Market Integration and Financial Linkages among Stock Markets in Pacific Basin Countries

Julien Chevallier, Duc Khuong Nguyen, Jonathan Siverskog, Gazi Salah Uddin

IPAG BUSINESS SCHOOL
184, Boulevard Saint-Germain
75006 Paris
France

https://faculty-research.ipag.edu/researchs/working-papers/
Market Integration and Financial Linkages among Stock Markets in Pacific Basin Countries

Julien Chevallier\textsuperscript{a}, Duc Khuong Nguyen\textsuperscript{a,\ast}, Jonathan Siverskog\textsuperscript{b}, and Gazi Salah Uddin\textsuperscript{b}

\textsuperscript{a} IPAG Business School, Paris, France
\textsuperscript{b} Linköping University, Linköping, Sweden

Abstract

Financial development and globalization have significantly integrated stock markets around the world. This higher degree of interdependence and integration not only provides firms with higher access to international capital markets with lower cost of equity but also generates upward vulnerabilities for local markets due to their exposure to global and regional shocks. This article focuses on the level of interdependence across the Pacific Basin stock markets using the return spillover measure proposed by Diebold and Yilmaz (2009, 2012), given their increasing role in global trade and finance. We are also interested in investigating the effect of shocks affecting the United States and the Japanese stock markets as well as their transmission to the emerging markets. We mainly find that: (i) the interdependence of the emerging stock markets in the ASEAN countries is driven by a higher exposure to the US shocks than to shocks affecting the developed economies of East Asia, and (ii) the cross-market linkages in the Pacific Basin region have become stronger over time, which may reduce the benefit of regional diversification strategies and expose the countries of the region to increasing contagion risk. These results have important implications for public policies related to the issue of regional and global financial integration.

\textit{JEL Classifications:} C32; C58; G10
\textit{Keywords:} Return spillover; equity markets; Pacific Basin.

\ast Corresponding author: IPAG Business School, 184 Boulevard Saint-Germain, 75006 Paris, France. Phone: +33 1 4940 7386 - Fax: +33 1 4940 7255.
Email addresses: J. Chevallier (julien.chevalier@ipag.fr), D.K. Nguyen (duc.nguyen@ipag.fr), J. Siverskog (jonathan.siverskog@liu.se), G. Salah Uddin (gazi.salah.uddin@liu.se)
1. Introduction

The degree of market comovements is a critical factor for assessing the diversification opportunities across national financial markets. Previous studies have shown that market comovements are strongly influenced by the international trade channel (Frankel and Rose, 1998 and Pentecôte et al., 2015), monetary integration (Ross and Engel, 2002; Bekaert et al., 2013), and financial market integration (Baele et al., 2004; Wälti, 2011; Aloui et al., 2011). To the extent that cross-sectional effects among financial markets provide useful information to set up asset pricing models in international context, the investigation of the cross-market dynamic interactions in terms of both return and volatility transmission is of paramount interest to investors, fund managers and policymakers. Indeed, a strong interdependence among national markets around the world may effectively lead to higher exposure to contagious effects if one market in the system goes through a crisis or experiences a serious crash.

In this paper we attempt to evaluate the degree of market interdependence and shock transmission between stock markets of fourteen selected countries in the Pacific Basin region for portfolio investment and public policy purposes. This geographical area, surrounding the edges of the Pacific Ocean, hosts some of the most dynamic and wealthy countries in the world such as Australia, Canada, and the United States. Over recent years, many other emerging countries have rapidly modernized their economies, in the aftermath of significant economic reform programs implemented in the 1990s and 2000s. Examples include the four Asian Tigers (Hong Kong, South Korea, Singapore, and Taiwan) and the group of Tiger Cubs (Indonesia, Malaysia, Philippines, and Thailand). Eight out of the fourteen selected Pacific Basin countries in our sample are expected to play important roles in the regional trade development and cross-border capital flows through the Trans-Pacific Partnership (TPP) negotiations. The proposed regional regulatory and investment treaty would establish a huge market for capital, goods and services covering about 3.5 billion of habitants and close to $33.5 trillion of GDP. It is worth
noting that even though the TPP will not enter in force due to the non-ratification of the United States\(^1\), its blueprints could serve other bilateral and multilateral trade agreement alternatives, with or without the United States, given the potential and dynamics of the Asia-Pacific regional trade.

Empirically, we employ the spillover measure of Diebold and Yilmaz (2009) and its generalized version as described in Diebold and Yilmaz (2012) to assess the cross-market interdependence among sample markets. In particular, we focus on the investigation of the mechanisms of shock transmissions from two leading countries in the region, Japan and the United States, to other markets. By doing so, the obtained results would permit us to shed light on several aspects of global and regional market integration and their implications for capital flows and portfolio investments. Our research is thus closely related to studies addressing the structural changes and market integration as well as the resulting shock transmission and volatility spillovers involving equity markets in the Pacific Basin region (e.g., Wei et al., 1995; Hu et al., 1997; Ng, 2000; Miyakoshi, 2003; Kim 2005; Singh et al., 2010; Zhou et al., 2012; Liu, 2014). The results of these studies mainly suggest an increase in the transmission of return and volatility shocks over recent periods, but a conflicting evidence as to the leading role of Japan and the United States in the region.

Overall, our study makes two major contributions to the related literature. First, we quantify the directional return spillover effects that a particular equity market receives from the other markets, while considering a large number of countries and the recent episodes of financial turbulences such as the US subprime crisis in 2007, the global financial crisis in 2008-2009, the Arab Spring in 2010, and the European debt crisis since the end of 2009. Besides the

\(^1\) On the 23rd of January 2017, the President Donald Trump signed an order to withdraw the United States from the Trans-Pacific Partnership. While this decision has to be approved by the U.S. congress, we decide to only stress on its potential implications for the development of regional trade, but avoid speculating on its implementation and effects.
spillover index developed by Diebold and Yilmaz (2012), we consider Klössner and Wagner (2014)’s methodological framework to deal with the problem of variable ordering, which allows one to measure average spillover effects. From a practical point of view, these spillover effects are informative of the price discovery in a particular market, which could then be transmitted to other markets due particularly to cross-listing of firms, and portfolio and fund investments. Coupled with the geographical proximity between different markets, the speed of information transmission depends greatly on specific-market characteristics including, among others, market microstructure, regulation and liquidity. Second, we rely on a unified framework to discriminate the information leadership between the United States and Japan, with respect to their spillover effects on the other markets of the Pacific Basin region. The obtained results would help to reconcile the empirical evidence from past studies which only consider either Japan or the United States in their sample.

The empirical results from our spillover analysis identify Australia, Canada, Mexico, Hong Kong, Sinagapore, the United States as the major transmitters (givers) and receivers of return spillovers in the Pacific Basin region. We also find evidence of increased integration of stock markets in the ASEAN countries with the U.S. markets, rather than with other neighbouring developed countries in East Asia (Japan, South Korea, and Taiwan). China, on the contrary to common expectations based on its current economic size and growth, is relatively disconnected from the rest of the region.

Regarding the relative importance of the United States and Japan in terms of shock transmission, we find the United States to be the single greatest contributor to shock spillover in the region, while the effects of shock spillover from Japanese stock markets are very limited. Our results therefore contrast those of Chuang et al. (2007) and Singh et al. (2010), but are consistent with those of Wei et al. (1995), Ng (2000), Miyakoshi (2003), Zhou et al. (2012) – and Hu et al. (1997) to a lesser extent – in that the stock markets of Pacific Basin countries
oscillate around the U.S. ones within the shock spillover framework. As to the evolving financial integration in the Pacific Basin region, our empirical evidence points to market interdependence increasing over the last 20 years, where stock market integration for the ASEAN emerging markets is driven particularly by their exposure to shocks affecting stock markets in the United States, rather than to shocks affecting the markets of the East Asian developed economies.

