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Abstract

This study provides evidence that international stock investors' transactions are a cause of stock market comovements. We analyze return and volatility spillovers between eight major stock markets and stocks cross-listed on an accessible market (H-shares in Hong Kong) and an inaccessible market (A-shares in mainland China) by applying the spillover indexes proposed by Diebold and Yilmaz (2012, 2014) to those markets. Results suggest that spillovers of both return and volatility are greater in an accessible market than in an inaccessible one. We also find that spillover effects intensify as openness of a stock market increases.

Keywords: investor-induced hypothesis; fundamentals-based hypothesis; cross-listed stocks; spillover index; inaccessible market

JEL Classification: G15

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Introduction

Global integration of national economies, as well as financial deregulation in major countries since the 1980s, has strengthened relationships among international stock markets, which led to closer comovements of stock prices across national borders. Global stock market selloffs caused by events such as a calamitous stock price plunge in New York (Black Monday of October 19, 1987), Shanghai (February 27, 2007), and again New York (September 29, 2008) have occurred as well. These events represent cases in which an incident occurring in one market had an immediate and widespread effect on global markets. As such, they aroused interest among economists to explore empirical and theoretical questions posed by stronger stock price comovements.

One hypothesis to explain such comovements is based on fundamentals (fundamentals-based hypothesis), and posits that, given a frictionless economy and rational investors, stock prices are determined by fundamentals and, thus, stock price comovements are solely caused by comovements in fundamentals (Barberis et al., 2005).

Another hypothesis is based on investor behavior (investor-induced hypothesis), and maintains that stock market comovements are caused by the behavior of international investors, such as adjustments in international portfolios. Theoretical models have been developed to explain the phenomenon in which stock price changes in one country lead to changes in other markets through portfolio holdings of international investors. As such, Kyle and Xiong (2001) assert that big losses incurred in a market plunge will result in selloffs in other markets because investors unwind positions to cover losses. Moreover, Kodres and Pritsker (2002) propose a theoretical model that shows propagation of crisis situations through portfolio adjustments involving several different stock markets. Hong and Stein (2003) show that new information that results in large-scale portfolio reallocations will cause international price changes. Finally, Mondria and Quintana

- Domeque (2013) find that shocks in a given market will cause investors to allocate too much attention to that market and that their portfolio reallocation helps spread the effects on other markets.

The aforementioned theoretical research hypothesizes that international investors' behavior causes stock market comovements, but there is little empirical research on this hypothesis. The limited empirical research tends to focus on periods of contagion following a major financial crisis, and not on comovements during normal periods (e.g., Boyer et al., 2006, Petmezas and Santamaria, 2014).[1] Consequently, one of the purposes of this study is to determine the factors that explain international stock market comovements in normal periods and not during crisis periods.

The question is how to determine which of the two hypotheses is valid in explaining comovements. As such, we consider two different stock markets: one that is open to international investors (accessible market) and one that is not (inaccessible market). We subsequently focus on stocks cross-listed on these two markets. By analyzing how these cross-listed stocks react to changes on a major foreign market such as the U.S. stock market, we can verify which hypothesis is supported. If the fundamentals-based hypothesis is valid, changes in fundamentals affecting American firms will have an impact on domestic firms, but the degree of response must be identical for the two markets. Alternatively, if the investor-induced hypothesis is correct, while the prices in the inaccessible market remain unaffected because of the absence of international investors, stock prices on the accessible market are affected by portfolio adjustments. In this instance, international stock market comovements are observed only on the accessible market. Examining whether

[1] In this paper, comovement of stock prices is defined as a phenomenon in which a rise (fall) in return/volatility on one market leads to a similar rise (fall) in return/volatility on other markets. Comovement is different from contagion which is defined by Forbes and Rigobon (2002) to signify "a significant increase in cross-market linkages after a shock to one country (or group of countries)."

comovements are observed equally in these cross-listed stocks enables us to determine which of the two hypotheses is valid in explaining international stock price comovements. A new contribution of this study is the method of focusing on differential responses of cross-listed stocks on an accessible and an inaccessible market.

Another analytical framework is exploring the effects of opening an inaccessible market to foreign investors. If the fundamentals-based hypothesis is correct, the spillover effects on the inaccessible market will remain unchanged after the market opens for foreign investors, because stock prices in such a market are determined with their fundamental values. However, if the investor-induced hypothesis holds true, the opening of an inaccessible market will increase the degree of international price linkage on this market.

