertainty measured by the average of the VIX index for the US and the DAX Volatility (VDAX) index for the eurozone was an important factor driving equity fund flows. Our paper is different from others in the sense that we focus on VRP, which is derived from the VIX index, not the VIX index itself. In other words, we aim to distill the risk premium itself associated with the volatility of equity returns and investigate its impact on cross-economy equity fund flows.

2. VARIANCE RISK PREMIUM

2.1 Definition of Variance Risk Premium

We obtain VRP by subtracting IV from ex-post 1-month average (backward-moving average) of RVs. This is the simplest estimate of VRP, and the background assumption is also simple: it assumes that option sellers set 1-month IV by adding an additional volatility risk premium to the past 1-month historical volatility. This estimate does not rely on any specific models to formulate development of asset return and volatility in question.

We define VRP by subtracting volatility under the risk-neutral probability measure (IV) from that under the real measure (RV), not vice versa, thereby making our definition consistent with the literature on risk premium of returns on a risky asset. With this definition, VRP is generally negative. This is because IV captures the risk of future volatility fluctuation and IV tends to be set higher than RV. Strictly speaking, in theory, a positive value of the VRP defined here does not make economic sense; traders should not get negative returns for bearing risks associated with uncertainty of volatility. In estimation, however, we may obtain positive values of VRP depending on the estimation method, as we see in section 2.3.

2.2 Data

This paper considers seven major equity indexes for underlying assets, i.e., Nikkei 225 in Japan (Nikkei), KOSPI 200 in the Republic of Korea (KOSPI), Hang Seng index in Hong Kong, China (HSI), NSE NIFTY index in India (NIFTY), EuroSTOXX 50 in the eurozone (EuroSTOXX), Mexican Bolsa IPC index (MEXBOL), and the S&P 500 index in the US (SPX). The sample period starts from the beginning of November 2007 and

² See IMF (2014) for a detailed discussion and a list of possible global factors relevant for equity portfolio flows.

ends at the end of September 2015. Because the estimation incorporates IV, data on the implied volatility indexes for the selected underlying assets should be available, or be calculated retroactively up to 2007. The sample period starts from the date when the time series of the implied volatility index for the Indian equity market (India VIX) started, which was released latest among all the indexes.

The data for RV is obtained from the Oxford-Man Institute's Realized Library (Heber et al. 2009). Several methods have been proposed for the computation of RV. We employ the standard one which uses 5-minute returns. The corresponding IV is obtained from various sources chosen as follows: Nikkei VI for Nikkei released from the Japan Exchange Group, VKOSPI for KOSPI from the Korean Stock Exchange, VHSI for HSI from the Hong Kong Stock Exchange, India VIX for Nifty from the National Stock Exchange of India, VSTOXX for EuroSTOXX from Eurex, VIMEX for MEXBOL from Mexdar, and VIX for SPX from the Chicago Board Options Exchange. All data are converted into annual rates in the variance dimension. Weekends, national holidays, and market closing dates of individual economies are excluded from the sample. In particular, if the market of at least one economy is closed, the whole data on the date are excluded from the sample. As the number of missing data is large for Hong Kong, China, its VRP is separately estimated from other EMEs. Daily estimates of VRP are converted to weekly averages to be consistent with the frequency of equity fund flow data we use in this paper.

2.3 Variance Risk Premium Estimates

Figure 1 plots the estimates of VRP for each economy's equity market. During market turmoil such as the Lehman Brothers' bankruptcy or the European sovereign debt crisis, VRPs widen their negativity. This indicates that market risk aversion dramatically increased during those crises, making the options quite expensive.

Another feature is that the VRPs take negative values almost throughout the sample period for all economies, while they sometimes have spikes into positive territory before they drop substantially into negative territory. This means that if traders sell options assuming historical volatility as a reasonable level of future volatility, they would incur losses because volatility spikes up more than the risk premium. But we also believe that the positive values can be a result of assumptions for a nonparametric approach to VRP estimation as explained earlier. Therefore, we exclude weeks with positive VRP from samples when we quantitatively estimate the relationship between levels of VRP and other economic variables including equity fund flows in section 4.

Figure 1: Variance Risk Premium Calculated from the Equity Market
(in annual rate gap in variance dimension)