The remainder of the article is structured as follows. Section 2 describes the financial development and integration of the Pacific Basin region. Section 3 details the empirical method. Section 4 presents the data used and their properties. Section 5 discusses the obtained results. Section 6 concludes the article.

2. Financial development and integration of Pacific Basin region

Our sample covers stock markets with different degrees of financial development. Table 1 provides data on the evolution of market size and market liquidity from 1992 to 2012 from the World Development Indicators. Market capitalization as a share of Gross Domestic Product indicates that stock markets have generally increased their relative importance over the whole period. Rapid development can particularly be observed for Hong Kong, China, Korea, the Philippines and Canada. The number of listed companies in most markets also grew by at least 50% during this twenty-year period; the most spectacular increase occurring in China where the number of listed companies has increased from 50 to 2500. Financial development is however not characterized by a steady ongoing growth. For instance, the stock markets in Hong Kong and China experienced a peak in market capitalization around the year of 2008, which seems to correspond to the booming periods prior to the global financial crisis 2008-2009.

Although the emerging stock markets of our sample have become more established and
more mature over time, we see that they are still less liquid than those of the developed countries. A notable exception is the Chinese stock market with a high turnover ratio, despite the existence of trading restrictions which constitute a major source of liquidity problems (Johansson and Ljungwall, 2009).

Table 2 reports a number of financial integration and economic openness indicators. The latter shows a preliminary picture of the interconnectedness among the stock markets in our sample. For instance, the high level of the trade to GDP ratio in Hong Kong, Singapore, Malaysia, Thailand, and South Korea suggests that these countries have important trade links with the rest of the world and are thus more exposed to global conditions. In particular, Hong Kong and Singapore are well known for being international financial and commercial hubs. In the case of South Korea and Thailand, the rapid increase in trade-to-GDP ratios reflects their higher degree of integration into global markets over the recent periods. For the United States and Japan, the changes in the trade/GDP ratio are relatively stable and the patterns are very comparable.

As to the capital mobility, Table 2 indicates that in 2012 China receives the most FDI inflows (US$296 billion), followed by the United States (US$218 billion), Hong Kong (US$75 billion), Singapore (US$61 billion) and Australia (US$54 billion). Japan receives the least FDI inflows in the same year (only US$1 billion). In terms of FDI outflows in 2012, the United States has a dominant position with US$239 billion, followed by Japan (US$35 billion) and China (US$30 billion). Altogether, these statistics show the crucial role of the United States, China, and Japan in the global growth and world development.

Previous literature has examined several aspects related to the financial linkages in the equity markets of the Pacific Basin region. In their study, Wei et al. (1995) use the moving
average-GARCH models to test for mean and volatility spillovers in three developed market places (New York, Tokyo, and London), and two emerging market places (Taiwan and Hong Kong). They identify that the Tokyo stock market has smaller influence than the New York stock market on the Taiwanese and Hong Kong stock markets. Hu et al. (1997) examine the spillover effects of volatility among the markets in the South China Growth Triangular using causality-in-variance tests. One of their main results features that the Japanese stock market affects the US stock market, and there is a feedback relationship between Hong Kong and the U.S. stock market. Ng (2000) investigates the magnitude and changing nature of volatility spillovers from Japan and the United States to six Pacific-Basin equity markets in multivariate GARCH models. The author points out a need for more research into the Pacific-Basin markets that may be driven by some forces that are specific to this particular region but unrelated to the Japanese market. Miyakoshi (2003) uses a bivariate EGARCH model to investigate the return and volatility spillovers from Japan and the United States to seven Asian equity markets and only documents the influence of the U.S. markets on Asian market returns.

More recent studies have looked at the volatility transmission with a special attention to the global financial crisis of 2008-2009 by using not only GARCH-based methodologies, but also explicit measures of volatility spillovers. For example, Mukherjee and Mishra (2010) focuses on stock market integration and volatility spillover between India and its major Asian counterparts. Hong Kong, Korea, Singapore and Thailand are found to be the four Asian markets from where there is a significant flow of market information to India. Singh et al. (2010) examine price and volatility spillovers across North American, European and Asian stock markets through VAR and AR-GARCH models. They identify the Japanese market as being the most influential in transmitting volatility to the other East Asian markets, and concur to the previous findings by Chuang and al. (2007) in the same context. Zhou et al. (2012) use the Diebold and Yilmaz (2012)’s framework to measure the directional volatility spillovers
between the Chinese and world equity markets. They also find that the U.S. market exhibits dominant volatility impacts on other markets, with data covering the subprime crisis.

3. Measures of spillover effects

The spillover index introduced by Diebold and Yilmaz (2009, 2012) is a novel measure of financial integration constructed using forecast error variance decompositions (FEVD) from a multivariate vector autoregressive (VAR) model. The index describes the proportion of forecast error variance in a system of assets/markets not explained by shocks originating in the own market. Bounded between 0 and 100, a low index value indicates limited interdependence between assets/markets, while high values imply strong cross-assets/cross-market linkages. In what follows, we briefly show how the spillover index is constructed and discuss the alternative solutions to some methodological issues. Our methodological presentation favors the impulse response function (IRF) rather than the FEVD as a starting point, since it allows for a more general definition of the index.

Let \( \mathbf{x}_t \) represent our \((N \times 1)\) vector of market returns at time \( t \). Furthermore, let \( \psi_{nm}^h \) denote the impulse response in the \( n^{th} \) market in \( \mathbf{x}_{t+h} \) for a shock to the \( m^{th} \) market at time \( t \). The directional spillover from market \( m \) to market \( n \) is defined as

\[
SO_{nm} = \frac{\sum_{h=0}^{H} (\psi_{nm}^h)^2}{\sum_{h=0}^{H} \sum_{n=1}^{N} (\psi_{nm}^h)^2} \times 100
\] (1)

where \( H \) is the selected forecast horizon. \( SO_{nm} \) is a rescaled FEVD multiplied by a factor of 100 and describes the percentage share of error variance in market \( n \) contributed by shocks to market \( m \). It is also possible to define the total spillover to market \( n \) excluding its own variance share as
\[ SO_{n\leftarrow} = \sum_{n=1, n \neq m}^{N} SO_{nm} \]  

and the total contribution of market \( m \) to variance shares in other markets as

\[ SO_{m\rightarrow} = \sum_{m=1, m \neq n}^{N} SO_{nm} \]  

Then, based on the above-defined measures, the spillover index can be calculated as

\[ SOI = \frac{\sum_{n=1}^{N} SO_{n\leftarrow}}{\sum_{n=1}^{N} \sum_{m=1}^{N} SO_{nm}} \times 100 \]  

Note that we get \( \sum_{n=1}^{N} SO_{nm} = 100 \) by construction, and also \( \sum_{n=1}^{N} \sum_{m=1}^{N} SO_{nm} = 100N \). Moreover, it is apparent that \( \sum_{n=1}^{N} SO_{n\leftarrow} = \sum_{m=1}^{N} SO_{m\rightarrow} \) which means that the index can be calculated for either the transmitted or received spillovers.