In order to execute the above tests, we use a unique feature of Chinese stock markets: the existence of two independent stock markets with differing degrees of international openness. An internationally accessible market is provided by the H-share market in Hong Kong and the inaccessible market by the A-share market in mainland China (Shanghai and Shenzhen).[2] We investigate the stocks of 86 companies that are cross-listed on these two markets. The stock of a cross-listed company is subject to the same fundamentals and external shocks (e.g., changes in regulation, shocks idiosyncratic to the industry, etc.), and the only difference between the two listings is whether the stock is purchasable by international investors or not. Because A-shares cannot be bought/sold by foreign investors,[3] if the H-share price more strongly comoves with a

[2] There is a B-share market in mainland China accessible to foreign investors. B-shares are specifically issued for foreign investors and denominated in a foreign currency (US dollars in the case of the Shanghai Stock Exchange and Hong Kong dollars in the case of the Shenzhen Stock Exchange). However, the market capitalization of B-shares represented only 0.46% of the entire market capitalization (A + B shares) at the end of 2014. Issuance of the two types of shares at the same time was banned in 1998, and issuance of B-shares has all but disappeared since then. Therefore, we ignore B-shares in our analysis.

[3] A-shares can also be purchased by the so-called Qualified Foreign Institutional Investors (QFII) and RMB

major foreign stock market than the A-share price, it can be interpreted as reflecting the behavior of international investors.

We attempt to analyze the average responses for the 86 stocks that are listed on both the A-share and H-share markets. Therefore, we need to compile a stock price index composed of these stocks. As such, we obtain tick data on them and extract prices at five-minute intervals. We subsequently compute the capitalization-weighted average of those prices to produce the desired price index for cross-listed stocks.

We estimate return and volatility spillovers between the two Chinese markets and major foreign stock markets, respectively. Preceding works in the field used various methods to estimate return and/or volatility spillovers. Our study adopts a new spillover index[4] proposed by (Diebold and Yilmaz (2012, 2014). This is a summary measure of forecast-error variance decompositions using vector autoregressions (VAR), which captures, in a simple manner, spillovers between markets as a whole and offers information on the magnitude and direction of spillovers.

The remainder of this paper is structured as follows: section 2 discusses related literature; section 3 explains the hypotheses we consider and the methodologies used to test the hypotheses; section 4 outlines the data used; section 5 discusses the estimation results; and section 6 concludes our paper.

1. Literature Review

Studies on the investor-induced hypothesis include Boyer et al. (2006) and Petmezas and

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Qualified Foreign Institutional Investors (RQFII). However, the actual amount of investment officially permitted is miniscule. Specifically, the amount allocated to the QFII is 72.15 billion US dollars and that to RQFII is 53.7 billion US dollars, amounting to only 0.21% of the market capitalization. Consequently, we can ignore international investors on the A-share market.

[4] Note that Diebold and Yilmaz (2014) refer to this index as the connectedness index.

Santamaria (2014). Boyer et al. (2006) examine whether transmission of the Asian financial crisis of 1997 to other markets occurred through stock holdings of international investors or through changes in fundamentals. As there are certain emerging markets not accessible to foreign investors, they compare responses on an accessible market with those on an inaccessible market for plunging stock prices in the crisis country (Thailand). The result is that the former is larger than the latter, implying that stock market contagion is more likely caused by investor behavior than by the common effects of fundamentals. Therefore, investor-induced contagion is more plausible than the fundamentals-based contagion. Their focus on different responses on accessible and inaccessible markets is interesting, but not without problems. They are not controlling for the effects of fundamentals. In our study, however, we analyze cross-listed stocks in two markets with or without accessibility to foreign investors. Since they are subject to the same fundamentals, we do not have to control for different fundamentals. While Boyer et al. (2006) focus on the issue of contagion during a major financial crisis, this study analyzes international stock market comovement periods without major crises. Moreover, Petmezas and Santamaria (2014) emphasize the wealth and portfolio-rebalancing effects as the cause of investor-induced contagion, and compare these effects during the global financial crisis, between 2007 and 2012, by analyzing correlations between stock and bond markets.[5]

This study also investigates spillover effects of return and volatility. Early research in this

[5] Additionally, there are studies which analyze the relationships between macroeconomic news and stock market comovements. King et al. (1994) conclude that observable economic variables (e.g., interest rates, industrial production, inflation, etc.) can explain only a small part of international stock market comovements. Connolly and Wang (2003) show that the bulk of the observed comovement in intraday and overnight returns on the U.S., the U.K., and Japanese stock markets cannot be attributed to public information about economic fundamentals. Albuquerque and Vega (2009) find that the U.S. macroeconomic news does not affect stock market comovement between the U.S. and Portugal. Consequently, we can conclude that we have not found clear evidence that macroeconomic news cause stock market comovements.

