Meteor Shower and Global Asset Allocation

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Keywords: Volatility, spillover, VIX, GARCH, financial crisis, portfolio optimization. JEL Code: F36, F65, G01, G11, G15.

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ABSTRACT

We show that basic materials, financials, industrial, technologies, and telecommunication equity sectors were the primary exporters of volatility from the U.S. and that the magnitude of the spillover increased especially during and post-2008 financial crisis. Investing in low volatility spillover countries generate high Sharpe ratios for U.S. portfolio managers, especially during the financial crisis.

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I. Introduction

An unintended consequence of capital markets connectedness is that systemic risk is transmitted across borders, affecting economic growth, investor confidence, and capital flows. As evidenced during the 2008 financial crisis, global equity market experienced large declines,[1] and according to Batram and Bodnar (2009), falling from an all-time high of $51 trillion in October 2007 to $22 trillion by the end of February 2009. Such catastrophic declines expose the inherent vulnerabilities of the global equity market. From a policymaker's viewpoint, it is important to identify whether volatility is home grown (heat wave) or imported (meteor shower)[2] so that appropriate policies can be designed and implemented to safeguard domestic capital market (see Elaysiani et. al. (2015)). Investors care about the linkage because volatility spillover can increase correlation between markets and reduce diversification benefits. While there is evidence that markets focus more on home grown volatility than external volatility during a contagion (Bekaert, et.al. (2014), more work is needed at the sectoral level to also identify the extent of volatility transmission across borders. Whether such transmission of volatility affects portfolio diversification and regulators' attempts to defend home country from external volatility has critical impact on capital flows and risk management.

[1]The major stock market indices, on average, have declined by more than 10%, while emerging stock market indices have fallen by close to 30%.

[2]Engle *et al.* (1990) was first to introduce these terms to describe whether market volatility is driven by its own volatility or affected by volatility from a foreign market.

In this paper, we identify volatility spillover from major U.S. investable[3] equity sectors (basic materials, consumer staples, financials, health care, industrials, oil and gas, technology, telecommunications, and utilities) to matched investable equity sectors in selected countries (Australia, Brazil, Canada, China, France, Germany, India, Italy, Japan, Korea, Spain, Russia and the United Kingdom). These U.S. equity sectors are selected on the basis of their exposure to the CBOE volatility index (VIX) and the foreign countries selected represent major trade and investment partners of the U.S. Our analysis is consistent with the existing research (see Yang and Yahngang (2016)) on the cross-border volatility spillover but differing in two ways: first, we pinpoint the magnitude of the connectedness at the industry level, and second, we examine the extent to which portfolio managers can use spillover coefficients to guide international investments.

We find evidence of spillover at the ***aggregate*** level especially during the financial crisis. Canada was most exposed to the U.S. while India the least exposed. Average spillover index across ***equity sectors*** shows Canada was most exposed to the U.S. volatility during the full sample, while China was least exposed. During the pre-financial crisis[4] period (January 2, 2002 – February 14, 2007), Canada was most exposed while China was least exposed in all 9 equity sectors. The same results are obtained for spillover during the financial crisis period (February 15, 2007 – April 30, 2009). These results make sense given Canada's proximity to the U.S. and trade between these two countries. What is interesting is that China was least exposed to the U.S.-specific volatility despite an increasing level of trade and investment between them[5]. Finally, spillover during post-financial crisis (May 1, 2009 – September 21, 2015) is similar. Canada was most exposed while China was least vulnerable.

Our analysis also highlights specific equity sectors that are vulnerable to spillover from the U.S. For full sample period, basic materials and oil and gas, contributed most to volatility spillover from the U.S, while utilities sector contributed the least. During the pre-financial crisis, oil and gas sector (utilities) was the highest (lowest) contributor to spillover. During the financial crisis, the technologies sector contributed to most spillover rather than the financial sector. The utilities sector

[3] Investable equity indices are typically custom tailored and are constructed taking into account several factors including liquidity, market capitalization, float, and trading volume. These indices are proprietary in nature.
[4] The dating of the samples is arbitrary though it generally matches the full timeline of the crisis as reported by the St. Luis Fed (https://www.stlouisfed.org/financial-crisis/full-timeline).
[5] We find this result very interesting and it perhaps supports our anecdotal claim that China has been able to keep its capital market insulated through restrictions on capital flows from to the rest of the world.

was the lowest contributor to spillover. Finally, the oil and gas (utilities) was the largest (smallest) transmitter of volatility during the post-financial crisis period.

These results have implications for global asset allocation decisions. High spillover translates into high equity market correlation, and as a result, diversification benefits from investing in these countries would be lower, and subsequently, capital flow to these countries should decline. Minimum variance portfolio optimizations exercise using spillover magnitude as a filter confirms that investing in low spillover countries can generate high Sharpe ratios for the U.S. portfolio managers.

We make several contributions to the literature. First, the results suggest that the use of broader stock indexes can offer only a limited view of the meteor shower volatility spillover for the countries in the sample. Rather, a sectoral analysis can pinpoint the important conduits of volatility spillover. Second, we show that the sector-to-sector magnitude of the spillover varies over time. Third, we also identify the countries and the equity sectors that can offer greater international diversification benefits to U.S. portfolio managers.

The paper is organized as follows. Section II reviews the relevant literature and motivates our hypotheses. Section III provides empirical analysis. The final section has the conclusions.

II. The Volatility Transmission Mechanism

Volatility spillover is the occurrence of shocks originating from one country affecting a network of countries interconnected through financial connections. A World Bank study identifies several volatility transmission channels based on trade, financial, commodity, and investor confidence[6]. Trade channels include imbalances in external trade as a result of currency volatility and technological innovation induced productivity changes. Financial transmission channel considers the flow of foreign direct investment and portfolio investment as a result of either arbitrage mechanism or international diversification. Linkages among banks can magnify volatility spillover because of interconnectedness in risk exposure. Remittances are also vital to the transmission of shocks from one country to another. Commodity channel points the effects of instability in the commodities market in light of imbalances

[6]Global Economic Prospects: Spillovers amid Weak Growth 2016, World Bank. Available at https://www.worldbank.org/content/dam/Worldbank/GEP/GEP2016a/Global-Economic-Prospects-January-2016-Spillovers-amid-weak-growth.pdf.

in supply and demand. Investor sentiment has also been cited in the study as an important catalyst for shocks being transmitted across borders.

Several prominent studies identify whether volatility is home grown or imported. Engle *et al.* (1990) examine the intra-daily behavior of the Yen/Dollar exchange rate with reference to the hypotheses of heat wave (home grown volatility) and meteor showers (imported volatility). The authors find evidence of meteor shower, as opposed to a heat wave type spillover. Susmel and Engle (1994) investigate the timing of mean and volatility spillover between the New York and London equity markets. Their study reports that the evidence of volatility spillover between these markets is minimal and the impact lasts for an hour or so. Melvin and Melvin (2003) examine volatility spillover of Mark/Dollar and Yen/Dollar exchange rates across global markets. In particular, they find statistically significant effects of both own-region and inter-regional spillover. They also suggest that heat waves are more important than meteor showers. Clemens *et al.* (2015) use high-frequency (10-minute) futures data on the dollar index, Treasury bond, and S&P500 equity index during 2003-2013 and find that meteor shower and heat wave effects are equally significant.