Finally, we define net spillover as either

\[ Net \ SO_n = SO_{n\rightarrow} - SO_{n\leftarrow} \]  

or

\[ Net \ SO_{nm} = SO_{nm} - SO_{mn} \]

At the heart of impulse response analysis lies the question of how to represent the shocks to the system. To the extent that shocks to different markets are usually correlated, there is no straightforward way of defining the *ceteris paribus* response of one variable to a shock to another variable. Following Sims (1980), the standard approach used in the original spillover index of Diebold and Yilmaz (2009) is to orthogonalize the shocks through Cholesky decomposition. The latter has, however, the drawback of making the results sensitive to the ordering of system variable. For this reason, Diebold and Yilmaz (2009) compute a small number of permutations of variable in order to demonstrate the robustness of their spillover measure. More recently, Klössner and Wagner (2014) show that the ordering of variables has a significant impact on the results, typically when all possible permutations are considered. This problem
makes difficult the assessment of the direction of return and volatility spillovers between different markets, if we do not impose strong prior assumptions about their relationships.

We address this issue in two distinct ways. First, similar to Diebold and Yilmaz (2012), we propose to use the Koop et al. (1996) and Pesaran and Shin (1998) generalized impulse response framework in order to produce spillovers invariant to the ordering of variables. While this approach is advantageous in that it avoids the creation of a recursive shock structure, it derives the marginal impact of individual shocks based on the assumption of a multivariate Gaussian error distribution. Second, we follow Klößner and Wagner (2012b, 2014)’s suggestion and compute the average spillover over all possible permutations of variable ordering as compared to the standard Cholesky decomposition. The main disadvantage of this “brute-force” method is that the computational time increases considerably with the number of system variables.

Following Pesaran and Shin (1998), we refer the first approach as “generalized spillover” and the second as “average orthogonalized spillover”. Both approaches use the Wold infinite moving average (MA) representation which exists for any VAR($p$) assuming that $x_t$ is covariance-stationary. The Wold decomposition yields

$$ x_t = \sum_{i=0}^{\infty} A_i e_{t-i} $$

(7)

where $e_t$ is a vector of Gaussian white noise errors at time $t$ and $A_i$ can be calculated recursively as

$$ A_i = \sum_{p=1}^{p} \Theta_p A_{i-p} $$

(8)

with $\Theta_p$ representing the coefficient matrices from a VAR($p$) model, and $A_0 = I$ and $A_i$ being the zero-matrix for $i < 0$. The generalized impulse response function for a one standard error shock to asset $m$ can be defined as
\[ \psi^h_{nm} (g) = \sigma^{-1}_{mm} e_n' A_h \Sigma e_m \]  

where \( \Sigma \) is the error covariance matrix, \( \sigma_{mm} \) is the \( m \)th element in the diagonal of \( \Sigma \), and \( e_n \) is a selection vector where all elements are zero, except the \( n \)th element which is set to one. The orthogonalized IRF for a unit shock to \( m \) is written as

\[ \psi^h_{nm} (o) = e_n' A_h L e_m \]  

where \( L \) is the lower triangular Cholesky decomposition matrix of \( \Sigma \). When Eqs. (9) and (10) are substituted into Eq. (1), we get the spillover measures as they were calculated in Diebold and Yilmaz (2009), and Diebold and Yilmaz (2012), respectively.  

We follow Pesaran and Shin (1998)’s approach to compute the \( H \)-step forecast-error covariance matrix as \( \sum_{h=0}^{H} A_h \Sigma A_h' \), instead of \( H - 1 \) steps for the same cumulative sum as in Diebold and Yilmaz (2012)3.

We estimate the VAR(\( P \)) models and compute the IRF (and implicitly the FEVD) for 10-day ahead forecasts.  

Similar to previous studies, we also perform our empirical analysis with 250-day rolling windows in order to examine the evolution of spillovers over time. We use \( P = 1 \) for all estimations (i.e., full sample as well as rolling sample VAR models), which is the optimal lag length according to both the Schwarz and Hannan-Quinn information criteria.

4. Data and properties

Our dataset contains time series of equity price indices with daily frequency for a sample of 14 countries in the Pacific Basin region: Australia, Canada, China, Hong Kong, Indonesia, Japan, South Korea, Malaysia, Mexico, the Philippines, Singapore, Taiwan, Thailand, and the United

---


3 This difference comes from the notation only and does not alter our empirical results.

4 VARs are estimated using Pfaff (2008)’s R package **vars**, while average orthogonalized spillover is computed following the procedure proposed by Klössner and Wagner (2012a). Models are confirmed to be stable by checking that all roots are within the unit circle.
States. The Morgan Stanley Capital International (MSCI) stock market indices for all sample countries are obtained from Datastream International. Our study period ranges from 1 January 1993 to 25 June 2014, totalling 5,605 daily observations. We compute the log returns by taking the difference in the natural logarithm of two successive index prices.

Country-level equity price indices are reproduced in Figure 1. We can note that stock markets of almost all countries under consideration reacted significantly to the Asian financial crisis of 1997-1998, as well as to the global financial crisis of 2008-2009. Other sharp declines in equity prices can mainly be attributed to country-specific events, such as the Mexican peso crisis in 1995 and the 2006 military coup in Thailand. Some of these events become more salient when we take a close look at the patterns of changes in the logarithmic returns (Figure 2).

Figures 1-2 about here

Table 3 reports the descriptive statistics for log returns. It is clearly observed that all return series are not normally distributed, with respect to the Jarque-Bera test for normality. The augmented Dickey-Fuller (ADF) test indicates, for its part, that log returns are stationary, and thus suitable for further statistical analysis. In order to simultaneously take the trend stationarity and potential structural breaks into account, we also consider the Zivot and Andrews (1992)’s single unknown structural break test and the Perron (1989)’s a one-time break unit root test. The results obtained from these tests are presented in the last two columns of Table 3. They are consistent with the results of the ADF test and show that the stationary property of the log returns cannot be rejected at the 1% level, even when structural breaks are accounted for.

Table 3 about here

5. Results and discussions

This section reports the estimation results of our empirical models where the methods of generalized spillovers and average orthogonalized spillovers are used to analyze the strength
and directions of return spillovers among the Pacific Basin countries. To give an overview of the direction of spillovers, we start with a full sample analysis containing some stylized facts about the characteristics of financial market linkages in the region. We focus on results that are confirmed by both estimation methods (i.e., generalized spillovers and average orthogonalized spillovers) and highlight some remarkable differences. In this way, we are able to check the robustness of the estimated spillover measures as well as to identify possible limitations to their practical application. We then discuss the dynamics of return spillovers based on the findings of our rolling sample analysis, which helps answer the question of whether cross-market linkages become stronger over time. Finally, we have a look at directional spillovers from the United States and Japan to the remaining markets of the region to investigate the nature of market integration (regional versus global) as far as shocks from the United States and Japan can be reasonably considered as the global and regional ones, respectively.

At first, the results of the average orthogonalized spillovers in Table 4 show that the United States is the single greatest contributor to return spillover in the region (94.95%, excluding own variance share). Shocks to the U.S. market returns are predominantly transmitted to Canada (19.20%), Australia (14.64%), and Mexico (11.87%), with Canada and Mexico being among the major trading partners of the United States through the North American Free Trade Agreement. The spillover results from United States to Australia are not unexpected likewise since the U.S. investors occupy the first place in Australia in terms of foreign investments, while the Australian investments abroad also go to the United States as the first destination.\(^5\) The U.S. spillover shocks only account for 2-8% in the total return variance of the remaining countries in the region. Other major spillover transmitters are Canada and Mexico with a total of given spillovers of 67.29% and 53.02% respectively, and by far Singapore (40.55%) and

\(^5\) http://www.abs.gov.au/ausstats/abs@.nsf/mf/5352.0
Hong Kong (33.91%).