field focused on returns only, such as studies by Eun and Shim (1989), Jeon and Von Furstenberg (1990), Cheung and Mak (1992), Janakiramanan and Lamba, (1998), Leong and Felmingham (2003). More recent studies analyze volatility spillovers in addition to return spillovers, including Hamao et al. (1990), Ng (2000), Bae et al. (2003), Baur and Jung (2006); Diebold and Yilmaz (2009), Mukherjee and Mishra (2010). Simultaneous analysis of return and volatility spillovers has become the mainstream research approach in this field. Although precise methods, markets for analysis, and sample periods vary greatly among these studies, the following consensus exists among researchers. (1) Significant return and/or volatility spillovers across national borders are observed among stock markets. (2) Spillovers from more advanced economies, especially the U.S., to other smaller markets are clearly observed. (3) Return and volatility spillovers intensify significantly during global financial crises, such as the Mexican Peso crisis of 1994, the Asian financial crisis of 1997, and the global crisis triggered by the demise of the Lehman Brothers in 2008. Hitherto, a plethora of studies exists on spillover effects, but few have attempted to focus on the causes of these effects. Consequently, this study is an endeavor to fill this gap.

Regarding studies that examine both return and volatility spillover effects, we notice that estimation results vary widely, namely results on return spillovers differ from those on volatility spillovers. For example, Hamao et al. (1990) analyze return and volatility spillovers among the Tokyo, London, and New York stock markets. They report significant volatility spillovers from New York to Tokyo, London to Tokyo, and New York to London, but return spillovers were less significant. On the other hand, Baur and Jung (2006) analyze spillovers between daytime returns in New York and overnight returns in Frankfurt and report significant return spillovers, but not volatility spillovers (Table 3, p.606). Spillover effects between stock markets arise through two channels: one, which affects returns and the other, which affects volatility. Moreover, we have no prior information as to which channel should be more significant, and, as such, we pay close attention to the relative importance of these channels.

This study belongs to a line of research on stock price comovements of cross-listed stocks. Most studies in this field focus on price discovery (e.g., Eun and Sabherwal, 2003; Su and Chong, 2007), but a few analyze international stock price spillovers. Gagnon and Karolyi (2009) analyze spillovers between stock prices of American firms and those on 36 other markets. They attempt to measure the effects of macroeconomic news on different stocks, but when using closing prices observed in other markets, time lags between them and the closing hour in New York prevent us from isolating the effects of news releases, because new information arises in the intervening hours. However, American depositary receipts (ADRs) are traded in New York, and, thus, enable us to avoid this timing problem. In this study, we focus on the H-share and A-share markets in China with or without accessibility to foreign investors, and compare the effects of the New York stock prices on these markets. This comparison is expected to provide evidence on the causes of return and volatility spillovers. Therefore, the reason for analyzing cross-listed stocks in this study is different from that of Gagnon and Karolyi (2009).

There are studies that analyze stocks cross-listed in A-share and H-share markets. However, there was a large price differential between the two markets (H-shares were much lower in price than A-shares), which was called a price disparity puzzle. Arquette et al. (2008) conclude that this disparity was caused by differences in expectations of exchange rate changes and in market sentiments. Additionally, Chung et al. (2013) conclude that this disparity arises due to informational asymmetry and market segmentation.

Subsequently, we need to determine whether the two prices are unrelated Su et al. (2007), analyze 29 stocks cross-listed in the A-share and H-share markets, and conduct cointegration tests.

It is notable that the extent of cointegration between A-shares and H-shares has intensified in many cases after the Closer Economic Partnership Arrangement between Hong Kong and mainland China. Cai et al. (2011) utilize a Markov switching error correction model to analyze the long-term discount on H-shares, short-term comovements between A-shares and H-shares, and the intensity of error correction. They find that comovements between A-shares and H-shares have strengthened in the presence of higher economic integration between Hong Kong and mainland China. Sun et al. (2013) report a similar result because of a rising presence of mainland Chinese firms in Hong Kong.[6]

While the above studies analyze comovements between A-share and H-share price indexes, this study analyzes spillover effects from foreign markets to shares that are cross-listed in mainland China and in Hong Kong to investigate the cause of international stock price comovements.

2. Method

3.1 Hypotheses

First, we compute and compare the magnitudes of the spillover indexes between foreign stock markets and either an accessible or an inaccessible market in China. If price comovements are caused by common changes in fundamentals (fundamentals-based hypothesis), the spillover must be identical across the two Chinese markets. However, if the comovements are caused by investor behavior (investor-induced hypothesis), the spillover effect will become stronger in an accessible market than in an inaccessible one. Therefore, if the spillover index measuring spillovers from foreign markets to an accessible market is greater than that from foreign markets to an inaccessible

[6] Instead of cross-listed stocks, Qiao et al. (2008) analyze comovements between the stock price indexes of Hong Kong and mainland China. They report a one-way volatility spillover from mainland China to Hong Kong.

market, the investor-based hypothesis is supported. Our working hypothesis is that stock market spillovers are caused by international investors. Consequently, we put forward the following testable hypothesis:

Hypothesis 1: The spillover index from foreign markets to an accessible market (S_A) is greater than that from foreign markets to an inaccessible market (S_{IA}).