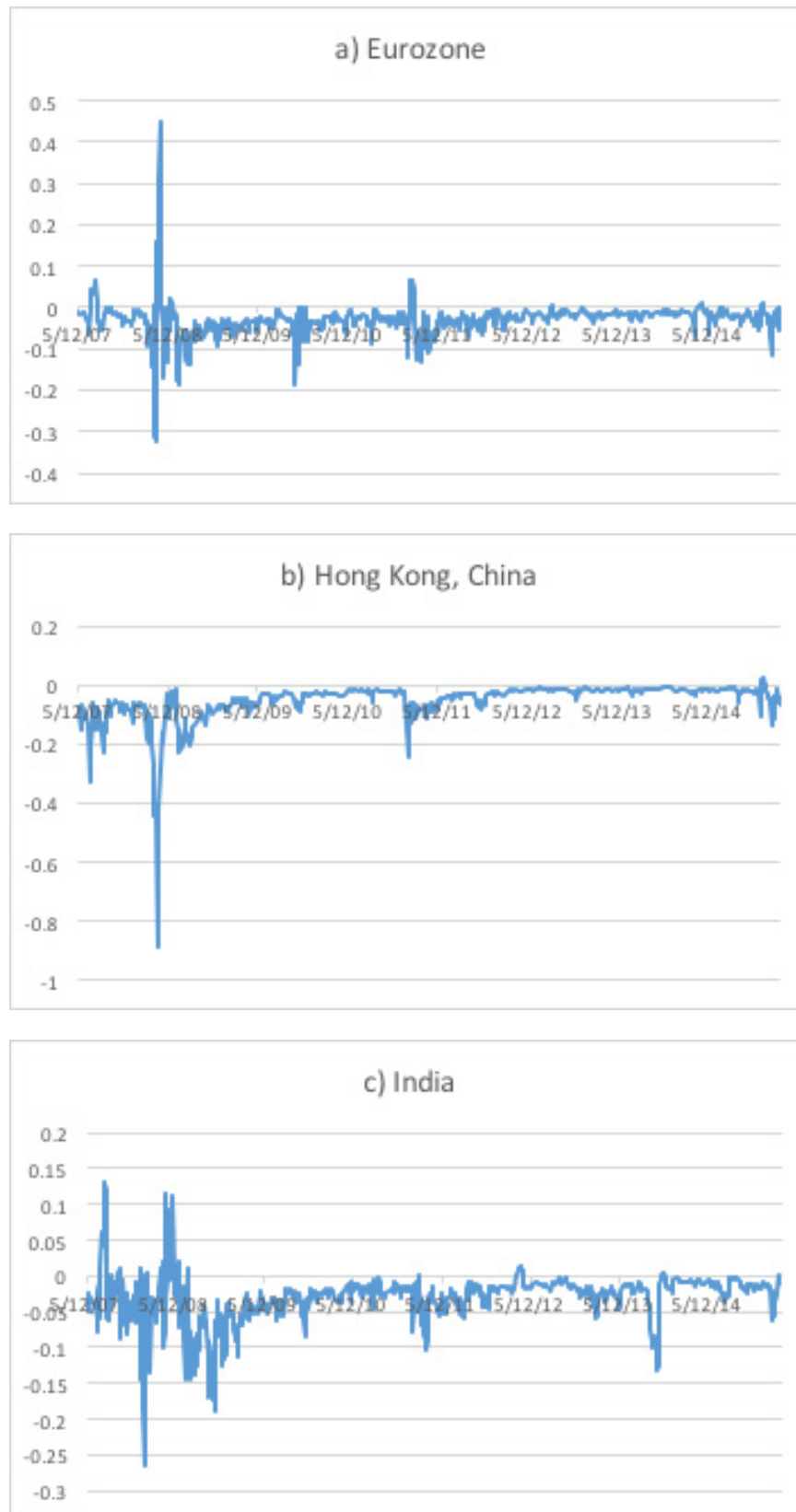


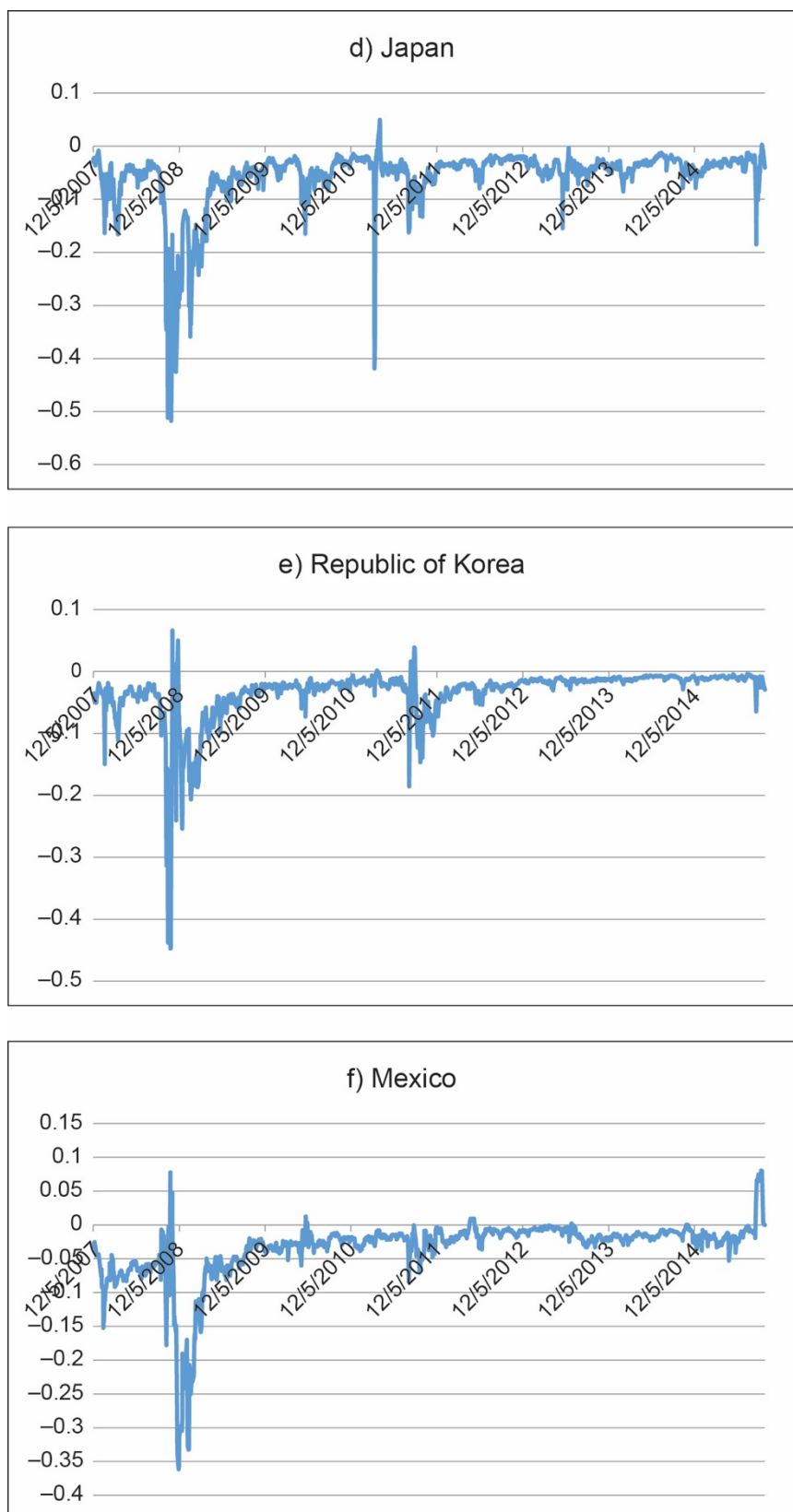
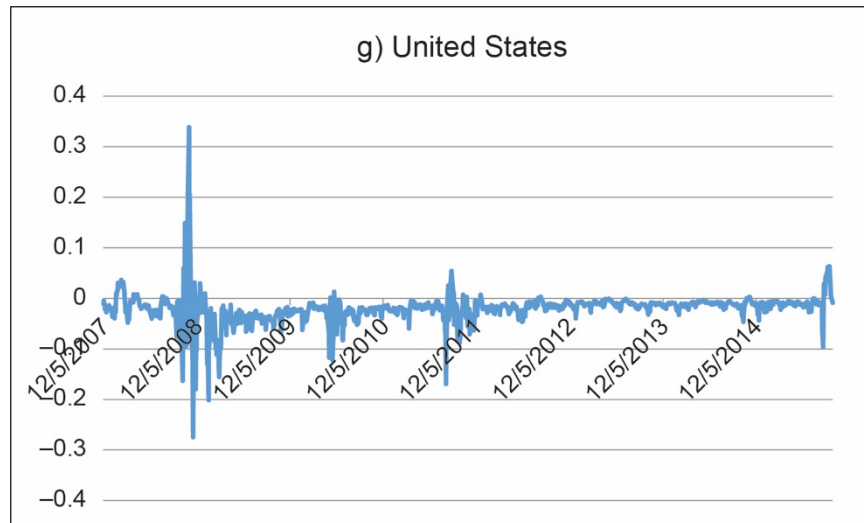
Figure 1 continued