When considering the return spillover received by each country separately, we find that the stock markets of Hong Kong, Singapore, Australia and China are the most responsive to non-domestic shocks; other markets in the sample accounting for 40-46% of total forecast error variance in each case. Other major receivers are the United States and Canada (at around 35%), while spillovers received from foreign markets range between 20% and 28% for the remaining countries. These findings suggest that the group of developed markets (Australia, Singapore, Hong Kong, Canada and the United States), but also China, have a high level of financial linkages and integration with the rest of the sample markets. Except for Hong Kong, this finding confirms the interest for these countries in joining bilateral or multilateral free trade agreements such as the TPP, which are set to bring lower both non-tariff and tariff barriers to trade, and to establish an investor-state dispute settlement mechanism. In additional, stock market interdependence seems to manifest in clusters, with both given and received spillovers being greater among certain groups of markets such as the United States, Canada, Mexico, and Australia, or China, Singapore, and Hong Kong. This is also true for the developing countries of the ASEAN. At a cursory glance, they appear to exhibit a low degree of financial linkages, but a closer look at the results reveals a certain level of spillover effects among these markets, with Singapore as the leading spillover contributor. We also note that shocks to U.S. market returns have a relatively strong influence on the sample ASEAN countries (Indonesia, Malaysia, Philippines, Singapore, and Thailand).

As for the East Asian countries (Japan, South Korea and Taiwan), their intermarket linkages are weaker than those found for other developed countries. They typically receive more spillovers than they give from foreign countries (24.95% vs. 10.34% for Japan, 25.78% vs. 16.44% for South Korea, and 22.41% vs. 11.40% for Taiwan). Moreover, these countries do
not display any substantial linkages with the ASEAN ones, which seems to suggest that stock market integration in the emerging countries of South East Asia is stronger with the United States than with the developed economies of East Asia.

When comparing the average orthogonalized spillovers to the generalized spillovers reported in Table 5, we see a considerable gap between the sizes of the variance shares provided by the two measures. Indeed, the spillover index has an overall value of 31.63% using the average orthogonalized spillover measure, while the generalized spillover measure produces a value of 56.62%. Despite this difference in magnitude, the patterns of transmitted and received spillovers are quite consistent between two measures. For instance, we still find the same countries among the most important givers and receivers of return shock spillovers. Another notable difference is that the generalized spillover measure indicates that several other markets, particularly Hong Kong and China, influence the emerging markets of the ASEAN; not just the member markets of the ASEAN and the United States as it was the case for the average orthogonalized spillover.

Table 5 about here

We show the dynamics of financial linkages among sample markets in Figure 3, which displays the evolution of the spillover index over the period 1994-2014. The spillover index constructed from the generalized spillover measure using 250-day rolling sample fluctuates between 20% and 50% of error variance during the first four years of the sample, then increases sharply and finally oscillates between 60% and 80% during the last four years of the sample. This result indicates strong evidence of increased financial market interdependence in the past two decades. Similar pattern of changes is also observed for the spillover index produced from the average orthogonalized spillover measure, except the fact that the spillover effect is of smaller magnitude. Figure 3 also reveals that return spillover is subject to instabilities and experienced some important peaks, particularly during and in the aftermath of financial crises
such as the Asian financial crisis of 1997-1998 and the global financial crisis of 2008-2009. This finding is consistent with past studies showing increased comovement of international stock markets in times of crises (e.g., Forbes and Rigobon, 2002; Aloui et al., 2011; and references therein).

Figure 3 about here

We now turn to the analysis of directional spillovers from stock markets in Japan and the United States to the markets of other countries in the Pacific Basin region. It is important to note that the results of directional spillovers are very similar, regardless of which of the two spillover measures we consider. Specifically, the return shock spillovers from the United States to the remaining markets of the sample totalize 94.95% and 105.76% in the case of average orthogonalized and generalized spillovers, respectively. Comparatively, the spillovers from Japan are 10.34% and 22.13% with respect to the same measures. Using a rolling sample analysis, we show in Figure 4 that the transmission of shocks from the U.S. stock market returns to the rest of the Pacific Basin region is highly time-varying in nature. The variance shares of the U.S. shocks accounted for an increasing part of other countries’ return variance during the years preceding the U.S. subprime crisis, with some peaks at the heart of the subsequent global financial crisis. The evolution of the directional spillovers from the U.S. stock markets suggests a gradual increase in the integration process of China, Indonesia, Malaysia, Mexico, the Philippines, South Korea, and Taiwan as stock markets in these countries are more responsive to the U.S. shocks in recent years than they were ten or twenty years ago.

Figures 4 and 5 about here

Similar to the case of the United States, directional spillovers from Japan, which are presented in Figure 5, also display a substantial time-variation, but the magnitude of spillover effects from Japan is generally much lower than from the United States. There is however little evidence of increasing integration between Japan and the other markets, except for China, South
Korea, and Taiwan. Moreover, we identify a decrease in spillover effects from Japan since 2005, particularly to Australia, Hong Kong, Malaysia, Singapore, South Korea, Taiwan, and Thailand, which seems to confirm that Japan has been losing its leading role in the region as a regional financial center. Japan only has considerable spillover linkages with Australia, South Korea, and Singapore.

Figures 6 and 7 about here

The net spillover effects from the U.S. and Japanese stock markets, which excludes own contributions of sample markets, are respectively presented in Figures 6 and 7. The area marked in red indicates negative net spillover (i.e., the Japanese or the U.S. stock market receives more spillover effect than it transmits to other markets). The results show that the U.S. stock market is almost always a net giver of spillover, except for a few instances in relation to Canada, and Mexico. In fact, the spillover effect from Canada and Mexico to the United States is bigger than the other way around during the years before and after the U.S. subprime crisis of 2007. This finding is not unexpected because Canada and Mexico are among the major trading partners of the United States (rank 1 and rank 3 as of December 2013 in terms of exports and imports). They are also key partners in the finalized proposal of the Trans-Pacific Partnership agreement. Moreover, the United States imports more from than exports to these countries. It should be noted, however, that these results are sensitive to the choice of spillover measure. The stock markets of Hong Kong, Singapore, South Korea, and Taiwan receive important net spillovers from the United States since the beginning of the 2000s. We also observe substantial net spillovers (between 5% and 20%) from the U.S. markets to those in ASEAN countries, but the effects only started around 2007.

By contrast, Japan is generally found to be a net receiver of spillover effects from the

6 https://www.census.gov/foreign-trade/statistics/highlights/top/top1312yr.html
remaining markets rather than a net giver of spillover, suggesting a limited role of the Japanese stock market in price discovery and return changes in other Pacific Basin countries. Net spillovers to Japan come mainly from Australia, Canada, Mexico, Malaysia, Singapore, and South Korea, which are also its main trading partners. This finding seems to contrast the predictive role of Japanese stock markets about the recent crashes of global stock markets. For instance, Figure 1 indicates that the general stock price levels in Japan have experienced bubble bursting a few months before the remaining markets of the sample. Therefore, a prudent investor would also need to pay attention to what happens in Japan’s stock markets, despite the lack of volatility spillovers between Japan and other countries.

Regarding the choice of framework and its impact on the spillovers produced, there has, to the best of our knowledge, been no prior attempt to explain the difference in results between the generalized and average orthogonalized spillover measures. The notable difference is that the generalized spillover measure attributes a smaller share of error variance to domestic shocks, which is of great importance if one wishes to interpret the magnitude of spillovers, in addition to their difference between markets and their time-variations. As explained by Pesaran and Shin (1998), the generalized IRF and its orthogonalized counterpart are identical for the first variable in the system. Since this variable is the one allowed to affect all other variables, the generalized IRF approach would produce impulse responses of a greater magnitude. From this, there is however no straightforward way of deriving how spillovers are affected, as IRFs make up both the numerator and denominator of Eq. (1). Our findings suggest that generalized spillovers will tend to be higher and consequently own variance shares will be lower, but there are several instances when this is not the case, particularly when the rolling samples are considered. As for which measure should be preferred, Klössner and Wagner (2014) state that the generalized spillover framework produces “quite large and therefore unrealistic values”, though we would argue that there is no obvious reference point for what should be deemed realistic.
Rather, the assumption of Gaussian errors seems more realistic than the shock structure imposed by Cholesky decomposition, even though normality might not be an ideal distributional assumption for financial data. Any such discussion is however beyond the scope of this paper and we content ourselves with urging greater caution in interpreting net spillovers and the absolute sizes of variance shares since they appear less robust to the choice of method.