Empirical evidence of a 'leadership role' of the U.S. towards the global financial markets, especially in times of stress, is well-documented in previous research. For example, see Elyasiani *et al.* (2015), Hamao *et al.* (1990), and Theodossiou and Lee (1993). Elyasiani *et al.* (2015) examine the return and volatility interdependence among the U.S., the UK, the EU and Japanese banks and insurers spanning the period 2003 to 2009. The study reports strong return and volatility transmission within and across banking and insurance sectors. The relationship exhibited a strengthened contagion spillover during the crisis period of 2007 to 2009, with the U.S. financial institutions as information providers in global markets. Kanas (1998) investigates the return volatility spillover across three major European markets, namely, London, Frankfurt and Paris, for the period from January 1984 to December 1993. The study reports bi-directional spillover between London and Paris and Frankfurt and Paris, with unidirectional spillover from London to Frankfurt. The study finds that the magnitude and intensity of spillover increased during the post-crash period.

Golosnoy *et al.* (2012) examined volatility spillover using the intra-daily data of the Dow Jones and DAX. They find evidence of significant short-term volatility spillover within both markets (heat-

wave effect), as well as across the two markets (meteor shower effect). Their study also discovers that the spillover effects between the U.S. and the German stock markets are of significantly longer duration and increased after the subprime crisis, which indicates substantial contagion effects. Beale (2005) investigates the contagion and volatility spillover from the U.S. markets to 13 European equity markets using weekly data over the period January 1980 to August 2001. The study finds that spillover intensities increased most in the second half of the 1980s and the first half of the 1990s. Beale contends that increased trade integration, equity market development, and low inflation have contributed to the increase in the European Union stock spillover intensity.

Beirne *et al.* (2008) explore the issue of volatility spillover and contagion from mature to 41 emerging stock markets. Their study suggests that spillover from established markets influences the conditional variance of return in many local and emerging markets. Furthermore, the spillover parameter changes during turbulent periods in developed countries. Diebold and Yilmaz (2012) examine both total and directional volatility spillover across U.S. stock, bond, foreign exchange and commodity markets using daily data and a framework of generalized vector autoregressive model spanning the period January 1999 to January 2010. The study finds evidence of very limited spillover prior to the global financial crisis period of 2007. However, volatility spillover intensified from the stock market to other market after the collapse of the Lehman Brothers in September 2008.

More recent studies examine industry level spillover around the 2008 financial crisis. Kouki *et al.* (2011) consider key industry sectors such as banking, financial services, industrial, real estate and oil, of selected developed and emerging markets over the period January 2002 to October 2009. They find that both shocks and the volatility of the U.S. banking sector are transmitted to developed and emerging markets, which confirms the hypothesis that the U.S. plays a dominant role in the diffusion of information. Barunik *et al.* (2016) investigate asymmetries in volatility spillovers using data of 21 most liquid U.S. stocks from seven sectors (financials, information technology, energy, consumer discretionary, consumer staples, telecommunication services and health care) spanning the period August 2004 to December 2011. The study finds evidence of asymmetric connectedness of stocks at the sectoral level with the spillover of bad and good volatility are transmitted at varying magnitudes across sectors over time. The study also reports that intra-market spillover increased substantially

during the global financial crisis (GFC). The sector-level heterogeneity in the transmission mechanism of volatility spillovers was attributed to the activity of informed traders (which reduces volatility) and uninformed traders (which increases volatility).

Studies by Barunik, *et al.* (2016) and Baur (2012) suggest that stock market spillover studies based broader stock indexes cannot show how much risk was transmitted by the sectoral components of the index. This is a major shortcoming because an identification of the equity sectors vulnerable to domestic or foreign equity sectors is critical for designing policies to safeguard capital markets. Furthermore, the degree to which a capital market is exposed to foreign shocks can also be used as a screening device for constructing internationally diversified portfolios. For example, investing in low volatility spillover countries and industries could allow U.S. portfolio managers to hedge U.S.-specific systemic risk. Surprisingly, this line of research where the magnitude of meteor shower is used as a screening device to guide portfolio diversification is missing.

III. Empirical Model

We use daily data for the period January 2, 2002 to September 21, 2015. The sample is split into four separate regimes to examine the dynamic nature of spillover: Full Sample (January 2, 2002 – September 21, 2015), Pre-Financial Crisis (January 2, 2002 – February 14, 2007), Financial Crisis (February 15, 2007 – April 30, 2009), and Post-financial Crisis (May 1, 2009 – September 21, 2015). Data on equity sectoral investable equity indices are collected from Datastream[7]. Log returns are based on end-of-day closing prices. To avoid nonsynchronous trading and time zone differences, European and North American financial data are matched on a daily basis. Asian market data were lagged one day to account for the fact that U.S. still remains as the leading source of all market volatility.

As noted earlier, our choice of equity sectors and countries is based on several factors. First, we select the VIX[8] index as a measure of uncertainty in the broad U.S. equity market. On the basis of negative correlation between VIX and the U.S. equity returns, we selected the following 10 U.S. investable equity sectors: the aggregate stock market index (MSCI Investable Index), basic materials, consumer staples, financials, health care, industrials, oil and gas, technology, telecommunications, and

[7]The sample period is based upon data availability. We thank ThomsonReuters for the data.
[8]VIX is based on out-of-the money front and second month expiration call and put options on S&P500. It has also been referred to as the 'fear index'.

utilities). These equity sectors are then matched with their corresponding investable sectoral indices in 13 trading partners of the US: Australia, Brazil, Canada, China, France, Germany, Italy, Japan, Korea, Spain, Russia and the United Kingdom. As reported by the U.S. Treasury, at the end of 2013, the U.S. equity portfolio managers held $5.7 trillion in foreign stocks out of $6.47 trillion investments in foreign securities (Table 1). The United Kingdom, Japan, Canada, France, Germany, Korea, Australia, Brazil, and China are among the leading countries receiving the bulk of equity investments from the United States. In addition, Russia[9] and India were added on the basis of recent data on foreign direct investment[10]. Table 2 reports the market value of the U.S. holdings of foreign stocks. We selected all equity sectors listed in the table, with the exception of few sectors where the composition of a particular U.S. sectoral equity index did not exactly match the foreign index.

We conducted several preliminary diagnostic tests (results not reported to save space) on equity returns. First, KPSS and the Augmented Dickey-Fuller (ADF) tests detected the presence of unit root (non-stationarity) in the raw data in the levels. Next, in majority of the cases, the returns are negatively skewed, suggesting that the equity markets experienced a large decline during the full sample period. The Bera-Jarque indicated departure from normality. The Lagrange Multiplier test (R^2 test) detected autocorrelation in the squared residuals.

As discussed earlier, the U.S. equity sectors are selected on the basis of their correlation with VIX, which would confirm that the volatility in these equity sectors convey information on the aggregate market uncertainty. In Table 3 (Panel A), correlation coefficients between returns on U.S. aggregate and sectoral equity indices and the VIX are reported. The returns on the VIX and the aggregate equity index (the U.S. MSCI Investible Index) are negatively correlated, supporting the view that the VIX is a conveyor of uncertainty in the U.S. market. Panel A, Table 3 also shows that during the financial crisis, correlation fell to -.76 and post-financial crisis correlation drops to -.80, suggesting uncertainty in the equity market is associated with larger decline in returns.