Figure 1 continued

Sources: Chicago Board Options Exchange; Eurex; Hong Kong Stock Exchange; Japan Exchange Group; Korean Stock Exchange; Mexdar; National Stock Exchange of India; Oxford-Man Institute's Realized Library; authors' calculation.

2.4 Cross-Equity Market Correlation of Variance Risk Premium

Table 1 summarizes cross-equity market correlations of VRP. The correlations are positive for all pairs of economies. Some pairs have relatively high correlations. In particular, the correlation between the US and the eurozone is high, and the pairs of East Asian economies, i.e., Japan–Republic of Korea; Hong Kong, China–Republic of Korea; and Hong Kong, China–Japan, also have high correlations.

Table 1: Cross-Equity Market Correlations of Variance Risk Premiums

	Japan	Republic of Korea	Hong Kong, China	India	Eurozone	Mexico	United States
Japan	1.00	0.75	0.69	0.09	0.18	0.62	0.25
Republic of Korea	0.71	1.00	0.80	0.29	0.33	0.52	0.33
Hong Kong, China	0.62	0.77	1.00	0.26	0.37	0.43	0.34
India	0.09	0.27	0.17	1.00	0.38	0.22	0.32
Eurozone	0.18	0.36	0.31	0.38	1.00	0.32	0.84
Mexico	0.63	0.55	0.49	0.23	0.32	1.00	0.42
United States	0.31	0.40	0.37	0.35	0.76	0.37	1.00

Note: Figures in the lower triangle indicate timing correlations with one-day difference, while those in the upper triangle indicate contemporaneous correlations.

Sources: Chicago Board Options Exchange; Eurex; Hong Kong Stock Exchange; Japan Exchange Group; Korean Stock Exchange; Mexdar; National Stock Exchange of India; Oxford-Man Institute's Realized Library; authors' calculation.

3. EQUITY FUND FLOW DATA AND GLOBAL AND LOCAL FACTORS

We obtain data on equity fund flows from EPFR Global. In particular, we use the EPFR data on the estimated investor flows to individual economies calculated for all equity funds available in the country flow database. Considering that new funds are added

over time to the EPFR database, we need to control for a potential bias created by the entry of new funds in the database. One way to do this is to normalize flows by dividing the total amount of flows into funds by the sum of the value of assets under management by the funds (that is, flows/net asset value [NAV]).³

Table 2 provides a matrix of cross-economy correlations of equity fund flows to all pairs of economies among the seven individual economies and the eurozone we consider in the previous section. We find that correlations involving a developed economy (cells highlighted in yellow and green) are much lower than those involving only EMEs. Another finding is that the correlations between equity fund flows to the US and those to the other economies in Table 2 are positive, but that the average value of the correlations involving the US is lower than the average value of the correlations involving any other economy.

Table 2: Cross-Economy Correlation of Normalized Equity Fund Flows
(flows/NAV)

	People's Republic of China	Hong Kong, China	India	Republic of Korea	Mexico	Euro- zone	Japan	United States
People's Republic of China	1.00	0.54	0.59	0.54	0.47	0.19	0.02	0.12
Hong Kong, China		1.00	0.76	0.66	0.54	0.34	0.21	0.15
India			1.00	0.76	0.67	0.27	0.10	0.10
Republic of Korea				1.00	0.70	0.20	0.12	0.13
Mexico					1.00	0.16	0.07	0.14
Eurozone						1.00	0.35	0.13
Japan							1.00	0.16
United States								1.00

NAV = net asset value.

Note: Weekly data from the beginning of November 2007 to the end of September 2015 (413 weeks).

Sources: EPFR Global; authors' calculation.

Figure 2 shows the two normalized country flow series, as an example, one for Japan and the other for the US. The green cell in Table 2 shows that their correlation is relatively low at 0.16.