As previously mentioned, if this hypothesis is accepted, it implies that spillovers are caused by international investors.

Second, we analyze the effects of opening an inaccessible market. If the fundamentals-based hypothesis is valid, changes in the number of international investors would not, ceteris paribus, affect spillover effects. Moreover, if spillovers are caused by investor behavior, an increase in international investors in the hitherto inaccessible market would raise the extent of spillovers into this market. During the sample period analyzed in this study, there was an important deregulatory change on November 17, 2014, called the Shanghai-Hong Kong Stock Connect Program. Under this Program, international investors can purchase some of the stocks (component stocks in the SSE 380 Index and those cross-listed in Shanghai and Hong Kong) listed at the Shanghai Stock Exchange through the Hong Kong Stock Exchange. We analyze changes in the spillover index following this substantial deregulation of the inaccessible market to obtain evidence on the cause of spillover effects.

Hypothesis 2A: The spillover index of the inaccessible market after opening to international investors ($S_{IA,after}$) is higher than that before $S_{IA,before}$).

If this hypothesis is accepted, it implies that stock market spillovers are caused by international investors, ceteris paribus. We subsequently relax this assumption and attempt to confirm whether we obtain the same result with changes in underlying conditions. Hypothesis 2A focuses only on the inaccessible market. As such, we infer that the accessible market should see no or little change in spillovers after deregulation. We then compare the spillover indexes of the inaccessible and the accessible market before and after the Shanghai-Hong Kong Stock Connect Program. The following hypothesis must hold even if other things change, as far as those changes arise equally in the two markets.

Hypothesis 2B: The relative change in the spillover index of the inaccessible market ($S_{IA,after} / S_{IA,before}$) *is greater than the relative change in the spillover index of the accessible market* ($S_{A,after} / S_{A,before}$).

If this hypothesis is accepted, it implies that stock market spillovers are caused by international investors.

Even under the Shanghai-Hong Kong Stock Connect Program, not all stocks listed in Shanghai were available for trading by foreign investors. If transactions by international investors cause spillovers, liberalization of the hitherto restricted A-shares market should cause spillover effects in stocks that became available to international investors more than in stocks inaccessible to foreigners. We thus compare the relative change in spillover indexes of the permitted and unpermitted stocks before and after the Shanghai-Hong Kong Stock Connect Program.

Hypothesis 2C: The relative change in the spillover index for newly permitted stocks ($S_{P,after} / S_{P,before}$) *is greater than that for stocks that remain unpermitted to foreigners* ($S_{UP,after} / S_{UP,before}$).

If this hypothesis is accepted, it implies that stock market spillovers are caused by international investors.

2.2 Spillover Index

To measure the stock price comovement mechanism, we employ the spillover index proposed by Diebold and Yilmaz (2009, 2012, 2014). The estimated spillover index is used to test our hypotheses on the cause of comovements. In preceding studies on international stock price comovements, researchers have applied long-run analyses using level data, as well as short-run analyses utilizing first differences of the price data. Namely, long-run analyses were conducted in cointegration analysis proposed by Engle and Granger (1987) or in multivariate system cointegration analysis proposed by Johansen (1988) and Johansen and Juselius (1990). The lag augmented-VAR (LA-VAR) model proposed by Toda and Yamamoto (1995) utilizes levels of original price data, and we can examine long-run relationships among these prices. Other methods have also been developed to analyze first differences of stock prices. Early research employed Granger's causality tests (Granger, 1969) in order to investigate return spillovers. Research on volatility spillovers followed, and the main-stream model was the autoregressive conditional heteroscedasticity model (ARCH) proposed by Engle (1982) and the extended ARCH-type models.[7] The cross correlation function (CCF) approach developed by Cheung and Ng (1996) can test causality in mean and variance among variables simultaneously. However, in recent years, economists have turned to the spillover indexes proposed by Diebold and Yilmaz (2009, 2012, 2014) to examine various issues regarding spillover effects (e.g., Bubák et al., 2011; Zhou et al., 2012; Cronin, 2014; Lucey et al., 2014; Grobys, 2015). This study also applies this method to

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[7] In addition to univariate ARCH-type models above, multivariate ARCH-type models are also widely used in the literature. For instance, there is the BEKK model by Engle and Kroner (1995). A Dynamic Conditional Correlation model is developed by Engle (2002). For these univariate and multivariate ARCH-type models, the reader is referred to Bollerslev et al. (1994) and Xekalaki and Degiannakis (2010).

analyze return and volatility of spillover effects.