The U.S. sectoral equity returns are also negatively correlated with VIX returns. For the full sample period, the lowest negative correlation (-.71) is observed for the industrial sector returns while

[9]Direct investment position of the United States in Russia from 2000 to 2014 (in billion U.S. dollars, on a historical-cost basis). http://www.statista.com/statistics/188637/united-states-direct-investments-in-russia-since-2000/ (accessed March 4, 2016).
[10]India West, Thursday, March 3, 2016.

the highest is observed for telecommunication and utilities sectors. During the crisis period, consumer staples, industrials, and technology sectors experienced higher negative correlation with VIX returns. Post-financial crisis correlations show an increase in negative correlation between returns on industrial sectors and the VIX. Overall, these sectors are reasonable conveyors of uncertainty in the U.S. market.

Panel B, Table 3 shows that the aggregate equity market returns from the selected countries in the sample are negatively correlated with the VIX returns[11]. The smallest correlation is observed for India while the largest negative correlation is observed for Canada. For sectoral equity indices, the results are similar. All correlation coefficients are found to be negative with the largest negative value observed for the industrial sector for Germany, while the telecommunication sector returns in China have the lowest correlation. Overall, the sample correlation coefficients indicate that the VIX and the U.S. sectoral indices have information content about uncertainty in the equity market.

Volatility Spillover Index Model

The study employs the generalized spillover index to identify the inter-linkages between the variables using a framework proposed by Diebold and Yilmaz (2009, 2012). The method optimally synthesize the notions of volatility spillover coined by Engle *et al.* (1990), variance decompositions (VDCs) proposed by Sims (1980a, 1980b) and a framework of generalized impulse response functions (IRFs) suggested by Koop, Pesaran and Potter (1996), and Pesaran and Shin (1998), and termed hereafter KPPS. The impacts of cross country inter-sector spillover are examined by evaluating generalized VDCs and VDCs are invariant to the ordering of variables. The VDCs, in percentage terms, decompose the forecast error variance of a dependent variable into components attributable to own innovations and innovations of other explanatory variables. We estimate a p-th order, N-variable vector autoregressive (VAR) model[12] as follow:

$$Z_t = \sum_{i=1}^{p} B_i Z_{t-i} + \varepsilon_t \qquad (1)$$

Where $Z_t = (Z_{1t}, Z_{2t,}..., Z_{Nt})$ is a vector of N endogenous variables, B_i are $i = 1,\ldots, p$ are NXN autoregressive coefficients matrices and ε_t is vector of error term that are serially uncorrelated; $t = 1, \ldots,$

[11]To conserve space, we only report the correlation coefficients for the full sample.
[12] For expository convenience, this section is heavily drawn from Diebold and Yilmaz (2012).

T. The VAR model contains fourteen variables (*N* = 14). The $\varepsilon \sim (0, \sum)$ is a vector of independently and identically distributed errors. The moving average representation of system (1) may be written as

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

where the *N*X*N* coefficients matrices *Ai* obey the recursion $A_i = B_1 A_{i-1} + B_2 A_{i-2} + \ldots + B_p A_{j-p}$ with A_0 being an *N*X*N* identity matrix and $A_i = 0$ for i < 0.[13] The total and directional spillovers are produced by the generalized forecast-error variance decompositions of the moving average representation of system (1). The VDCs define the '*own variance shares*' as a fraction of *H*-step-ahead variance in forecasting Z_i, for *i* = 1, 2, …*N* and '*cross variance share or spillover*', as the fraction of *H*-step-ahead error variances in forecasting Z_j, for *i*, *j* =1, 2,…*N*, such that $i \neq j$. Using the notion of *H*-step-ahead generalized forecast error variance decomposition of KPPS, we may write the VDCs as

$$\theta_{ij}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H} (e_i' A_h \sum e_j)^2}{\sum_{h=0}^{H} (e_i' A \sum A_h' e_i)} \tag{3}$$

where $\sum$ is variance matrix for the error ε, σ_{jj} signifies the standard deviation of the error term for the *j*-th equation, and e_i is the selection vector with one as the *i*-th element and zeros elsewhere. The own variance and cross variance shares are contained in the main diagonal and off-diagonal elements of $\theta(H)$ matrix, respectively. Each entry of the VDC matrix is normalized by its row sum as the own and cross-variance shares contribution do not sum to one under the generalized decompositions:

$$\theta_{ij}(H) = \frac{\theta_{ij}(H)}{\sum_{j=1}^{N} \theta_{ij}(H)} \tag{4}$$

[13] Interested readers are referred to Judge, Hill, Griffiths, Lutkepohl and Lee (1988), and Sims (1980b) for detailed derivation of the moving average representation and the calculation of VDCs, and for a discussion of generalized impulse response functions, to Koop *et al.* (1996).

With $\sum_{j=1}^{N}\tilde{\theta}_{ij}(H)=1$ and $\sum_{i,j=1}^{N}\tilde{\theta}_{ij}=N$ by construction (see Diebold and Yilmaz 2012, p. 58). Using (3) and (4), the total spillover index can be calculated as:

$$TS(H)=\frac{\sum_{\substack{i,j=1\\ i\neq j}}^{N}\tilde{\theta}_{ij}(H)}{\sum_{i,j=1}^{N}\tilde{\theta}_{ij}(H)}.100=\frac{\sum_{\substack{i,j=1\\ i\neq j}}^{N}\tilde{\theta}_{ij}(H)'}{N}.100 \qquad (5)$$

The total spillover index (*TS*) measures the average contribution of spillovers from shocks to all system variables/sectors to the total forecast error variance.[14]

Table 4 reports aggregate and sector volatility spillover to the foreign equity sectors during the 4 distinct regimes. The foreign countries are arranged in an alphabetical order. In Panel A, 13% (highest spillover) of the aggregate market volatility of Canada during the sample period was contributed by the U.S. In contrast, 3.6% (lowest spillover) of the Indian equity market volatility was contributed by the U.S. There is also evidence that the U.S. market volatility during the period has affected the remaining countries in the sample. These are (in order of low to high spillover) Russia, Korea, China, Italy, Spain, Japan, France, Germany, the UK, Australia, and Brazil.

Unfortunately, these results do not address the reasons for this volatility spillover. We believe investor sentiment and portfolio diversification are critical elements of this spillover. As reported earlier (Table 1), the U.S. portfolio managers held over $5.7 trillion worth of foreign equities from these high spillover countries. Such cross-border holdings of foreign equities can provide the transmission mechanism of connectedness between capital markets. Second, the aggregate volatility spillover analysis is flawed because it assumes that all constituent sectors of the index would be equally affecting their counterparts in foreign countries. In the next section, we explore volatility spillover at the sectoral level to provide more insights into the degree of connectedness among the equity sectors.

Volatility Spillover: Sectoral Evidence

[14]We ignore returns spillover because our focus is on the transmission of risk. Returns spillover may have broader implications for market efficiency which is not addressed in this paper. We ignore reverse volatility spillover from these selected countries to the U.S.

Sectoral spillover (Panel A, Table 4) shows that the U.S basic metals industry contributed to 15.1% of the volatility in Canada, while China was least affected (1.9%) among the countries in the sample. For consumer staples industry, Canada was most exposed (15.3%) while China was least sensitive (.9%) to the U.S. volatility. The U.S. financial sector was responsible for 16% volatility in the Canadian financial sector, the largest spillover among the countries in the sample. Again, China was least sensitive. Exposure for the remaining countries to the U.S. financial sector are (from low to high spillover): India, Russia, Italy, Korea, Spain, France, Japan, Germany, the UK, Brazil, and Australia. The average magnitude of spillover in these countries was 6.9%. This is hardly surprising given that the U.S. portfolio managers held almost $6 trillion of equities from these countries (Table 1).