6. Conclusion

In this article, we employed the spillover measures developed by Diebold and Yilmaz (2009, 2012) and the Klößner and Wagner (2012a, 2012b, 2014)’s computational procedure for dealing with the variable ordering dilemma to empirically assess the extent of return spillovers among equity markets of the Pacific Basin region. Our investigation also focuses on the role played by the stock markets of the two world’s leading economies, Japan and the United States, in terms of shock transmissions to other markets of the region.

The results of our spillover analysis, which is generally consistent for two methods of spillover measurement (i.e., average orthogonized spillover and generalized orthogonized spillover), provide several important insights about both the level and the dynamics of stock market linkages in the Pacific Basin region over the past 20 years. First, the overall picture is that the cross-market linkages in the Pacific Basin region are time-varying and have become stronger over time, with large increases in the level of shock spillover effects towards the end of our sample period, in comparison with the beginning years of our sample. Second, the spillover effects are particularly apparent and significant among the markets of the most developed countries in the region (Australia, Singapore, Hong Kong, Canada and the United States), except Japan which does not have a dominant role in terms of shock transmission. Japan also receives more spillover effects from other markets than it transmits spillover effects to them. Third, our results show some evidence to suggest that the emerging markets of the ASEAN
countries have become more integrated with the United States than with other neighbouring
developed countries in the East Asia (Japan, South Korea, and Taiwan. Finally, while it has
significant spillovers with markets of close geographical proximity, the Chinese stock market is
found to be relatively disconnected from the developed markets.

The above-mentioned empirical findings have important implications for regulation
policies and portfolio investments in the Pacific basin stock markets, to the extent that they help
identify regional influences, gauge potential contagion mechanisms that could arise from shock
transmission, and design portfolio diversification and hedging strategies given the sensitivity
of each market to shocks affecting the other markets in the region.
References


Table 1: Financial sector development indicators

<table>
<thead>
<tr>
<th>Country</th>
<th>Market capitalization (% of GDP)</th>
<th>Number of listed companies</th>
<th>Turnover (% of Market capitalization)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-----------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>UNITED STATES</td>
<td>69</td>
<td>105</td>
<td>147</td>
</tr>
<tr>
<td>JAPAN</td>
<td>62</td>
<td>66</td>
<td>67</td>
</tr>
<tr>
<td>AUSTRALIA</td>
<td>45</td>
<td>78</td>
<td>90</td>
</tr>
<tr>
<td>CANADA</td>
<td>41</td>
<td>78</td>
<td>114</td>
</tr>
<tr>
<td>HONG KONG</td>
<td>165</td>
<td>281</td>
<td>363</td>
</tr>
<tr>
<td>INDONESIA</td>
<td>9</td>
<td>40</td>
<td>16</td>
</tr>
<tr>
<td>KOREA</td>
<td>30</td>
<td>23</td>
<td>31</td>
</tr>
<tr>
<td>MALAYSIA</td>
<td>159</td>
<td>305</td>
<td>125</td>
</tr>
<tr>
<td>MEXICO</td>
<td>38</td>
<td>27</td>
<td>18</td>
</tr>
<tr>
<td>PHILIPPINES</td>
<td>29</td>
<td>97</td>
<td>32</td>
</tr>
<tr>
<td>SINGAPORE</td>
<td>94</td>
<td>156</td>
<td>159</td>
</tr>
<tr>
<td>CHINA</td>
<td>4</td>
<td>13</td>
<td>48</td>
</tr>
<tr>
<td>THAILAND</td>
<td>52</td>
<td>55</td>
<td>24</td>
</tr>
</tbody>
</table>

Notes: All data are collected from the World Development Indicators (WDI). Taiwan is not listed as a separate country in the WDI statistics, and is neither included in the indicator for China. Data are available on an annual basis up to 2012, but displayed for only six selected years during our sample period. Market capitalization measures share prices times the number of outstanding shares of companies listed on the country’s stock exchanges at the end of the year. Listed companies do not include investment companies, mutual funds, or other collective investment vehicles. Turnover ratio is the total value of shares traded during the period divided by the average market capitalization for the period. Average market capitalization is calculated as the average of the end-of-period values for the current period and the previous period.
### Table 2: Financial integration and economic openness

<table>
<thead>
<tr>
<th></th>
<th>Trade (% of GDP)</th>
<th>Net FDI inflows (current US$, billions)</th>
<th>Net portfolio inflows (current US$, billions)</th>
</tr>
</thead>
</table>
| UNITED STATES  | 20    | 23    | 25   | 24   | 30   | 31   | 20   | 87    | 321  | 146  | 333  | 218  | -6   | 11   | 194  | 62   | 127  | 239
| JAPAN         | 17    | 19    | 20   | 24   | 35   | 31   | 3   | 0     | 8    | 8    | 25   | 1    | 9    | 49   | -1   | 98   | -70  | 35
| AUSTRALIA     | 33    | 38    | 41   | 37   | 42   | 43   | 6   | 6     | 14   | 37   | 45   | 54   | 1    | 2    | -1   | -25  | 20   | 14
| CANADA        | 53    | 70    | 83   | 71   | 67   | 62   | 5   | 10    | 66   | -1   | 62   | 39   | 1    | 6    | 24   | 27   | 3    | 1
| HONG KONG     | 270   | 274   | 279  | 365  | 407  | 450  | 5   | 2     | 60   | 34   | 67   | 75   | 47   | 2    | 17   | 29
| INDONESIA     | 53    | 52    | 71   | 60   | 59   | 50   | 2   | 6     | 5    | 2    | 9    | 21   | 0    | 2    | -1   | 2    | 0    | 2
| KOREA         | 50    | 55    | 68   | 73   | 100  | 110  | 1   | 2     | 9    | 9    | 11   | 9    | 2    | 6    | 13   | 9    | -33  | 17
| MALAYSIA      | 151   | 182   | 220  | 210  | 177  | 159  | 5   | 5     | 4    | 5    | 8    | 10   | 5    | 11   | 5    | -11  | 5    | -11
| MEXICO        | 36    | 51    | 53   | 54   | 58   | 66   | 4   | 9     | 18   | 25   | 29   | 18   | 5    | 3    | 0    | -3   | -4   | 10
| PHILIPPINES   | 63    | 90    | 105  | 103  | 76   | 65   | 0   | 2     | 2    | 2    | 1    | 1    | 3    | 2    | 0    | 1    | 0    | 2
| SINGAPORE     | 311   | 336   | 366  | 406  | 440  | 368  | 2   | 10    | 16   | 21   | 12   | 61   | 1    | 1    | -1   | 2    | -12  | 4
| CHINA         | 31    | 38    | 44   | 66   | 62   | 52   | 11  | 40    | 38   | 62   | 187  | 296  | 7    | 11   | 8    | 30   | 2
| THAILAND      | 78    | 85    | 125  | 137  | 150  | 149  | 2   | 2     | 3    | 6    | 9    | 11   | 0    | 1    | 1    | 1    | -4   | 3