The spillover index was first proposed by Diebold and Yilmaz (2009), and it utilizes forecast errors as computed by a VAR model. Variance decomposition of forecast errors gives us the share of variance which is explained by the shock to a certain variable, and “it can be used to measure the spillovers in returns or return volatilities across individual assets, asset portfolios, asset markets, etc., both within and across countries” (Diebold and Yilmaz, 2012, pp. 57-58). However, this procedure has certain issues. Shocks that drive the VAR system must be orthogonal in order to be able to compute variance decomposition. If they are correlated, we cannot reach a clear-cut decomposition. To achieve this goal, Diebold and Yilmaz (2009) apply a Cholesky decomposition of shocks, which makes results dependent upon the ordering of variables. Consequently, their method allows us only to analyze total spillover effects (i.e., spillovers from one market to all other markets or from all other markets to one market). However, by utilizing the generalized VAR model of Koop et al. (1996) and Pesaran and Shin (1998), Diebold and Yilmaz (2012, 2014) propose a new spillover index, which can capture directional spillovers (from/to a particular market) independent of the causal ordering of variables (see Appendix A for details). This study uses this new spillover index to investigate spillovers, their magnitudes, and directions.

3. Data

We use two types of stock price indexes of stocks cross-listed in both the A-share market (mainland China) and the H-share market (Hong Kong) between January 2, 2012 and February 27, 2015. We also use eight representative stock price indexes from major economies. Since the stock price index of the Chinese cross-listed shares is not available, we compiled two types of indexes (see Appendix B for specific compilation detail). The cross-listed stocks are quoted in Renminbi (RMB) in mainland China, thus the index measured in RMB is denominated as the AHA index. The index measured in Hong Kong dollars is called the AHH index. Since international investors hold widely-diversified portfolios across different economies, as a reference index of global stock markets, we employ U.S.'s S&P500 Index (USA), U.K.'s FTSE100 (GBR), Japan's Nikkei225 (JPN), Germany's DAX (DEU), France's CAC40 (FRA), Taiwan's TWSE (TWN), India's SENSEX (IND), and Australia's AS51 (AUS).[8]

We follow Diebold and Yilmaz (2009) in using weekly data, and define a weekly return utilizing closing prices of Fridays.[9] One of the reasons for using weekly data is due to different closing hours of national stock exchanges. On a calendar day, *t*, Chinese stock exchanges open and close prior to the opening of the New York Stock Exchange. Therefore, there cannot be spillovers from the U.S. to China on day *t*. There is also the day-of-the-week effect of daily data. Lo and MacKinlay (1988) write: "Weekly sampling is the ideal compromise, yielding a large number of observations while minimizing the biases inherent in daily data" (p.27).

Descriptive statistics of weekly returns are displayed in Table 1. Every mean takes a positive value in these markets, indicating a rising trend during the sample period. Standard deviations are the highest for AHA and AHH returns.

[Insert Table 1 about here]

Since volatility of stock returns is not directly observable in the market, it has to be estimated. We employ realized volatility (RV) as a measure of this volatility. This concept was proposed by Andersen and Bollerslev (1998), and has a higher precision than other estimates.[10]

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[8] Data on foreign markets were all obtained through Bloomberg.
[9] If price data on a Friday is missing due to a national holiday or other reasons, we copied the previous day's value to Friday, following Jeon and Von Furstenberg (1990).
[10] Andersen et al. (2003), Koopman et al. (2005), and Angelidis and Degiannakis (2008) have compared various volatility estimates and concluded that the RV is a better predictor of volatility relative to the ARCH-type and

The RV on day *t* is an accumulated sum of intraday returns:

$$RV_t = \sum_{i=1}^{n} r_{t(i)}^2 . \tag{1}$$

If the number of intraday observations, *n*, is sufficiently large, RV_t is a consistent estimator of the true volatility given certain conditions (e.g., Andersen et al., 2001; Barndorff-Nielsen and Shephard, 2002; Andersen et al., 2003).

However, there are questions to be tackled before obtaining RV using intraday data. The first is that intraday prices are subject to microstructure noise.[11] The higher the frequency of daily observations, *n*, the larger the effect of microstructure noise on estimates of volatility, creating a deviation from true volatility. As such, we need to search for the optimal frequency of intraday data, minimizing the effects of microstructure noise. Many researchers, such as Andersen et al. (2001) and Koopman et al. (2005) have applied the five-min frequency to solve this problem and we also follow this procedure.