For the health care sector, Germany, Canada, the UK, France, Japan, Australia, Italy, Spain, India, China, Korea, Canada, and Italy were most affected by volatility in the U.S. health care industry[15]. In contrast, Korea, China, and India were least exposed. For the industrial sector, the order of spillover (from low to high) is as follows: China, India, Korea, Italy, Spain, Brazil, France, the UK, Japan, Australia, Germany, and Canada. In the oil and gas sector, 19.1% of the volatility in Canada was contributed by the U.S., which is consistent with the fact that Canada is the major provider of energy to the U.S. India, China, and Korea were the only countries least affected by the U.S. spillover. In the technologies sector, China, India, Italy, Australia, Korea, and Spain were the least affected countries. In contrast, 14.7% volatility of the Canadian technologies sector returns can be explained by the U.S. For the telecommunication sector, Brazil was most affected while China was least exposed. Finally, Canada was most affected (11.1%) in the utilities sector while China again was least affected.

Overall, spillover during the full sample period suggests that China experienced the least volatility spillover from the U.S. in 7 out of 9 equity sectors while Canada was the highest recipient of volatility spillover in 7 out of 9 equity sectors. Brazil experienced the second highest level of spillover during the same period, which is surprising given that the 2013 U.S. holdings of Brazilian equities was valued at less than $130 billion. A fundamental assumption in our paper is that high volatility spillover indicates connectedness of the markets through international diversification of U.S. equity portfolios. It could also reflect the flow of information across international borders. We believe that volatility

[15]Health care equity index data were not available for Russia and Brazil.

spillover and asset allocation decisions are correlated, i.e., low volatility index countries included in a portfolio should offer superior risk reduction compared to alternative investment strategies. We examine this issue in a later section.

Sectoral Volatility Spillover: Pre-Financial Crisis

Pre-financial crisis spillover is presented in Panel B. At the aggregate level, Canada was affected most by the U.S. aggregate volatility to the tune of 13.6%, while India was affected the least (2.6%). In essence, most developed countries were exposed to the U.S., leaving the developing countries least exposed. With regard to sectoral spillover, Canada was most affected by the U.S. basic materials sector (17.2%) and China was least affected (.7%). For the consumer staples industry, Canada was most exposed (18%) while China was least sensitive (.1%). The U.S. financial sector was responsible for 16.1% volatility in the Canadian financial sector. Again, China was least sensitive. The remaining vulnerable countries are Germany, France, Italy, the UK, Spain and Australia. In contrast, China, India and Russia were least sensitive to the U.S. Surprisingly, Japan had low spillover despite the fact that during 2013, the U.S. portfolio managers held over $600 billion of Japanese equity.

For the health care sector, Canada, the UK, Germany, and France were most affected by the U.S. In contrast, China, Korea, India, Spain, Australia, Japan, and Italy were least exposed to the US. For the industrial sector, the U.S. affected volatility in mostly the developed countries, while the spillover in China, India, Brazil, and Spain were less than 5% on average. In the oil and gas sector, 21.2% of the volatility in Canada was contributed by the US. India, China, Korea, Russia, for example, were among the countries least affected. In the technologies sector, China, Australia, Korea, and India were the least affected countries in the sample. In contrast, 15.6% volatility of the Canadian technologies sector can be explained by the U.S. market volatility. For the telecommunication sector, Canada was most affected while China was least vulnerable to the volatility spillover from the US. Finally, Brazil was most affected in the utilities sector while China again was least affected.

Sectoral Volatility Spillover: Financial Crisis

Volatility spillover from the U.S. during the financial crisis is reported in Panel C. At the aggregate level, India was least exposed while Canada was the largest recipient of volatility spillover from the U.S. The level of spillover is slightly higher than the pre-crisis level. The median level of

volatility spillover is 6.9% and Japan, France, the UK, Australia, Brazil and Canada have higher than the median volatility spillover. Among the lowest spillover countries are India, Russia, Korea, and China. With the exception of Brazil, all countries in the high volatility category are developed countries with mature capital markets free of investment restrictions.

Sectoral volatility spillover shows the level of U.S.-specific exposure of these countries. Canada was most affected by the U.S. basic materials sector volatility (14.6%) and China was least affected (1.8%). For consumer staples industry, Canada was most exposed (13.4%) while China was least sensitive (2.2%). The U.S. financial sector volatility was responsible for 14.8% volatility in Canada. Again, China was least sensitive. Among the remaining countries exposed to the U.S. are Australia, Brazil, the UK, Germany, Japan, Spain, France, Italy, Korea, India, and Russia (from high to low spillover). In contrast, China, India and Russia were least sensitive to the U.S.-specific volatility.

For the health care sector, China, Korea, and India were least exposed to the U.S. For the industrial sector, the U.S. affected volatility in mostly the developed countries, while the spillover in China, India, and Korea was less than 5%, on average. Canada was ranked as the country receiving the most spillover from the U.S. In the oil and gas sector, 17.4% of the volatility in Canada was contributed by the U.S. India, China, and Korea, for example, were among the countries least affected by the U.S. spillover. In the technologies sector, China registered volatility spillover at less than 5% (1.5%). In contrast, 15.2% volatility in Canada can be explained by the U.S. market volatility. For the telecommunication sector, Brazil was most affected while China was least vulnerable to the U.S. Finally, Canada was most affected in the utilities sector while China again was least affected.

Sectoral Volatility Spillover: Post-Financial Crisis

We expected a lower level of spillover post-financial crisis for the countries that were most exposed during the financial crisis. The rationale is that these countries would implement appropriate policies to reduce their U.S.-specific exposure. However, the results do not support this conjecture. At the *aggregate* level, India was the lowest recipient while Canada was the largest recipient of volatility spillover from the U.S. The level of spillover is slightly higher than the crisis level. All countries, with the exception of India, remained significantly exposed to the U.S. volatility.

Regarding sectoral volatility spillover, Canada was most affected by the U.S. basic materials sector (14%) and China was least affected (2.5%). For the consumer staples industry, Canada was most exposed (12.6%) while China was least sensitive (1%) to the U.S. consumer staples industry volatility spillover. The U.S. financial sector contributed to 13.9% volatility in the Canadian financial sector. Again, China was least sensitive. Among the remaining countries that were also affected by spillover in the financial sector are Brazil, Germany, Australia, UK, Japan, Korea, France, Italy, Spain, Russia, and India (in order of high to low spillover). The magnitude of the U.S. contribution in these countries except India and Russia was more than 4% on average. In the oil and gas sector, 18% of the volatility in Canada was contributed by the U.S. China, India, and Korea, for example, were among the countries least affected by the U.S. spillover. In the technologies sector, China, Italy, India, and Australia were the least affected countries in the sample. In contrast, 11.6% volatility of the German technologies sector returns can be explained by the U.S. market volatility. For the telecommunication sector, Canada was most affected while China and Italy were the lowest receiver of spillover. Finally, Canada was most affected in the utilities sector while China again was least affected.

In summary, these results show the transmission of volatility by country and by sector over time, a unique perspective that has been long overdue. Our analysis identifies the countries and the industrial sectors that were most and least exposed during several periods, including the financial crisis. These results may have policy implications. From a regulatory standpoint, countries on the receiving end can design appropriate policies to curb the extent of meteor shower effects. This can promote a sense of stability and resilience of their markets to attract foreign investors.