**Notes:** All data are collected from the World Development Indicators (WDI). Taiwan is not listed as a separate country in the WDI statistics, and is neither included in the indicator for China. Data are available on an annual basis up to 2012, but displayed for only six selected years during our sample period. Trade is the sum of export and imports of goods and services. Foreign direct investment is new investment inflows less disinvestment in the reporting economy from foreign investors. Portfolio equity includes net inflows from equity securities other than those recorded as direct investment.
Table 3: Descriptive statistics and unit root tests of log returns

<table>
<thead>
<tr>
<th>Country</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Jarque-Bera</th>
<th>ADF Test</th>
<th>Perron Test</th>
<th>Zivot-Andrews Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNITED STATES</td>
<td>6.71%</td>
<td>18.40%</td>
<td>-0.25</td>
<td>12.05</td>
<td>19185.95***</td>
<td>-80.153(0)**</td>
<td>-36.82(4)***</td>
<td>10-9-2008</td>
</tr>
<tr>
<td>JAPAN</td>
<td>9.21%</td>
<td>22.59%</td>
<td>0.05</td>
<td>7.39</td>
<td>45111.84***</td>
<td>-56.589(1)***</td>
<td>-46.66(2)**</td>
<td>10-9-1998</td>
</tr>
<tr>
<td>AUSTRALIA</td>
<td>6.71%</td>
<td>22.46%</td>
<td>-0.72</td>
<td>12.60</td>
<td>22018.57***</td>
<td>-73.397(0)**</td>
<td>-74.06(0)**</td>
<td>10-24-2008</td>
</tr>
<tr>
<td>CANADA</td>
<td>8.01%</td>
<td>21.05%</td>
<td>-0.80</td>
<td>13.60</td>
<td>26869.94***</td>
<td>-34.828(4)**</td>
<td>-35.45(4)**</td>
<td>11-20-2008</td>
</tr>
<tr>
<td>HONG KONG</td>
<td>5.50%</td>
<td>24.71%</td>
<td>-0.01</td>
<td>11.79</td>
<td>18062.23***</td>
<td>-72.637(0)**</td>
<td>-38.07(3)**</td>
<td>10-28-1997</td>
</tr>
<tr>
<td>INDONESIA</td>
<td>3.91%</td>
<td>41.56%</td>
<td>-1.06</td>
<td>32.57</td>
<td>205446.47***</td>
<td>-32.70(0)***</td>
<td>-42.13(0)***</td>
<td>01-8-1998</td>
</tr>
<tr>
<td>KOREA</td>
<td>6.04%</td>
<td>36.70%</td>
<td>0.13</td>
<td>16.15</td>
<td>40429.97***</td>
<td>-38.163(4)**</td>
<td>-38.95(4)**</td>
<td>12-23-1997</td>
</tr>
<tr>
<td>MALAYSIA</td>
<td>4.15%</td>
<td>26.77%</td>
<td>-1.11</td>
<td>75.89</td>
<td>1242748.04***</td>
<td>-32.142(5)**</td>
<td>-34.56(4)**</td>
<td>10-28-1998</td>
</tr>
<tr>
<td>MEXICO</td>
<td>7.38%</td>
<td>29.49%</td>
<td>-0.40</td>
<td>13.64</td>
<td>26594.07***</td>
<td>-52.369(1)***</td>
<td>-52.43(1)**</td>
<td>09-11-1998</td>
</tr>
<tr>
<td>PHILIPPINES</td>
<td>2.63%</td>
<td>26.71%</td>
<td>0.39</td>
<td>14.74</td>
<td>32348.29***</td>
<td>-63.848(0)***</td>
<td>-35.06(4)**</td>
<td>02-02-1998</td>
</tr>
<tr>
<td>SINGAPORE</td>
<td>4.67%</td>
<td>22.16%</td>
<td>-0.02</td>
<td>9.73</td>
<td>10584.64***</td>
<td>-69.640(0)***</td>
<td>-70.42(0)**</td>
<td>01-12-1998</td>
</tr>
<tr>
<td>CHINA</td>
<td>-2.25%</td>
<td>30.62%</td>
<td>0.05</td>
<td>8.74</td>
<td>7705.68***</td>
<td>-66.837(0)**</td>
<td>-67.33(0)**</td>
<td>10-27-2008</td>
</tr>
<tr>
<td>TAIWAN</td>
<td>3.32%</td>
<td>26.31%</td>
<td>-0.03</td>
<td>5.87</td>
<td>1932.60***</td>
<td>-37.731(3)**</td>
<td>-33.06(0)**</td>
<td>10-20-1997</td>
</tr>
<tr>
<td>THAILAND</td>
<td>0.95%</td>
<td>32.18%</td>
<td>0.43</td>
<td>13.15</td>
<td>24264.13***</td>
<td>-65.252(0)**</td>
<td>-34.59(4)**</td>
<td>02-02-1998</td>
</tr>
</tbody>
</table>

Notes: Means and standard deviations are annualized as $r \times 250$ and $\sigma \times \sqrt{250}$. Jarque-Bera test examines the null hypothesis of normality of log returns. The ADF test examines the null hypothesis of a unit root, and is performed with both a constant and a trend. The integer within parentheses gives the lag length which was set to minimize the Schwarz Information Criterion, with a maximum of 10 lags. The Zivot and Andrews (1992)’s single unknown structural break test and the Perron (1989)’s a one-time break unit root test examine the null hypothesis of a unit root, while allowing for an endogenous unknown structural break in the log-return series. The identified break dates are put in brackets and presented in the month-day-year format. ***, **, and * denotes rejection of null hypotheses at the 1%, 5%, and 10 % levels of significance.
Table 4: Average orthogonalized full sample spillovers