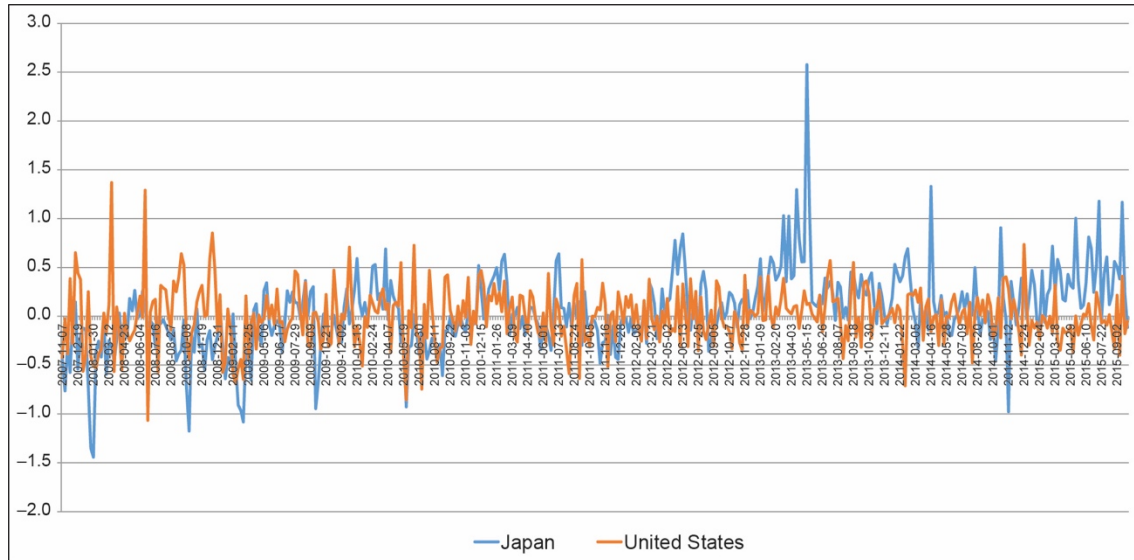
In the empirical analysis, we consider global and local factors as control variables. For global factors, in addition to VRP related to the VIX, we consider a “world” nominal short-term interest rate.⁴ As a local factor reflecting economy fundamentals, we use the Citi Economic Surprise Index from Bloomberg. An increase in this index means positive surprise. Finally, in order to capture the return-chasing behavior of retail investors in equity mutual funds and exchange-traded funds (ETFs), whose performance is measured by US dollar returns, we consider Morgan Stanley Capital International (MSCI) economy-level (or region-level) US dollar total return indexes. It should be

³ To be precise, it is calculated as (US dollar amount of net inflows during week t) ÷ (US dollar value of NAV at the beginning of week t) in percent. The value of assets at the beginning of week t is the same as the value at the end of week $t-1$. NAV stands for net asset value.

⁴ We calculate the world interest rate as a weighted average of short-term interest rates in developed economies (Canada, France, Germany, Italy, Japan, the Netherlands, Norway, Spain, Switzerland, Sweden, the United Kingdom, and the United States) and EMEs (Argentina; Brazil; Chile; the People's Republic of China; Colombia; the Czech Republic; Hong Kong, China; Hungary; India; Indonesia; the Republic of Korea; Mexico; Malaysia; Peru; the Philippines; Poland; Russian Federation; Singapore; Taipei, China; Thailand; Turkey; and Viet Nam) using 2005 purchasing power parity-adjusted gross domestic product as weights.

noted that the US dollar return is the sum of the foreign exchange return over a period and the local currency total return on equities.

Figure 2: Normalized Equity Fund Flows to Japan and the United States (%)



Note: Weekly data from the beginning of November 2007 to the end of September 2015 (413 weeks).

Sources: EPFR Global; authors' calculation.

4. QUANTITATIVE ANALYSIS ON A CROSS-EQUITY MARKET SPILLOVER CHANNEL FOR VARIANCE RISK PREMIUM

In section 2.4, we report cross-equity market correlations of VRP. We find that some pairs of markets in the sample economies have a very high correlation of VRP, although the correlation coefficients differ across market pairs. The difference in the correlations draws our attention, as in other papers that consider these correlations, and motivates us to investigate the cause.

In this section, we discuss a possible link between cross-equity market variance risk spillover and equity fund flows via mutual funds, specifically the US-based mutual funds. With the dominant presence of the US-based mutual funds in the global mutual fund flows, variations in the fund flows could influence the equity markets of the investment destinations. Our conjecture is that variations in VRP in the US market would affect the equity fund flows, and the variation in fund flows in turn would cause volatility of the equity prices of a market in which these funds invest, thereby affecting VRP in the market. It is possible that such a link works as a mechanism generating the cross-economy correlations of VRPs.

We follow a two-step approach to investigate the possible link. First, we try to assess the degree of fund flow variations explained by the US VRP, by conducting simple OLS estimation. Second, we try to gauge the impact of the US VRP on the variation in VRPs in other economies via the equity fund flows, by conducting 2SLS regressions.

4.1 Univariate Ordinary Least Squares Analysis

Tables A1 and A2 in the appendix show the results from regressions of equity fund flows to investment destinations on the US VRP. Table A1 summarizes the results for the sample period from November 2007 to December 2009 that we assume as the global financial crisis period, while Table A2 is for the sample period from January 2010 to September 2015 that we call the post-crisis period. The fund flow data, i.e., the dependent variable, are weekly flows/NAV. The VRPs used in the regressions are weekly averages of the estimated daily VRPs reported in section 2.

We have some notable findings. First, as expected, the US VRP is a significant explanatory variable for the equity fund flows into the equity funds designated to invest in the US markets in both sample periods. In the global financial crisis period (Appendix, Table A1), it is also a significant explanatory variable for the equity fund flows to India and Japan, despite somewhat weak significance for India. The positive sign on the coefficient is what we expect: the larger the US VRP becomes, i.e., more negativity, the smaller the amount of funds flowing via equity funds to non-US economies. In contrast, the US VRP is not a significant explanatory variable for the equity fund flows to developed eurozone economies; the People's Republic of China; Hong Kong, China; the Republic of Korea; and Mexico. In terms of R-squared, the US VRP as the single explanatory variable explains more than 10% of the variation of the equity fund flows to Japan, which is even more influential than the US VRP is for the equity fund flows to the US markets.