Vulnerability to the U.S. originated volatility spillover

Table 5 summarizes the spillover results by ranking these countries in order of high to low vulnerability to the U.S. based on their spillover index. The country with the highest spillover index is noted as 'Most Exposed' and the country with the lowest vulnerability is identified as 'Least Exposed'. For the full sample period, at the ***aggregate*** level, Canada remains as most vulnerable to the U.S. As we have noted earlier, this is consistent given the geographical proximity and international trade flows between the countries. In comparison, India was least exposed to the U.S. equity market. While India remains as an important trade partner to the U.S., capital market restrictions that still exist in India for

two-way investment flows may be responsible for the low exposure of India to meteor shower from the U.S.

Table 5 also presents the most exposed and least exposed for all 4 samples at the ***sectoral*** level. During the full sample, out of 9 equity sectors, Canada received the highest spillover in 7 sectors while China scored the lowest rank in 7 sectors. During the pre-financial crisis period, Canada scored the highest spillover in 8 while China was ranked as the country with the lowest spillover in 8 sectors. During the financial crisis period, Canada was ranked again as the most exposed country in terms of spillover in 7 out of 9 equity sectors. During the same period, China was least exposed in 7 out of 9 equity sectors. Finally, during the post-financial crisis period, Canada was most exposed in 8 out of 9 sectors. During the same period, China received the lowest spillover in 6 out of 9 equity sectors.

These results may have policy implications. From a regulatory standpoint, countries on the receiving end can design policies to curb the extent of meteor shower effects and insulate their equity sectors. As markets become less subject to external volatility, it promotes a sense of stability and resilience which may be attractive to global investors.

Portfolio Asset Allocation using Spillover Index as a Criterion

In this section, we conduct minimum variance optimization[16] to build globally diversified portfolios by allowing a portfolio manager to use the spillover index as a screening tool. We assume that portfolio managers would prefer to invest in low spillover countries for good diversification benefits. Table 6 reports the Sharpe ratio for several portfolios. The benchmark return is assumed to be the U.S. equity return (S&P500). The risk-free rate is based on the 10-yr U.S. Treasury bond.

We adopt 3 different allocation strategies based on the spillover index: Strategy 1: invest without screening, Strategy 2: invest in low spillover (defined as spillover less than the median spillover) countries, and Strategy 3: invest in high spillover countries. At the ***aggregate*** level (Panel A), the Sharpe ratios from strategy 1 are: .08 (full sample), .59 (pre-financial crisis), -1.72 (financial crisis), and .22 (post-financial crisis). For strategy 2, the Sharpe ratios are: .17 (full sample), .59 (pre-financial crisis), -1.02 (financial crisis), and .58 (post-financial crisis). Finally, for strategy 3, the Sharpe

[16]We do not allow short sell and maximum weight on a single country or sector is capped at 25%.

ratios are: -.04 (full sample), .37 (pre-financial crisis), -1.01 (financial crisis), .25 (post-financial crisis). At the aggregate, strategy 2 has the best Sharpe ratios, even during the financial crisis.

At the ***sectoral*** level (Panel B), similar investment strategies were applied to all sectors. With strategy 1, the Sharpe ratio was .33, which was higher than the Sharpe ratio from an aggregate index-based investment strategy (Panel A). During the pre-financial crisis, the strategy has a Sharpe ratio of .88. During the financial crisis, the performance of this strategy (-1.89) was worse than the strategy 1 applied to the aggregate indices (-1.72). The post-financial crisis performance of the strategy is better than the results based on aggregate stock indices. The Sharpe ratio was .68, which shows a 209% improvement over the results based on aggregate stock indices.

When the universe included only low spillover sectors (sectors with less than the median level of spillover), the Sharpe ratios are as follows: .38 (full sample), .98 (pre-financial crisis), -.88 (financial crisis), and .93 (post-financial crisis). Finally, when the universe included sectors scoring higher than the median spillover (strategy 3), the Sharpe ratios are as follows: .18 (full sample), .53 (pre-financial crisis), -1.57 (financial crisis), and .54 (post-financial crisis).

Sector Diversification

We also experimented with single sector (Panels C-K) diversification strategies. For basic materials sector, strategy 2 generated the highest Sharpe ratio of 1.32 during the pre-financial crisis period. Strategy 1 would have produced a Sharpe ratio of -1.27 during the financial crisis. In the consumer staples sector, strategy 3 produced the highest Sharpe ratio of 1.11 during the post-financial crisis period, which is surprising. We believe that taking an aggressive investment strategy on a bull market (recovery period) produces this result. Strategy 1 produced a Sharpe ratio of -1.91 during the financial crisis period. For the financial sector, strategy 2 would have produced a Sharpe ratio of 1.03 during the pre-financial crisis period. The same strategy would have been the ideal choice during the financial crisis as the portfolio would have lost the least. The healthcare industry offers the best Sharpe ratio during the post-financial crisis. The Sharpe ratio was 1.66 for strategy 2. The lowest Sharpe ratio for this sector was for strategy 1 during the financial crisis. For the remaining sectors, the highest Sharpe ratios for the sample periods are as follows: 1.0 (industrial; pre-financial crisis; low spillover strategy), .94 (oil and gas; pre-financial crisis; low spillover strategy), .84 (technology; post-financial

crisis; low spillover strategy), .33 (telecommunications; post-financial crisis; low spillover strategy), and .82 (utilities; pre-financial crisis; no screening).

IV. Conclusions

The extant literature suggests that volatility is both home grown (heat wave) and imported (meteor shower), making policy decisions even more complicated. Previous attempts to capture the extent of global connectedness have relied on aggregate stock indexes. Unfortunately, one of the shortcomings of these attempts is that one cannot identify the principal investable equity sectors that are most susceptible to meteor showers from the U.S. Additionally, there has not been any attempt to use the magnitude of meteor shower as a screening device to guide international investment from the U.S. Our paper addresses these two shortcomings. We identify the extent of volatility spillover from the major U.S. equity sectors (basic materials, consumer staples, financials, health care, industrials, oil and gas, technology, telecommunications, and utilities) to their corresponding equity sectors in 13 trading and investment partners of the U.S. (Australia, Brazil, Canada, China, France, Germany, India, Italy, Japan, Korea, Spain, Russia and the United Kingdom). Subsequently, we use spillover coefficients at the industry level to guide international investments.

During the full sample period (January 2, 2002 – September 21, 2015), two industries, basic materials and oil and gas, contributed most to volatility spillover from the U.S. During the same period, utilities sector was the least contributor to the spillover. During the pre-financial crisis (January 2, 2002 – February 14, 2007), oil and gas sector (utilities) was the highest (lowest) contributor to spillover. During the financial crisis (February 15, 2007 – April 30, 2009), we find that the financial sector was not the largest contributor to spillover. Rather, the technologies sector contributed to most spillover. The utilities sector was the lowest contributor to spillover. Finally, during the post-financial crisis period (May 1, 2009 – September 21, 2015), oil and gas (utilities) was the largest (smallest) contributor to spillover.

As expected, high spillover leads to high equity market correlation and as a result, lower diversification benefits from investing in these countries. Our minimum variance portfolio optimizations using spillover coefficients as a filter confirms this hypothesis. The U.S. portfolio managers can earn high Sharpe ratios by investing in low spillover countries.