<table>
<thead>
<tr>
<th>U.S.</th>
<th>JAPAN</th>
<th>AUSTRALIA</th>
<th>CANADA</th>
<th>HONG KONG</th>
<th>INDONESIA</th>
<th>KOREA</th>
<th>MALAYSIA</th>
<th>MEXICO</th>
<th>PHILIPPINES</th>
<th>SINGAPORE</th>
<th>CHINA</th>
<th>TAIWAN</th>
<th>THAILAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>66.03</td>
<td>75.05</td>
<td>2.45</td>
<td>4.37</td>
<td>1.22</td>
<td>0.30</td>
<td>1.56</td>
<td>0.37</td>
<td>3.22</td>
<td>0.29</td>
<td>2.18</td>
<td>0.99</td>
<td>0.77</td>
<td>0.56</td>
</tr>
<tr>
<td>6.68</td>
<td>1.80</td>
<td>55.47</td>
<td>10.60</td>
<td>2.07</td>
<td>0.61</td>
<td>1.39</td>
<td>0.50</td>
<td>5.31</td>
<td>0.59</td>
<td>3.64</td>
<td>1.59</td>
<td>0.91</td>
<td>0.88</td>
</tr>
<tr>
<td>19.20</td>
<td>0.26</td>
<td>3.87</td>
<td>64.19</td>
<td>0.70</td>
<td>0.17</td>
<td>0.40</td>
<td>0.13</td>
<td>7.89</td>
<td>0.15</td>
<td>1.53</td>
<td>0.69</td>
<td>0.21</td>
<td>0.60</td>
</tr>
<tr>
<td>7.59</td>
<td>1.31</td>
<td>2.39</td>
<td>3.99</td>
<td>53.92</td>
<td>1.51</td>
<td>1.56</td>
<td>1.54</td>
<td>4.19</td>
<td>0.98</td>
<td>6.65</td>
<td>10.87</td>
<td>1.25</td>
<td>2.26</td>
</tr>
<tr>
<td>2.20</td>
<td>0.40</td>
<td>0.89</td>
<td>1.73</td>
<td>1.84</td>
<td>76.90</td>
<td>1.35</td>
<td>2.30</td>
<td>1.98</td>
<td>2.23</td>
<td>3.58</td>
<td>1.28</td>
<td>0.66</td>
<td>2.66</td>
</tr>
<tr>
<td>5.07</td>
<td>1.48</td>
<td>1.85</td>
<td>3.21</td>
<td>1.53</td>
<td>0.54</td>
<td>74.22</td>
<td>0.53</td>
<td>3.32</td>
<td>0.48</td>
<td>2.40</td>
<td>1.62</td>
<td>2.26</td>
<td>1.49</td>
</tr>
<tr>
<td>2.81</td>
<td>0.35</td>
<td>0.74</td>
<td>1.36</td>
<td>1.79</td>
<td>2.75</td>
<td>0.65</td>
<td>79.47</td>
<td>1.31</td>
<td>1.16</td>
<td>3.77</td>
<td>1.11</td>
<td>0.52</td>
<td>2.21</td>
</tr>
<tr>
<td>11.87</td>
<td>0.10</td>
<td>1.66</td>
<td>7.92</td>
<td>0.73</td>
<td>0.17</td>
<td>0.60</td>
<td>0.23</td>
<td>73.89</td>
<td>0.22</td>
<td>1.33</td>
<td>0.55</td>
<td>0.17</td>
<td>0.55</td>
</tr>
<tr>
<td>5.67</td>
<td>0.41</td>
<td>1.06</td>
<td>3.29</td>
<td>1.36</td>
<td>3.77</td>
<td>0.74</td>
<td>1.45</td>
<td>3.52</td>
<td>72.17</td>
<td>2.49</td>
<td>1.07</td>
<td>0.50</td>
<td>2.50</td>
</tr>
<tr>
<td>6.37</td>
<td>1.52</td>
<td>3.92</td>
<td>3.80</td>
<td>6.38</td>
<td>2.95</td>
<td>1.80</td>
<td>3.09</td>
<td>3.70</td>
<td>1.42</td>
<td>55.52</td>
<td>3.91</td>
<td>2.00</td>
<td>3.62</td>
</tr>
<tr>
<td>5.47</td>
<td>1.21</td>
<td>2.01</td>
<td>4.11</td>
<td>11.53</td>
<td>1.24</td>
<td>1.65</td>
<td>1.30</td>
<td>3.98</td>
<td>0.78</td>
<td>4.41</td>
<td>59.23</td>
<td>1.38</td>
<td>1.70</td>
</tr>
<tr>
<td>4.76</td>
<td>0.81</td>
<td>1.34</td>
<td>2.42</td>
<td>1.57</td>
<td>0.59</td>
<td>2.43</td>
<td>0.72</td>
<td>2.06</td>
<td>0.50</td>
<td>2.90</td>
<td>1.46</td>
<td>77.59</td>
<td>0.85</td>
</tr>
<tr>
<td>2.62</td>
<td>0.54</td>
<td>1.17</td>
<td>1.86</td>
<td>2.60</td>
<td>3.04</td>
<td>1.79</td>
<td>2.19</td>
<td>1.97</td>
<td>1.79</td>
<td>4.49</td>
<td>1.76</td>
<td>0.65</td>
<td>73.54</td>
</tr>
</tbody>
</table>

\[
\sum_{n=1}^{N} SO_{on} = 160.98 \quad 85.39 \quad 80.08 \quad 131.49 \quad 87.83 \quad 94.65 \quad 90.66 \quad 93.91 \quad 126.91 \quad 82.84 \quad 96.07 \quad 86.53 \quad 88.99 \quad 93.67 \quad 1400.00 \quad 442.81
\]

\[
SO_{on} = 94.95 \quad 10.34 \quad 24.61 \quad 67.29 \quad 33.91 \quad 17.75 \quad 16.44 \quad 14.43 \quad 53.02 \quad 10.67 \quad 40.55 \quad 27.29 \quad 11.40 \quad 20.12 \quad 442.81 \quad 31.63
\]

Net \[
SO_{on} \quad 60.98 \quad -14.61 \quad -19.92 \quad 31.49 \quad -12.17 \quad -5.35 \quad -9.34 \quad -6.09 \quad 26.91 \quad -17.16 \quad -3.93 \quad -13.47 \quad -11.01 \quad -6.33
\]

Notes: This table presents the results of the full sample analysis performed with the ‘average orthogonalized’ spillover measure. Elements of the main section of the table contain directional return spillovers (SO_{on}) which correspond to the percentage share of error variance in market n (rows) contributed by shocks to market m (columns). Total received spillover for market n is given by its row sums reported in the columns added to the right of the table, both including (Σ_{m=1}SO_{on} = 100) and excluding (SO_{on}) own variance share. Similarly, column sums reported in the two additional rows below the table represent total given spillover. Own contributions to variance shares make up the diagonal of the main section of the table and are emphasized. The n^{th} element of the final row contains net spillover for market n which is the difference between its given and received spillovers, i.e. its row sum minus its column sum. Finally, the bottom right section of the table reports total spillover, which includes own variance shares, always equals 100 \times N. Total spillover excluding own contribution is obtained by summing either total received or total given spillover excluding own contribution. The spillover index (SOI) is calculated by dividing the total given or received spillover excluding own contributions by the total spillover and multiplied the result by 100.
The contribution is spillovers, i.e. its row sum minus its column sum. Finally, the bottom right section of the table reports the total spillover for market $n$ which is the difference between its given and received spillovers, i.e. its row sum minus its column sum. Finally, the bottom right section of the table reports the total spillover, which -- including own variance shares -- always equals $100 \times N$. Total spillover excluding own contribution is obtained by summing either total received or total given spillover excluding own contribution. The spillover index (SOI), also emphasized, is calculated by dividing the total given or received spillover excluding own contributions by the total spillover and multiplied the result by 100.