In the post-crisis period (Appendix, Table A2), the US VRP is a significant explanatory variable for Japan as it is in the earlier sample period. Moreover, in this sample period, it is also significant for the equity fund flows to developed eurozone economies and Hong Kong, China, while it is not significant for India in contrast to the result in the global financial crisis period. As in Table A1, the US VRP is not a significant explanatory variable for the equity fund flows to the People's Republic of China, the Republic of Korea, and Mexico.

Table A3 in the appendix shows the regression results for the two distinct regional groups: developed economies (excluding the US) and EMEs. The US VRP strongly influences equity fund flows to developed economies excluding the US in the post-crisis period, explaining more than 15% of variations in the equity fund flows. The feature is in stark contrast to that in the global financial crisis period. As for the equity fund flows to EMEs, the US VRP has some explanatory power in the global financial crisis period, but it has virtually no influence on the equity fund flows to the region in the post-crisis period. In terms of R-squared, there is notable difference between the values for developed economies (excluding the US) and those for EMEs in the post-crisis period.

4.2 Two-Stage Least Squares Regression Analysis

In this section, we attempt to investigate the relationship between the US VRP and the equity fund flows in a stricter manner than the univariate OLS regressions conducted in section 4.1, and then detect the effect of the US VRP via the fund flows on VRPs in the fund flow's destination equity markets. By relying on 2SLS estimation, we test our conjecture on a specific mechanism generating the cross-equity market correlation of VRPs.

In conducting the 2SLS regression, we first estimate the effect of the US VRP on the equity fund flows to six non-US equity markets, controlling for global and local factors.

The markets are the eurozone; Hong Kong, China; India; Japan; the Republic of Korea; and Mexico, for which we can estimate VRP for the local equity market index. In the second stage of the 2SLS regression, we use the fitted value of the fund flows as the main explanatory variable. Besides the US VRP, the Citi Economic Surprise Index for the US and the total return on a local equity index in US dollar terms are used as instrumental variables in the first stage. As for the control variables, the world nominal short-term interest rate is used as the global factor affecting global equity markets, and the Citi Economic Surprise Index as the local or regional factor capturing news in macroeconomic fundamentals. As in the OLS regression analysis in section 4.1, we perform the quantitative analysis for two subsample periods: the global financial crisis period and the post-crisis period as defined in section 4.1.

Table A4 in the Appendix shows the results of the first stage regression for the global financial crisis period, and Table A5 shows the results of the second stage regression for the same period. In the first stage regression, we find that the estimated effect of the US VRP on the equity fund flows to the EMEs is highly significant. For Hong Kong, China; India; the Republic of Korea; and Mexico, the local equity index return in US dollar terms in the previous week is also highly significant, which indicates that the fund flows to those economies tend to follow past investment returns. The world nominal short-term interest rate tends to reduce equity fund flows to the sample economies. Paradoxically, the sign of the coefficient on the Citi Economic Surprise Index for the eurozone and Japan is negative.

In the second stage regression, the fitted value of the equity fund flows has a significant impact on the VRP for Japan and, with lesser significance, on the VRP for the eurozone. The sign of the coefficients is economically correct: a fall in fund flows from the US would decrease equity prices in the local markets, which would urge investors to ask for greater premiums for equity price volatility. It is also the case that VRP is strongly autoregressive for Hong Kong, China; India; the Republic of Korea; and Mexico.

In the post-crisis period, Tables A6 and A7 in the Appendix show the results of the first and the second stage regressions, respectively. In the first stage regression, the US VRP is a significant explanatory variable only for the developed economies, which is contrary to the result for the global financial period. Again, it is strongly indicated that the fund flows to the EMEs tend to follow past investment returns and global nominal short-term interest rate tends to reduce equity fund flows to the investment destinations.

In the second stage regression, the fitted value of the equity fund flows has a significant impact only on the VRP in the eurozone and Japan as in the results of the analysis for the global financial crisis period. The coefficient on the explanatory variable is paradoxically negative for Mexico. VRP is, again, strongly autoregressive for Hong Kong, China; India; the Republic of Korea; and Mexico.

In summary, the results of the 2SLS regression analysis point to a spillover path of the US VRP to the equity markets in developed economies via equity fund flows. The finding is more robust for the post-crisis period. As for equity markets in other economies such as Hong Kong, China; India; the Republic of Korea; and Mexico, the spillover path does not seem to be significantly strong, and the VRPs in those markets are highly autoregressive. One possible interpretation of these findings is that, once the VRP in a market is heightened due to any reason, the persistence dominates its development and the dominant effect would make it hard to detect the effect of other factors.

5. CONCLUSION

We investigate cross-economy correlations of VRPs calculated from their equity markets, and test our conjecture on the US-based mutual fund flows as a path through which VRPs spill over globally. This paper has two novel features. First, the inclusion of VRPs in selected EMEs' equity markets in the scope of investigation is unprecedented to our knowledge. Therefore, gauging the degree of VRP correlations between equity markets in developed economies and EMEs is also unprecedented. On top of this feature, investigation of the background for the cross-equity market correlations of VRP is a new contribution. Specifically, we gauge the impact of the US VRP on other markets' VRPs via equity fund flows.

Concerning the correlations of VRP, we find that cross-equity market correlations including the EMEs' equity markets are positive for all pairs of economies. Moreover, some pairs have relatively high correlations. Regression analyses detect the impact of the US VRP on the equity fund flows to some economies and point to evidence that the equity fund flows are a path causing equity market investors' resonance concerning risk associated with equity price volatility in major equity markets in the developed economies, i.e., the eurozone and Japan.

Admittedly, the results presented in this paper deserve more examination. For example, in order to investigate the causality between VRPs of different economies' equity markets, it would be worth considering conducting an event study in each equity market. Furthermore, we plan to obtain finer estimates of VRP by employing modeling approaches rather than the nonparametric approach we use in this paper, ideally isolating a premium for tail risk from premiums for other risks such as liquidity risk. Even so, we think the empirical results reported in this paper shed light on research topics that have not been delved into in the current literature.