As the extent of global connectedness rises, there is urgency among policymakers to correctly identify the principal sources of volatility in the domestic capital market. The fact that domestic capital markets respond to internal and external systematic risk suggests the need for appropriate policy responses to deal with disparate sources of shocks, without disrupting the free flow of capital. Investors also worry that increased uncertainty from volatility spillover can affect their international asset allocation decisions. There have been several policy recommendations to deal with volatility spillover. Reinhart and Rogoff (2012) recommend the IMF and other institutions to play a greater role with early warning and implementation of market discipline. To limit the financial vulnerabilities associated with the sectoral spillovers, some form of capital control may be prudent. Ostry *et al* (2012) constructed foreign-currency (FX)-related prudential measures and financial-sector specific controls for emerging markets economies over the period 1995-2008. The study found both capital controls and FX-related prudential measures lead to a lower proportion of FX lending in domestic bank credit and a lower proportion of portfolio debt in total external liabilities. These prudential measures reduce the intensity of aggregate credit booms and enhance economic resilience of financial system during stressed financial markets. There is evidence that higher regulatory quality and higher credit-to-deposit ratio increases the effectiveness of prudential measures in managing cross-border bank flows and in mitigating systemic risks for 66 advanced and emerging market economies spanning the period 1999-2012 (Beirne and Friedrich (2017)). In short, prudential measures may restrict access to capital markets by restricting capital flows across borders, regulatory agencies must not limit the maturity of emerging capital markets. To this extent, the results in this paper offer a framework for identifying the sectoral sources of volatility propagation and the need to adopt sound regulatory policies that promote bilateral capital flows but limit excessive volatility spillover.

Table 1: Market value of U.S. holdings of foreign equity, by country, and type of equity, for the countries attracting the most U.S. investment (as of December 31, 2013)

Billions of dollars

Country or region	Total	Common stock	Fund shares	Others*
United Kingdom	978	898	27	54
Cayman Islands	677	277	277	124
Japan	604	597	6	0
Switzerland	430	427	1	1
Canada	405	387	12	6
France	343	335	5	4
Germany	302	279	1	22
Netherlands	230	216	7	7
Ireland	228	209	12	7
Bermuda	179	160	10	9
Korea, South	147	141	0	6
Australia	144	131	12	2
Hong Kong	135	129	5	1
Brazil	129	98	1	30
China, mainland	101	98	3	0
Taiwan	98	98	0	0
Rest of world	1343	1238	50	56
Total	**6473**	**5715**	**429**	**329**

*Source: U.S. Treasury. Includes preferred stock, interests in limited partnerships and other types of equity. Excludes Hong Kong and Macau, which are reported separately.

Table 2: Market value of U.S. holdings of foreign securities, by industry, as of December 31, 2013

Billions of dollars

GICS Code*	Industry	Total	Equity	Debt	
				Long-Term	Short-term
1010	Total Energy	789	614	174	1
1510	Total Materials	596	456	138	2
2000	Total Industrial	741	658	82	1
2500	Total Consumer Discretionary	789	739	49	1
3000	Total Consumer Staples	586	530	53	3
3500	Total Health Care	582	548	32	2
4000	Total Financial	2977	1853	851	272
4500	Total Informational Technology	653	621	32	0
5010	Total Telecommunications Services	363	283	79	1
5510	Total Utilities	192	127	63	2
	Government**	759	1	695	63
	Industry Classification Unknown	103	41	57	5
	Total all industries	**9130**	**6473**	**2305**	**353**

Source: U.S. Treasury.
*Stands for Global Classification Industry Standard Code.
**Government includes central, local, and provincial governments, and government-sponsored or guaranteed corporations. Debt issued by international and regional organizations is classified as private.

Table 3: Panel A: Correlation between U.S. aggregate and sectoral stock returns with VIX returns

	Aggregate	Basic Materials	Consumer Staples	Financials	Health Care	Industrials	Oil and Gas	Technology	Telecommunication	Utilities
Full Sample	-0.75	-0.66	-0.68	-0.63	-0.68	-0.71	-0.61	-0.65	-0.55	-0.55
Pre-financial Crisis	-0.73	-0.66	-0.62	-0.66	-0.61	-0.66	-0.52	-0.59	-0.49	-0.46
Financial Crisis	-0.76	-0.67	-0.73	-0.66	-0.69	-0.73	-0.65	-0.72	-0.67	-0.67
Post-financial crisis	-0.80	-0.71	-0.77	-0.71	-0.74	-0.76	-0.69	-0.74	-0.60	-0.57

Note: The U.S. aggregate index is the U.S. MSCI Investible Index.

Table 3: Panel B: Correlation between foreign aggregate and sectoral stock returns with VIX returns

	Aggregate	**Basic Materials**	**Consumer Staples**	**Financials**	**Health Care**	**Industrials**	**Oil and Gas**	**Technology**	**Telecommunication**	**Utilities**
Australia	-0.43	-0.39	-0.22	-0.36	-0.27	-0.39	-0.37	-0.24	-0.16	-0.26
Brazil	-0.5	-0.45	-0.28	-0.44	-	-0.37	-0.38	-	-0.38	-0.36
Canada	-0.56	-0.39	-0.45	-0.48	-0.32	-0.49	-0.44	-0.35	-0.29	-0.38
China	-0.32	-0.12	-0.09	-0.09	-0.08	-0.1	-0.11	-0.09	-0.06	-0.09
France	-0.48	-0.41	-0.43	-0.44	-0.36	-0.44	-0.4	-0.38	-0.32	-0.31
Germany	-0.47	-0.48	-0.35	-0.49	-0.37	-0.49	-	-0.4	-0.36	-0.37
India	-0.21	-0.18	-0.14	-0.18	-0.14	-0.19	-0.13	-0.18	-0.11	-0.11
Italy	-0.46	-0.32	-0.4	-0.43	-0.29	-0.44	-0.37	-0.21	-0.31	-0.38
Japan	-0.39	-0.36	-0.38	-0.34	-0.32	-0.38	-0.32	-0.37	-0.27	-0.16
Korea	-0.29	-0.26	-0.19	-0.26	-0.08	-0.25	-0.21	-0.2	-0.14	-0.15
Russia	-0.28	-0.17	-	-0.22	-	-	-0.22	-	-0.2	-0.17
Spain	-0.45	-0.4	-0.28	-0.42	-0.31	-0.41	-0.38	-0.31	-0.38	-0.39
The UK	-0.46	-0.38	-0.36	-0.41	-0.3	-0.42	-0.35	-0.35	-0.32	-0.3

Correlation for the full sample period (January 2002- September 15, 2015) only. Missing indices are noted as -.

Table 4: Volatility Spillover Index – Percentage of foreign country's equity market volatility contributed by the U.S. equity market volatility

Panel A: Full Sample

	Australia	Brazil	Canada	China	France	Germany	India	Italy	Japan	Korea	Russia	Spain	UK
Aggregate	8.9%	10.0%	13.0%	5.8%	7.3%	7.7%	3.6%	6.3%	7.2%	5.3%	4.9%	6.4%	7.7%
Basic Materials	10.3%	11.9%	15.1%	1.9%	8.2%	9.1%	2.8%	8.0%	7.7%	6.6%	5.5%	7.0%	9.6%
Consumer Staples	5.6%	5.9%	15.3%	0.9%	10.3%	8.4%	2.2%	7.7%	8.7%	3.8%	--	5.0%	9.5%
Financials	9.9%	8.2%	16.0%	1.5%	6.9%	7.8%	3.5%	5.5%	7.0%	5.6%	3.6%	5.7%	8.0%
Health Care	6.9%	--	10.3%	0.7%	9.8%	10.3%	2.0%	6.7%	9.4%	0.5%	--	6.5%	9.9%
Industrials	9.3%	8.1%	14.4%	1.2%	8.3%	9.6%	2.7%	7.1%	8.4%	5.1%	--	7.1%	8.3%
Oil and Gas	10.8%	11.6%	19.1%	1.4%	8.9%	--	0.7%	8.1%	9.0%	4.0%	5.8%	6.6%	10.0%
Technologies	5.1%	--	14.7%	0.8%	11.0%	11.5%	4.3%	4.9%	10.5%	5.1%	--	6.8%	9.6%
Telecommunication	2.2%	8.9%	8.0%	0.3%	4.5%	5.9%	0.7%	4.9%	5.9%	2.4%	2.2%	5.8%	6.9%
Utilities	3.8%	8.5%	11.1%	0.3%	5.1%	5.6%	0.6%	4.4%	1.9%	2.2%	2.0%	5.1%	5.6%