### Table 5: Generalized full sample spillover

<table>
<thead>
<tr>
<th></th>
<th>U.S.</th>
<th>JAPAN</th>
<th>AUSTRALIA</th>
<th>CANADA</th>
<th>HONG KONG</th>
<th>INDONESIA</th>
<th>KOREA</th>
<th>MALAYSIA</th>
<th>MEXICO</th>
<th>PHILIPPINES</th>
<th>SINGAPORE</th>
<th>CHINA</th>
<th>TAIWAN</th>
<th>THAILAND</th>
<th>$\sum_{m=1}^{N} SO_{mn}$</th>
<th>$SO_{mm}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>47.96</td>
<td>0.26</td>
<td>3.19</td>
<td>23.41</td>
<td>1.87</td>
<td>0.28</td>
<td>1.27</td>
<td>0.16</td>
<td>15.49</td>
<td>0.28</td>
<td>3.07</td>
<td>1.32</td>
<td>0.59</td>
<td>0.87</td>
<td>100.00</td>
<td>52.04</td>
</tr>
<tr>
<td>JAPAN</td>
<td>8.09</td>
<td>49.43</td>
<td>5.62</td>
<td>6.85</td>
<td>3.97</td>
<td>1.30</td>
<td>3.88</td>
<td>1.36</td>
<td>5.11</td>
<td>1.13</td>
<td>5.69</td>
<td>3.26</td>
<td>2.23</td>
<td>2.15</td>
<td>100.00</td>
<td>50.57</td>
</tr>
<tr>
<td>AUSTRALIA</td>
<td>13.13</td>
<td>3.19</td>
<td>32.92</td>
<td>12.71</td>
<td>5.15</td>
<td>1.85</td>
<td>3.28</td>
<td>1.58</td>
<td>7.80</td>
<td>1.63</td>
<td>7.58</td>
<td>4.21</td>
<td>2.27</td>
<td>2.70</td>
<td>100.00</td>
<td>67.08</td>
</tr>
<tr>
<td>CANADA</td>
<td>22.14</td>
<td>0.71</td>
<td>6.84</td>
<td>43.99</td>
<td>2.32</td>
<td>0.67</td>
<td>1.36</td>
<td>0.51</td>
<td>12.27</td>
<td>0.54</td>
<td>4.03</td>
<td>2.08</td>
<td>0.78</td>
<td>1.78</td>
<td>100.00</td>
<td>56.01</td>
</tr>
<tr>
<td>HONG KONG</td>
<td>6.38</td>
<td>2.32</td>
<td>5.13</td>
<td>5.04</td>
<td>32.10</td>
<td>3.38</td>
<td>3.43</td>
<td>3.23</td>
<td>4.90</td>
<td>2.33</td>
<td>10.84</td>
<td>13.40</td>
<td>2.71</td>
<td>4.80</td>
<td>100.00</td>
<td>67.90</td>
</tr>
<tr>
<td>INDONESIA</td>
<td>2.93</td>
<td>1.15</td>
<td>3.01</td>
<td>2.99</td>
<td>5.41</td>
<td>48.76</td>
<td>2.84</td>
<td>4.97</td>
<td>3.09</td>
<td>4.60</td>
<td>8.29</td>
<td>4.06</td>
<td>1.84</td>
<td>6.07</td>
<td>100.00</td>
<td>51.24</td>
</tr>
<tr>
<td>KOREA</td>
<td>6.22</td>
<td>3.23</td>
<td>4.81</td>
<td>5.17</td>
<td>4.74</td>
<td>1.94</td>
<td>46.02</td>
<td>1.78</td>
<td>5.15</td>
<td>1.62</td>
<td>6.35</td>
<td>4.47</td>
<td>4.57</td>
<td>3.94</td>
<td>100.00</td>
<td>53.98</td>
</tr>
<tr>
<td>MALAYSIA</td>
<td>3.07</td>
<td>1.21</td>
<td>2.68</td>
<td>2.52</td>
<td>5.37</td>
<td>5.64</td>
<td>2.26</td>
<td>52.00</td>
<td>2.59</td>
<td>2.97</td>
<td>8.59</td>
<td>3.80</td>
<td>1.80</td>
<td>5.51</td>
<td>100.00</td>
<td>48.00</td>
</tr>
<tr>
<td>MEXICO</td>
<td>16.98</td>
<td>0.24</td>
<td>4.14</td>
<td>13.62</td>
<td>2.44</td>
<td>0.73</td>
<td>1.79</td>
<td>0.82</td>
<td>50.22</td>
<td>0.77</td>
<td>3.85</td>
<td>1.96</td>
<td>0.66</td>
<td>1.78</td>
<td>100.00</td>
<td>49.78</td>
</tr>
<tr>
<td>PHILIPPINES</td>
<td>6.82</td>
<td>0.98</td>
<td>3.40</td>
<td>5.65</td>
<td>4.38</td>
<td>6.19</td>
<td>2.35</td>
<td>3.39</td>
<td>5.67</td>
<td>43.96</td>
<td>6.56</td>
<td>3.59</td>
<td>1.56</td>
<td>5.48</td>
<td>100.00</td>
<td>56.04</td>
</tr>
<tr>
<td>SINGAPORE</td>
<td>5.52</td>
<td>2.82</td>
<td>6.68</td>
<td>5.05</td>
<td>10.13</td>
<td>5.03</td>
<td>3.85</td>
<td>4.96</td>
<td>4.63</td>
<td>2.87</td>
<td>31.37</td>
<td>7.17</td>
<td>3.53</td>
<td>6.37</td>
<td>100.00</td>
<td>68.63</td>
</tr>
<tr>
<td>CHINA</td>
<td>5.56</td>
<td>2.14</td>
<td>4.55</td>
<td>5.29</td>
<td>14.88</td>
<td>3.02</td>
<td>3.68</td>
<td>2.80</td>
<td>4.92</td>
<td>2.07</td>
<td>8.82</td>
<td>35.36</td>
<td>2.79</td>
<td>4.11</td>
<td>100.00</td>
<td>64.64</td>
</tr>
<tr>
<td>TAIWAN</td>
<td>5.71</td>
<td>2.26</td>
<td>4.08</td>
<td>4.41</td>
<td>4.92</td>
<td>2.03</td>
<td>5.22</td>
<td>2.11</td>
<td>3.73</td>
<td>1.69</td>
<td>7.08</td>
<td>4.40</td>
<td>49.47</td>
<td>2.88</td>
<td>100.00</td>
<td>50.53</td>
</tr>
<tr>
<td>THAILAND</td>
<td>3.22</td>
<td>1.63</td>
<td>3.70</td>
<td>3.54</td>
<td>6.52</td>
<td>5.65</td>
<td>3.98</td>
<td>4.65</td>
<td>3.41</td>
<td>3.81</td>
<td>9.43</td>
<td>4.62</td>
<td>2.04</td>
<td>43.80</td>
<td>100.00</td>
<td>56.20</td>
</tr>
</tbody>
</table>

\[
\sum_{m=1}^{N} SO_{mn} = 153.72 \\
SO_{mm} = 105.76 \\
Net SO_{mn} = 53.72
\]

Notes: This table presents the results of the full sample analysis performed with the ‘generalized’ spillover measure. Elements of the main section of the table contain directional return spillovers ($SO_{mn}$) which correspond to the percentage share of error variance in market $n$ (rows) contributed by shocks to market $m$ (columns). Total received spillover for market $n$ is given by its row sums reported in the columns added to the right of the table, both including ($\sum_{m=1}^{N} SO_{mn} = 100$) and excluding ($SO_{mn}$) own variance share. Similarly, column sums reported in the two additional rows below the table represent total given spillover. Own contributions to variance shares make up the diagonal of the main table and are emphasized. The $n^{th}$ element of the final row contains net spillover for market $n$, which is the difference between its given and received spillovers, i.e. its row sum minus its column sum. Finally, the bottom right section of the table reports the total spillover, which -- including own variance shares -- always equals $100 \times N$. Total spillover excluding own contribution is obtained by summing either total received or total given spillover excluding own contribution. The spillover index (SOI), also emphasized, is calculated by dividing the total given or received spillover excluding own contributions by the total spillover and multiplied the result by 100.
Figure 1: Evolution of stock market indices in natural logarithm
Figure 2: Logarithmic returns of equity indices
Notes: This Figure plots $SOI$ (Equation 4) from our rolling sample analysis. The date of each observation is the last date of the 250-day rolling sample from which it was generated. The shaded area represents the generalized spillover index of Diebold and Yilmaz (2012) while the black line plots the average orthogonalized spillover index computed following Klössner and Wagner (2012a).
Figure 4: Return spillover from the United States

Notes: This Figure plots $SO_{mM}$ (Equation 1) for $m = United States$ from our rolling sample analysis. See Figure 3 for further details.
Figure 5: Return spillover from Japan

Notes: This Figure plots $SO_{m}^{max}$ (Equation 1) for $m = Japan$ from our rolling sample analysis. See Figure 3 for further details.
Figure 6: Net return spillover from the United States

Notes: This Figure plots $Net\;SO_{nm}$ (Equation 6) for $m = United\;States$ from our rolling sample analysis. The red area indicates negative net spillover. See Figure 3 for further details.
Figure 7: Net return spillover from Japan

Notes: This Figure plots $Net \, SO_{nm}$ (Equation 6) for $m = Japan$ from our rolling sample analysis. See Figure 6 for further details.