REFERENCES

- Aït-Sahalia, Y., J. Cacho-Diaz, and R. Laeven. 2015. Modeling Financial Contagion Using Mutually Exciting Jump Processes. *Journal of Financial Economics* 117(3): 585–606.
- Barras, L., and A. Malkhozov. 2015. Does Variance Risk Have Two Prices? Evidence from the Equity and Option Markets. BIS Working Papers No 521. Basel: Bank for International Settlements.
- Bekaert, G., M. Ehrmann, M. Fratzscher, and A. Mehl. 2014. The Global Crisis and Equity Market Contagion. *Journal of Finance* 69(6): 2597–2649.
- Bollerslev T., G. Tauchen, and H. Zhou. 2009. Expected Stock Returns and Variance Risk Premia. *Review of Financial Studies* 22(11): 4463–4492.
- Bollerslev, T., and V. Todorov. 2011. Tails, Fears and Risk Premia. *Journal of Finance* 66(6): 2165–2211.
- Bollerslev, T., J. Marrone, L. Xu, and H. Zhou. 2011. Stock Return Predictability and Variance Risk Premia: Statistical Inference and International Evidence. Federal Reserve Board Finance and Economics Discussion Series 2011-52. Washington, DC: Federal Reserve Board.
- Broadie, M., M. Chernov, and M. Johannes. 2007. Model Specification and Risk Premia: Evidence from Futures Options. *Journal of Finance* 62(3): 1453–1490.
- Carr P., and L. Wu. 2009. Variance Risk Premiums. *Review of Financial Studies* 22(3): 1311–1341.
- EPFR Global. 2015. Equity Fund Flows Database (Country Flows). <http://www.epfr.com/data.aspx> (accessed 6 November 2015).
- Feunou, B., M. Jahan-Parvary, and C. Okou. 2015. Downside Variance Risk Premium. Federal Reserve Board Staff Working Papers No. 2015-020. Washington, DC: Federal Reserve Board.
- Heber, G., A. Lunde, N. Shephard, and K. Sheppard. 2009. *Oxford-Man Institute's Realized Library*. Oxford, UK: Oxford-Man Institute, University of Oxford.
- Lo Duca, M. 2012. Modelling the Time Varying Determinants of Portfolio Flows to Emerging Markets. European Central Bank Working Paper No. 1468, September. Frankfurt: European Central Bank.
- International Monetary Fund (IMF). 2014. How Do Changes in the Investor Base and Financial Deepening Affect Emerging Market Economies? In *Global Financial Stability Report. April 2014*. Washington, DC: International Monetary Fund. Chapter 2.
- . 2015. The Asset Management Industry and Financial Stability. In *Global Financial Stability Report, April 2015*. Washington, DC: International Monetary Fund. Chapter 3.
- Maneesoonthorn, W., G. Martin, C. Forbes, and S. Grose. 2012. Probabilistic Forecasts of Volatility and its Risk Premia. *Journal of Econometrics* 171(2): 217–236.
- Raczko, M. 2015. Volatility Contagion: New Evidence from Market Pricing of Volatility Risk. Bank of England Staff Working Paper No 552, September. London: Bank of England.

APPENDIX

Table A1: Effects of the US Variance Risk Premium on Equity Fund Flows to Individual Economies

Global Financial Crisis Period				
Dependent Variable: Equity Fund Flows to an Economy	Japan	Eurozone	Hong Kong, China	Mexico
VRP for the US	4.3499*** [0.001]	−0.6047 [0.635]	1.9460 [0.145]	2.8149 [0.155]
Constant	0.0068 [0.892]	−0.1180** [0.038]	0.0467 [0.461]	0.1957* [0.085]
Observations	94	94	94	94
Prob>F	0.000	0.634	0.144	0.155
R-squared	0.1376	0.0023	0.0196	0.0133
Dependent Variable: Equity Fund Flows to an Economy	Republic of Korea	India	People's Republic of China	United States
VRP for the US	2.1207 [0.323]	2.5442* [0.079]	3.5419 [0.304]	3.8507** [0.041]
Constant	0.1810** [0.049]	0.2310*** [0.006]	0.3092** [0.025]	0.1561* [0.067]
Observations	94	94	94	94
Prob>F	0.322	0.079	0.304	0.040
R-squared	0.0112	0.0178	0.0234	0.0674

US = United States, VRP = variance risk premium.

Notes: This table shows results from regressions of the equity fund flows to investment destinations on the US VRP. *p*-values are reported in brackets. The sample period is from November 2007 to December 2009. The fund flow data, i.e., the dependent variable, are weekly flows divided by net asset value. VRPs are weekly average for the same definition of a week. Heteroscedasticity-adjusted robust ordinary least squares are used.

Table A2: Effects of the US Variance Risk Premium on Equity Fund Flows to Individual Economies

Post-Crisis Period				
Dependent Variable: Equity Fund Flows to an Economy	Japan	Eurozone	Hong Kong, China	Mexico
VRP for the US	8.8569*** [0.000]	5.6896*** [0.000]	2.5621* [0.072]	1.2957 [0.567]
Constant	0.3025*** [0.000]	0.1395*** [0.000]	0.0938*** [0.002]	0.0022 [0.964]
Observations	289	289	289	289
Prob>F	0.000	0.000	0.072	0.567
R-squared	0.0822	0.1134	0.0103	0.0011
Dependent Variable: Equity Fund Flows to an Economy	Republic of Korea	India	People's Republic of China	United States
VRP for the US	0.6428 [0.649]	2.0352 [0.115]	-1.9647 [0.317]	4.3442*** [0.000]
Constant	0.0908*** [0.003]	0.0705*** [0.010]	-0.0223 [0.649]	0.0816*** [0.001]
Observations	289	289	289	289
Prob>F	0.648	0.114	0.317	0.000
R-squared	0.0005	0.0060	0.0023	0.0430

US = United States, VRP = variance risk premium.