Panel B: Pre-financial Crisis

	Australia	Brazil	Canada	China	France	Germany	India	Italy	Japan	Korea	Russia	Spain	UK
Aggregate	9.5%	8.5%	13.6%	5.3%	7.7%	8.6%	2.6%	6.4%	5.5%	5.3%	3.8%	6.6%	7.3%
Basic Materials	8.3%	8.3%	17.2%	0.7%	8.2%	9.7%	1.5%	5.6%	5.5%	6.1%	3.6%	5.4%	7.9%
Consumer Staples	4.1%	3.4%	18.0%	0.1%	10.2%	11.1%	1.3%	7.9%	6.1%	4.0%	--	3.6%	8.8%
Financials	8.5%	4.7%	16.1%	0.1%	8.3%	8.8%	1.0%	6.6%	3.4%	4.8%	2.0%	6.3%	6.9%
Health Care	4.4%	--	13.0%	0.2%	8.7%	8.9%	1.2%	4.8%	4.4%	0.6%	--	1.8%	9.6%
Industrials	6.5%	4.2%	10.9%	0.1%	7.8%	9.4%	1.4%	7.4%	7.2%	5.3%	--	4.9%	8.0%
Oil and Gas	10.7%	11.8%	21.2%	0.2%	8.2%	--	0.1%	7.1%	6.4%	2.1%	4.9%	6.9%	9.8%
Technologies	2.4%	--	15.6%	0.0%	10.9%	11.2%	3.5%	7.4%	8.2%	3.2%	--	7.0%	8.8%
Telecommunication	1.4%	6.4%	8.0%	0.1%	4.7%	5.8%	0.1%	4.8%	5.0%	3.3%	1.0%	5.2%	6.0%
Utilities	1.8%	5.8%	4.8%	0.1%	3.2%	2.3%	0.6%	2.9%	0.6%	0.9%	0.4%	3.8%	2.6%

Table 4: Volatility Spillover Index – Percentage of foreign country's equity market volatility contributed by the U.S. equity market volatility (contd.)

Panel C: Financial Crisis

	Australia	Brazil	Canada	China	France	Germany	India	Italy	Japan	Korea	Russia	Spain	UK
Aggregate	8.4%	9.9%	12.5%	5.1%	7.2%	6.9%	3.7%	6.9%	7.1%	4.7%	4.4%	6.9%	7.3%
Basic Materials	10.8%	13.0%	14.6%	1.8%	8.2%	8.6%	2.5%	9.1%	7.7%	6.3%	6.6%	6.8%	10.1%
Consumer Staples	8.6%	5.8%	13.4%	2.2%	11.4%	6.5%	3.8%	6.8%	10.2%	3.9%	--	6.9%	11.4%
Financials	9.2%	8.3%	14.8%	2.8%	6.6%	7.1%	4.6%	6.4%	7.0%	5.5%	3.4%	6.8%	7.1%
Health Care	8.0%	--	9.6%	2.3%	11.2%	12.1%	3.4%	6.4%	10.8%	0.7%	--	6.7%	9.8%
Industrials	9.2%	9.3%	15.8%	1.7%	8.3%	8.9%	2.9%	6.4%	8.0%	4.2%	--	7.0%	7.7%
Oil and Gas	10.7%	13.2%	17.4%	1.7%	9.6%	--	0.9%	9.8%	9.0%	3.2%	5.6%	6.8%	10.2%
Technologies	8.8%	--	15.2%	1.5%	10.1%	11.0%	5.1%	6.1%	11.7%	7.3%	--	7.2%	10.3%
Telecommunication	3.2%	12.8%	6.9%	0.5%	4.9%	5.6%	3.1%	7.3%	8.5%	3.8%	4.0%	7.4%	7.2%
Utilities	3.8%	12.5%	14.5%	0.3%	6.8%	8.0%	0.3%	6.6%	5.6%	4.4%	4.5%	6.5%	6.9%

Panel D: Post-Financial Crisis

	Australia	Brazil	Canada	China	France	Germany	India	Italy	Japan	Korea	Russia	Spain	UK
Aggregate	8.2%	9.8%	12.7%	6.4%	7.2%	7.5%	4.2%	6.3%	7.4%	5.8%	5.8%	6.2%	7.8%
Basic Materials	9.8%	11.3%	14.0%	2.5%	7.9%	9.3%	4.1%	7.9%	8.1%	7.0%	5.5%	7.4%	9.1%
Consumer Staples	5.0%	9.0%	12.6%	1.0%	8.3%	9.3%	2.8%	7.6%	8.7%	3.2%	--	6.2%	8.6%
Financials	8.7%	8.9%	13.9%	1.2%	7.3%	8.8%	3.1%	5.8%	7.6%	7.3%	4.8%	5.5%	8.5%
Health Care	7.1%	--	10.8%	0.7%	9.5%	10.0%	2.0%	8.3%	9.6%	0.5%	--	8.5%	9.9%
Industrials	9.5%	9.1%	15.5%	2.0%	8.4%	9.9%	3.4%	7.4%	8.6%	6.2%	--	7.4%	8.6%
Oil and Gas	10.2%	9.4%	18.0%	3.0%	8.6%	--	2.0%	7.7%	9.2%	6.8%	7.3%	7.2%	9.7%
Technologies	5.0%	--	10.2%	1.4%	10.7%	11.6%	4.9%	2.6%	10.2%	6.7%	--	6.7%	9.4%
Telecommunication	3.2%	6.2%	7.4%	0.9%	4.6%	6.3%	0.8%	4.8%	3.7%	1.1%	3.2%	6.0%	7.1%
Utilities	4.3%	7.4%	11.2%	0.6%	4.9%	5.4%	1.3%	3.6%	1.0%	1.7%	3.0%	4.7%	5.7%

Volatility spillover Index measures the percentage of a country's return volatility contributed by the corresponding stock market volatility in the U.S. The Diebold-Yilmaz (2012) uses the variance decomposition method to identify the extent of volatility spillover from one market to the other.

Table 5: Winners and Losers on the basis of vulnerability to the U.S. originated volatility spillover

		Equity Sectors									
	Degree of Vulnerability to Volatility Spillover	Aggregate	Basic Materials	Consumer Staples	Financials	Health Care	Industrials	Oil and Gas	Technologies	Telecommunication	Utilities
Sample											
Full Sample	Highest	Canada	Canada	Canada	Canada	Germany	Canada	Canada	Canada	Brazil	Canada
	Lowest	India	China	China	China	Korea	China	India	China	China	China
Pre-financial Crisis	Highest	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Brazil
	Lowest	India	China	China	China	China	China	India	China	China	China
Financial Crisis	Highest	Canada	Canada	Canada	Canada	Germany	Canada	Canada	Canada	Brazil	Canada
	Lowest	India	China	China	China	Korea	China	India	China	China	China
Post-financial Crisis	Highest	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Germany	Canada	Canada
	Lowest	India	China	China	China	Korea	China	India	China	India	China

Note: In this table, we sort the 13 countries in order of volatility spillover from the U.S. to identify the highest and lowest volatility spillover countries. Volatility spillover is measured using Diebold and Yilmaz (2012) methodology. Highest represents the country that was most exposed to the volatility spillover while lowest represents the country least exposed.