Another problem with intraday data is how to treat the overnight return from the previous day's closing price to the current day's opening. We cannot compute high-frequency returns during the overnight period when there is no trading. Consequently, the close-to-open return is based on a long period of time that would add noise to RV. However, if we simply exclude it from computation, that would underestimate RV. Hansen and Lunde (2005) offer a solution by using the equation below:

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stochastic volatility (SV) models.

[11] A well-known example of microstructure noise is the bid-ask bounce. Since transactions occur either at ask or bid prices, the transaction price tends to fluctuate between them, resulting in alternatively positive and negative returns. Hence, returns data has an apparent negative first-order autocorrelation. For more details see Campbell et al. (1997), Chapter 3.

$$RV_t^{(HL)} = \frac{\sum_{t=1}^{T}(R_t - \overline{R})^2}{\sum_{t=1}^{T} RV_{t(intra)}} RV_{t(intra)}, \quad (2)$$

where R_t is the daily return, $\overline{R}$ is the mean of daily returns, and $RV_{t(intra)}$ is RV without overnight returns. This study utilizes weekly data to measure spillover effects and, thus, we compute the weekly average of daily RV series given by equation (2). Numerous studies report that the logarithm of RV approaches a normal distribution, and it is now a common practice to use log RV as a measure of volatility in model estimations (e.g., Andersen et al., 2001; Andersen et al., 2003; Koopman et. al., 2005), which we will also follow in this study.

Table 2 shows the descriptive statistics on weekly volatility measures. The means of AHA and AHH are the highest, which signify that mainland Chinese and Hong Kong stock markets were the most volatile in this group of markets. This is consistent with high standard deviations of returns in these markets, as per Table 1. Volatilities in European and American markets are generally lower.

[Insert Table 2 about here]

4. Estimation Results

This section presents the estimation results of the four hypotheses put forward in section 3. Section 5.1 discusses spillovers between major global markets and accessible and inaccessible markets in China, while section 5.2 discusses the effects of market liberalization, which opens the hitherto closed market to foreign investors.

5.1 Test Results of Hypothesis 1

Tables 3 and 4 (spillover tables) exhibit the spillover indexes proposed by Diebold and Yilmaz (2009, 2012). The 10x10 matrix in the upper-left hand corner is a variance decomposition matrix,

$D^H = [d_{ij}^H]$, and each (*i*, *j*) element shows the spillover effect from market *j* (column) to market *i* (row). For instance, the first row, second column element is 25.09, which means the spillover effect in returns from AHH (price index of cross-listed stocks in Hong Kong) to AHA (price index of cross-listed stocks in mainland China) amounts to 25.09%. The greater this number, the greater the spillover effect. Numbers given in the right-most column, labeled "Directional FROM others (off-diagonal row sums)," display the Spillover Index, $S_{i\leftarrow\bullet}^H$, which measures the spillover effect from all other markets to market *i* (equation (A.4) in Appendix A). For example, the element in the first row, last column is 43.78, which indicates the effect of all other markets on the return in AHA is 43.78%. The antepenultimate row, labeled "Directional TO others (off-diagonal column sums)," gives the spillover index from market *i* to all other markets, $S_{\bullet\leftarrow i}^H$ (equation (A.5) in Appendix A). The penultimate row, labeled "TO-FROM," is defined as $S_i^H = S_{\bullet\leftarrow i}^H - S_{i\leftarrow\bullet}^H$, which gives the net spillover effect of market *i* on other markets. The last row, labeled "TO+FROM," gives the sum of $S_{i\leftarrow\bullet}^H$ and $S_{\bullet\leftarrow i}^H$, which measures the degree of interrelationships between market *i* and other markets.

[Insert Table 3 about here]

[Insert Table 4 about here]

The spillover indexes in Tables 3 and 4 are computed with all data points in the sample.[12] The indexes of AHA for the inaccessible market (mainland China) and that of AHH for the accessible market (Hong Kong) are composed of the cross-listed firms. Therefore, they are subject

[12] The lag order *p* of the VAR(*p*) model is determined so as to minimize the Akaike information criterion (AIC) by varying *p* from 1 to 10. The lag order is 1 in both return and volatility models. All spillover indexes in this paper are based on a forecasting horizon of two periods. This horizon was varied from 1 to 10 periods, and the computed spillover indexes similar to the ones we display in this paper.