Note: This table shows results from regressions of the equity fund flows to investment destinations on the US VRP. *p*-values are reported in brackets. The sample period is from January 2010 to September 2015. The fund flow data, i.e., the dependent variable, are weekly flows divided by net asset value. VRPs are weekly average for the same definition of a week. Heteroscedasticity-adjusted robust ordinary least squares are used.

Table A3: Effects of the US Variance Risk Premium on Equity Fund Flows to Developed Economy and EME Regions

Dependent Variable: Equity Fund Flows to a Region	Developed Economy (except the US) (crisis period)	EME (crisis period)	Developed Economy (except the US) (post-crisis period)	EME (post-crisis period)
VRP for the US	0.8665 [0.547]	3.1270* [0.068]	6.1024*** [0.000]	0.3920 [0.776]
Constant	-0.0734 [0.182]	0.2204*** [0.008]	0.1612*** [0.000]	0.0375 [0.187]
Observations	94	94	289	289
Prob>F	0.546	0.067	0.000	0.776
R-squared	0.0053	0.0294	0.1542	0.0002

EME = emerging market economy, US = United States, VRP = variance risk premium.

Notes: This table shows results from regressions of the equity fund flows to investment destinations on the US VRP. *p*-values are reported in brackets. The crisis period is from November 2007 to December 2009, and the post-crisis period from January 2010 to September 2015. The fund flow data, i.e., the dependent variable, are weekly flows divided by net asset value. VRPs are weekly average for the same definition of a week. Heteroscedasticity-adjusted robust ordinary least squares are used.

Table A4: Effects of the US Variance Risk Premium on Variance Risk Premiums in Other Economies: First Stage Regressions

Global Financial Crisis Period						
Dependent Variable: Equity Fund Flows to an Economy	Japan	Eurozone	Hong Kong, China	Mexico	Republic of Korea	India
VRP (lagged)	1.7140*** [0.008]	2.4980 [0.120]	-0.2094 [0.816]	-0.7333 [0.526]	-0.5653 [0.623]	-0.3044 [0.828]
Citi Economic Surprise Index	-0.0026*** [0.000]	-0.0009** [0.025]	-0.0001 [0.773]	-0.0000 [0.942]	-0.0017 [0.176]	n.a. [n.a.]
Nominal short-term interest rate (world)	-0.0177 [0.473]	-0.1940*** [0.000]	-0.1265*** [0.000]	-0.2752*** [0.000]	-0.1831*** [0.000]	-0.2014*** [0.000]
VRP for the US	3.3657* [0.056]	1.1712 [0.391]	4.1399*** [0.002]	6.8410*** [0.003]	5.6744*** [0.007]	4.5812*** [0.006]
Citi Economic Surprise Index (US)	-0.0005 [0.382]	-0.0012* [0.068]	0.0001 [0.807]	-0.0029** [0.031]	0.0000 [0.969]	-0.0017** [0.045]
MSCI index return in US dollars (lagged)	0.0070 [0.570]	-0.0013 [0.895]	0.0367*** [0.003]	0.0409*** [0.003]	0.0399*** [0.001]	0.0494*** [0.000]
Constant	0.1811 [0.172]	0.8191*** [0.000]	0.6242*** [0.000]	1.4003*** [0.000]	1.0289*** [0.000]	1.0943*** [0.000]
Observations	91	88	85	91	91	83
Prob>F	0.000	0.000	0.000	0.000	0.000	0.000
R-squared	0.3376	0.2680	0.4214	0.3776	0.4463	0.4938

MSCI = Morgan Stanley Capital International, n.a. = not available, US = United States, VRP = variance risk premium.

Notes: This table shows results from the first stage regressions of the two-stage least squares to estimate effects of VRP in the US market on the VRP in markets in other economies via equity fund flows. The fitted value of the dependent variable in the first stage is used as an explanatory variable in the second stage. *p*-values are reported in brackets. The sample period is from November 2007 to December 2009. *Equity fund flows to an economy* are weekly flows divided by net asset value. *VRP* is weekly average for the same definition of a week. An increase in the *Citi Economic Surprise Index* means increase in ratio of economic news surpassing market expectations in the economy in question. *Nominal short-term interest rate (world)* is world nominal short-term rate explained in footnote 4 in the main body of this paper. The *MSCI index return in US dollars* is weekly return in the MSCI equity index for the economy in question evaluated in US dollar terms. Heteroscedasticity-adjusted robust ordinary least squares are used.

Table A5: Effects of the US Variance Risk Premium on Variance Risk Premiums in Other Economies: Second Stage Regressions

Global Financial Crisis Period						
Dependent Variable: VRP in the Local Market	Japan	Eurozone	Hong Kong, China	Mexico	Republic of Korea	India
Equity fund flows to an economy (fitted in the first stage)	0.2746* [0.050]	0.1028* [0.099]	0.0151 [0.718]	−0.0059 [0.635]	0.0132 [0.536]	−0.0055 [0.586]
VRP (lagged)	0.3430 [0.257]	0.4483** [0.027]	1.2543*** [0.000]	0.9359*** [0.000]	0.8534*** [0.000]	0.6169*** [0.000]
Citi Economic Surprise Index	0.0006* [0.082]	0.0001* [0.054]	−0.0000 [0.684]	−0.0000 [0.205]	0.0001 [0.301]	n.a. [n.a.]
Nominal short-term interest rate (world)	−0.0057 [0.347]	0.0200 [0.108]	−0.0009 [0.866]	−0.0068* [0.052]	−0.0017 [0.675]	0.0027 [0.413]
Constant	0.0090 [0.764]	−0.0940* [0.055]	0.0228 [0.461]	0.0195 [0.164]	−0.0068 [0.767]	−0.0314* [0.090]
Observations	91	88	85	91	91	83
Prob>chi-squared	0.000	0.000	0.000	0.000	0.000	0.000

n.a. = not available, US = United States, VRP = variance risk premium.