Table 6: Portfolio construction using Spillover Index as a screening tool

Panel A: Aggregate

	2002-2015			Pre-financial Crisis			Financial Crisis			Post Financial Crisis		
	No Screening	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**
Annual Return	5.51%	7.10%	3.78%	12.44%	14.04%	10.63%	-19.17%	-19.94%	-19.82%	7.33%	10.21%	5.62%
Annual Std.	13.70%	15.75%	14.50%	9.42%	11.76%	9.55%	22.41%	23.42%	23.55%	11.48%	13.07%	12.38%
Sharpe Ratio	0.08	0.17	-0.04	0.59	0.59	0.37	-1.72	-1.02	-1.01	0.22	0.58	0.25

Panel B: All Sectors

	2002-2015			Pre-financial Crisis			Financial Crisis			Post Financial Crisis		
	No Screening	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**
Annual Return	7.18%	7.97%	6.20%	11.71%	13.89%	11.03%	-11.49%	-7.98%	-16.46%	10.10%	10.24%	7.51%
Annual Std.	8.38%	9.36%	10.02%	6.05%	6.89%	7.42%	11.40%	13.54%	12.98%	7.07%	8.22%	9.19%
Sharpe Ratio	0.33	0.38	0.18	0.88	0.98	0.53	-1.89	-0.88	-1.57	0.68	0.93	0.54

Panel C: Basic Materials

	2002-2015			Pre-financial Crisis			Financial Crisis			Post Financial Crisis		
	No Screening	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**
Annual Return	6.22%	6.35%	6.29%	22.12%	22.04%	20.27%	-15.96%	-20.27%	-12.32%	3.53%	3.53%	3.53%
Annual Std.	16.04%	16.53%	19.39%	10.71%	11.36%	13.02%	24.56%	25.19%	30.35%	14.80%	15.46%	17.18%
Sharpe Ratio	0.12	0.12	0.10	1.11	1.32	1.01	-1.27	-0.96	-0.53	-0.05	0.06	0.06

Panel D: Consumer Goods

	2002-2015			Pre-financial Crisis			Financial Crisis			Post Financial Crisis		
	No Screening	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**
Annual Return	10.07%	9.94%	7.26%	15.32%	16.67%	8.66%	-15.72%	-8.53%	-19.44%	12.15%	10.67%	15.36%
Annual Std.	10.51%	10.81%	13.89%	9.89%	10.56%	12.76%	12.78%	17.46%	13.61%	8.61%	8.78%	11.49%
Sharpe Ratio	0.54	0.51	0.21	1.04	0.91	0.12	-1.91	-0.71	-1.72	0.74	0.92	1.11

Panel E: Financials

	2002-2015			Pre-financial Crisis			Financial Crisis			Post Financial Crisis		
	No Screening	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**
Annual Return	4.88%	6.02%	3.78%	12.64%	19.61%	11.19%	-23.18%	-23.18%	-23.18%	7.95%	9.09%	7.65%
Annual Std.	14.10%	17.78%	14.93%	8.04%	12.16%	8.33%	24.75%	27.92%	27.15%	11.55%	15.37%	12.28%
Sharpe Ratio	0.04	0.09	-0.04	0.59	1.03	0.49	-1.95	-0.97	-1.00	0.25	0.42	0.41

Table 6: Portfolio construction using Spillover Index as a screening tool(contd.)

Panel F: Health Care

	2002-2015			Pre-financial Crisis			Financial Crisis			Post Financial Crisis		
	No Screening	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**
Annual Return	10.07%	10.30%	7.66%	8.49%	9.97%	4.54%	-8.41%	-8.29%	-15.37%	16.85%	18.93%	13.97%
Annual Std.	9.94%	10.51%	12.05%	7.45%	7.81%	10.33%	12.89%	14.69%	15.89%	9.22%	9.83%	11.36%
Sharpe Ratio	0.57	0.56	0.27	0.41	0.37	-0.25	-1.29	-0.83	-1.21	1.26	1.66	1.00

Panel G: Industrials

	2002-2015			Pre-financial Crisis			Financial Crisis			Post Financial Crisis		
	No Screening	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**
Annual Return	6.85%	8.67%	3.78%	15.52%	16.58%	7.71%	-23.18%	-22.23%	-23.18%	11.57%	9.36%	11.09%
Annual Std.	13.14%	14.38%	14.38%	9.42%	9.50%	13.98%	20.04%	20.77%	23.74%	11.19%	13.83%	11.85%
Sharpe Ratio	0.19	0.30	-0.04	0.85	1.00	0.04	-2.10	-1.26	-1.14	0.55	0.49	0.72

Panel H: Oil and Gas

	2002-2015			Pre-financial Crisis			Financial Crisis			Post Financial Crisis		
	No Screening	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**
Annual Return	5.37%	6.31%	3.78%	19.01%	19.38%	15.82%	-16.18%	-17.61%	-2.16%	3.53%	3.53%	3.53%
Annual Std.	15.77%	16.50%	19.37%	12.12%	13.01%	14.97%	22.49%	22.89%	30.46%	14.76%	14.76%	19.93%
Sharpe Ratio	0.06	0.12	-0.03	0.93	0.94	0.58	-1.30	-0.94	-0.20	-0.05	0.06	0.05

Panel I: Technology

	2002-2015			Pre-financial Crisis			Financial Crisis			Post Financial Crisis		
	No Screening	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**
Annual Return	5.03%	5.09%	3.78%	8.20%	8.73%	4.54%	-19.58%	-23.18%	-16.15%	12.84%	13.72%	10.89%
Annual Std.	15.33%	15.71%	20.22%	14.49%	14.67%	22.66%	19.66%	19.98%	25.92%	12.47%	13.24%	14.69%
Sharpe Ratio	0.04	0.05	-0.03	0.25	0.11	-0.11	-1.56	-1.36	-0.77	0.55	0.84	0.57

Panel J: Telecommunication

	2002-2015			Pre-financial Crisis			Financial Crisis			Post Financial Crisis		
	No Screening	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**
Annual Return	3.78%	3.78%	3.80%	4.54%	4.75%	4.54%	-10.37%	-9.75%	-14.28%	6.25%	5.91%	8.09%
Annual Std.	10.94%	12.67%	14.70%	10.16%	11.80%	13.80%	15.69%	16.02%	20.29%	8.38%	10.02%	10.41%
Sharpe Ratio	-0.05	-0.05	-0.04	0.01	-0.20	-0.19	-1.35	-0.85	-0.90	0.17	0.33	0.53

Panel K: Utilities

	2002-2015			Pre-financial Crisis			Financial Crisis			Post Financial Crisis		
	No Screening	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**	**No screening**	**Low vol.**	**High vol.**
Annual Return	4.81%	3.78%	5.18%	12.23%	12.56%	11.29%	-10.60%	-16.43%	-10.28%	3.53%	3.53%	3.92%
Annual Std.	9.64%	11.63%	11.32%	6.33%	8.10%	7.99%	14.95%	17.58%	17.85%	8.71%	10.83%	9.28%
Sharpe Ratio	0.05	-0.05	0.07	0.82	0.67	0.53	-1.55	-1.16	-0.79	-0.09	0.09	0.14

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