to identical fundamentals, which means these indexes will adjust the same way to changes in fundamentals such as policy changes and downgrading of profit perspectives. Obviously, these two indexes are closely linked and, to capture the effects from other major markets, it would be desirable to remove this part of cross effects within China. The results of this removal are given between parentheses in the cells involving either AHA or AHH. After removal, the spillover index AHA, $S^{H}_{AHA\leftarrow\bullet}$ (shown in the last column, first row of the matrix) is 18.68% in the case of returns (Table 3) and 7.53% in the case of volatility (Table 4). The same spillover index of AHH is 37.46% in the case of returns (Table 3) and 33.57% in the case of volatility (Table 4). As these numbers clearly indicate, spillovers to AHH are much higher than those to AHA, indicating that Hypothesis 1 is supported. Namely, stocks in the accessible market are more closely linked to major foreign markets than those in the inaccessible market. Moreover, the result is consistent with the investor-induced hypothesis rather than the fundamentals-based hypothesis.

In numerous preceding studies, the result varies substantially regarding the channel of spillovers through either return or volatility (see section 2). As such, we can determine which channel is more important by comparing relevant spillover indexes (Diebold and Yilmaz, 2009). The previously cited values concerning AHA indicate that the spillover index of return (18.68%) is much higher than that of volatility (7.53%). In other words, spillover effects in mainland China are more strongly observed in the case of returns than in the case of volatility.[13] Regarding spillover indexes measuring effects from all other markets (the last column in both Tables 3 and 4), when we compare values between return and volatility, they are rather similar in magnitude.

[13] In the case of Hong Kong (AHH), the Spillover Index measuring effects from other markets net of cross effects is 37.46% for return and 33.57% for volatility. Since the difference is very small, we cannot judge which channel was more important.

Stock markets in advanced economies exhibit higher spillover effects both in return and volatility, but the stock market in mainland China is affected by other markets more strongly in return than in volatility.

However, spillover indexes measuring effects from other markets to mainland China ($S^H_{AHA\leftarrow\bullet}$) exhibit the smallest values compared with other markets. The finding that mainland China is not responsive to stock price changes in other major economies is consistent with results obtained in previous studies (i.e., Liu and Chen, 2008; Nishimura and Men, 2010). We can account for this finding by the fact that access to stocks in mainland China was limited for foreign investors (see section 1). Another reason may relate to the tendency of Chinese investors not to hold sufficiently diversified international portfolio. Additionally, the Chinese government has actively implemented numerous measures to promote Chinese investment abroad, such as defining Qualified Domestic Institutional Investors (QDII), as well as measures to open domestic market to foreigners, such as granting permission to Qualified Foreign Institutional Investors (QFII) and RMB Qualified Foreign Insititutional Investors (RQFII).[14] However, the result obtained here suggests that these measures are still short of a fully open and internationalized stock market, and that further liberalizing measures are necessary to attain such a market.

The net spillover effect given by $S^H_i = S^H_{\bullet\leftarrow i} - S^H_{i\leftarrow\bullet}$ is shown in the row labeled "TO-FROM" in both Tables 3 and 4. Positive values are observed only for USA, GBR, DEU, and FRA.

[14] Investment abroad by domestic Chinese investors started in 2006, when QDII were allowed to do so. As of July 2014, the amount of approved investment for QDII is 80.793 billion U.S. dollars and the total market capitalization of the Hong Kong Stock Exchange (HKSE) stands at 3248.459 billion HK dollars (source: The State Administration of Foreign Exchange of the People's Republic of China). Even if the entire amount of the approved investment by QDII is placed on the HKSE, it is a mere 2.49% of the total capitalization of the HKSE (using the exchange rate of 7.85 USD/HKD). Furthermore, since there is a restriction on risky foreign investment by QDII, the actual investment in stocks abroad is much more limited.

Only these countries affect others more than the reverse direction, and the sum of TO and FROM indexes, TO+FROM, is over 150% for these four countries. These advanced economies exert great influence on other stock markets, which is consistent with preceding research (e.g., Cheung and Mak, 1992; Diebold and Yilmaz, 2009).

The sum labeled TO+FROM is also adjusted for cross-effects between AHA and AHH, and the results are given between parentheses. The sum for AHH is 63.58% in the case of return and 35.67% in the case of volatility, and 26.64% and 8.1% for AHA, respectively. These low values indicate, relative to other major economies, how small spillovers are in mainland China.

The analysis in this section shows that the H-shares, which can be traded by international investors, are more sensitive to price changes in other markets than the A-shares, which are severely restricted for foreign investors. Although they are issued by the same firms, the prices react differently according to the openness of the market. This fact strongly implies that the stock price comovements are caused by investor behavior.