Notes: This table shows results from the second stage regressions of the two-stage least squares to estimate effects of VRP in the US market on the VRP in markets in other economies via equity fund flows. The fitted value of the dependent variable, i.e., *equity fund flows to an economy*, in the first stage is used as an explanatory variable in the second stage. *p*-values are reported in brackets. The sample period is from November 2007 to December 2009. *Equity fund flows to an economy* are weekly flows divided by net asset value. *VRP* is weekly average for the same definition of a week. An increase in the *Citi Economic Surprise Index* means increase in ratio of economic news surpassing market expectations in the economy in question. *Nominal short-term interest rate (world)* is world nominal short-term rate explained in footnote 4 in the main body of this paper. Heteroscedasticity adjusted robust ordinary least squares are used.

Table A6: Effects of the US Variance Risk Premium on Variance Risk Premiums in Other Economies: First Stage Regressions

Post-Crisis Period						
Dependent Variable: Equity Fund Flows to an Economy	Japan	Eurozone	Hong Kong, China	Mexico	Republic of Korea	India
VRP (lagged)	1.0316 [0.372]	2.6857* [0.088]	3.5384* [0.077]	14.8429*** [0.000]	1.7947 [0.192]	0.6005 [0.504]
Citi Economic Surprise Index	0.0006 [0.251]	0.0010*** [0.001]	0.0011*** [0.009]	0.0028*** [0.001]	0.0010 [0.166]	n.a. [n.a.]
Nominal short-term interest rate (world)	-0.3201*** [0.013]	0.0707 [0.323]	-0.0388 [0.698]	-0.3152** [0.025]	-0.2234* [0.053]	-0.2136** [0.020]
VRP for the US	8.6033*** [0.000]	4.1750** [0.037]	0.5028 [0.804]	-2.3611 [0.331]	-0.1427 [0.930]	1.1345 [0.318]
Citi Economic Surprise Index (US)	-0.0006 [0.162]	-0.0001 [0.466]	-0.0004 [0.310]	0.0008 [0.189]	0.0005 [0.280]	-0.0002 [0.584]
MSCI index return in US dollars (lagged)	-0.0017 [0.883]	0.0050 [0.425]	0.0420*** [0.000]	0.0312*** [0.004]	0.0346*** [0.000]	0.0398*** [0.000]
Constant	1.3027*** [0.001]	-0.0326 [0.872]	0.2716 [0.372]	1.1894*** [0.007]	0.7852*** [0.019]	0.7034*** [0.011]
Observations	285	281	283	280	288	280
Prob>F	0.000	0.000	0.000	0.000	0.000	0.000
R-squared	0.1294	0.2099	0.1658	0.1818	0.1383	0.1476

MSCI = Morgan Stanley Capital International, n.a. = not available, US = United States, VRP = variance price premium.

Notes: This table shows results from the first stage regressions of the two-stage least squares to estimate effects of VRP in the US market on the VRP in markets in other economies via equity fund flows. The fitted value of the dependent variable in the first stage is used as an explanatory variable in the second stage. *p*-values are reported in brackets. The sample period is from January 2010 to September 2015. *Equity fund flows to an economy* are weekly flows divided by net asset value. *VRP* is weekly average for the same definition of a week. An increase in the *Citi Economic Surprise Index* means increase in ratio of economic news surpassing market expectations in the economy in question. *Nominal short-term interest rate (world)* is world nominal short-term rate explained in footnote 4 in the main body of this paper. The *MSCI index return in US dollars* is weekly return in MSCI equity index for the economy in question evaluated in US dollar terms. Heteroscedasticity-adjusted robust ordinary least squares are used.

Table A7: Effects of the US Variance Risk Premium on Variance Risk Premiums in Other Economies: Second Stage Regressions

Post-crisis Period						
Dependent Variable: VRP in the Local Market	Japan	Eurozone	Hong Kong, China	Mexico	Republic of Korea	India
Equity fund flows to an economy (fitted in the first stage)	0.0784*** [0.001]	0.2258** [0.030]	0.0065 [0.474]	-0.0142** [0.038]	-0.0130 [0.225]	-0.0011 [0.831]
VRP (lagged)	0.4962** [0.022]	-0.3159 [0.594]	0.8222*** [0.000]	0.9682*** [0.000]	0.8615*** [0.000]	0.8431*** [0.000]
Citi Economic Surprise index	-0.0000 [0.391]	-0.0002** [0.046]	-0.0000* [0.083]	0.0000 [0.174]	-0.0000 [0.859]	n.a. [n.a.]
Nominal short-term interest rate (world)	0.0211** [0.048]	-0.0269 [0.163]	-0.0069 [0.248]	-0.0051 [0.246]	-0.0102* [0.050]	-0.0031 [0.363]
Constant	-0.0958*** [0.005]	0.0376 [0.426]	0.0150 [0.417]	0.0151 [0.306]	0.0288* [0.068]	0.0059 [0.586]
Observations	285	281	283	280	288	280
Prob>chi-squared	0.000	0.001	0.000	0.000	0.000	0.000

n.a. = not available, US = United States, VRP = variance risk premium.

Notes: This table shows results from the second stage regressions of the two-stage least squares to estimate effects of VRP in the US market on the VRP in markets in other economies via equity fund flows. The fitted value of the dependent variable, i.e., *equity fund flows to an economy*, in the first stage is used as an explanatory variable in the second stage. *p*-values are reported in brackets. The sample period is from January 2010 to September 2015. *Equity fund flows to an economy* are weekly flows divided by net asset value. *VRP* is weekly average for the same definition of a week. An increase in the *Citi Economic Surprise Index* means increase in ratio of economic news surpassing market expectations in the economy in question. *Nominal short-term interest rate (world)* is world nominal short-term rate explained in f4 in the main body of this paper. Heteroscedasticity-adjusted robust ordinary least squares are used.