5.2 Testing Hypotheses 2: Effects of Market Liberalization

In this section, we report test results of Hypotheses 2A–C, which predict greater spillovers between global and Chinese markets after opening the latter to global investors, based on the premise that spillovers are mainly caused by investor behavior. Hypothesis 2A, which analyzes the effects of a liberalizing measure is tested by focusing on two three-month periods prior to and following the start of the Shanghai-Hong Kong Stock Connect Program on November 17, 2014. Specifically, we compare the values of the spillover index, $S^{H}_{AHA\leftarrow\bullet}$, which gives the spillover effects from all other markets to mainland China (the last column of both Tables 3 and 4, labeled "Directional FROM others"). The reason for adopting a three-month window is that if the window is too long, other major events may obfuscate estimation results. However, with a weekly frequency, there are only

15 observations in a three-month period. As such, we have a rolling window by using a one-year (52-week) span. One year is long enough to avoid the problems of seasonal anomalies reported by Rozeff and Kinney (1976), Ariel (1987) and others. The spillover indexes estimated by the rolling method are graphed in Figure 1, a *spillover plot* (Diebold and Yilmaz, 2009, 2012).

Figure 1 plots spillover indexes for return and volatility separately. The vertical, dotted line indicates the time (third week of November 2014) when the Shanghai-Hong Kong Stock Connect Program started. Return spillover effects to mainland China have rapidly risen after this liberalization (Figure 1 (a)). The average spillover index before the policy change is 13.27%, but rises to 29.16%, which is over 2.2 times the previous value. This result implies that international investors flocked to mainland China, and that this change caused a higher linkage between the hitherto closed market and other global markets. Hypothesis 2A seems to be supported.

As previously mentioned, the mainland Chinese stock market has been found to be lesser influenced by other global markets in the past. However, now that this market is partly open to foreign investors, the influence has substantially increased, as shown in this section. Moreover, as the Chinese government further liberalizes its stock market, the comovements with global markets will grow more in the future.

Volatility spillovers, however, are not affected significantly by the opening of mainland China market (Figure 1 (b)). Return spillovers exhibit a rising trend after liberalization, but volatility spillovers do not show any trend, but clear bursts. The average spillover index is 18.37% before liberalization and 19.90% afterwards, showing no significant change. This feature is consistent with the finding in the previous section that spillovers into Chinese market are observed only for return, but not for volatility, similar to the work of Diebold and Yilmaz (2009). They studied 19 major markets between January 1992 and December 2007 and found that return spillovers display an increasing trend and no bursts, but that volatility spillovers display no trends and clear bursts.

[Insert Figure 1 about here]

We now conduct tests for Hypothesis 2B, and compare the spillover indexes from all other markets to AHA and AHH price indexes before and after the Shanghai-Hong Kong Stock Connect Program. We focus on the six months surrounding liberalization, but one-year rolling windows are used to estimate indexes. Table 5 shows mean return and volatility spillover indexes from other markets to mainland China (AHA) and Hong Kong (AHH) for the sub-period before liberalization (first week of August to second week of November 2014) and after (third week of November 2014 to fourth week of February 2015).

Return spillovers to AHA from all other markets net of cross effects between mainland China and Hong Kong (bottom row of Table 5) increased from 13.27% before liberalization to 29.16% afterwards, and for AHH to 30.91% and 29.91%, respectively, showing minimal change. Volatility spillovers to AHA are 18.37% before liberalization and 19.90% after liberalization, and for AHH the numbers are 39.24% and 37.35%, respectively. The inaccessible market experienced a large increase in return spillovers after liberalization, while the accessible market saw little change in return spillovers. Consequently, Hypothesis 2B is accepted. We reconfirm the conclusion that the volatility channel is not important in the case of spillovers to mainland China.

[Insert Table 5 about here]

We finally test for Hypothesis 2C. We compare the spillover effects on stocks that became accessible thanks to the Shanghai-Hong Kong Stock Connect Program and on those that remain inaccessible after liberalization. The stocks cross-listed both in Shanghai and Hong Kong became purchasable to foreigners. The AHA index of these stocks in Shanghai represents new stocks that can now be traded by foreigners. However, compiling a price index of stocks that remain inaccessible is too complicated and demanding because of the large number of firms involved. As a proxy for this index, we utilize the Shanghai Composite Index (SHCOMP) which covers all stocks listed at the Shanghai Stock Exchange (1,040 firms as of March 2015) and includes many stocks that remain inaccessible even after the Connect Program.[15] We utilize the SHCOMP as a rough proxy for the price index of stocks not accessible to foreigners. Additionally, we compute the spillover indexes for AHA and SHCOMP in order to check how spillover effects change after liberalization. If the premise of Hypothesis 2C is correct, the result would be strengthened if we used the true price index of inaccessible stocks.

Table 6 shows mean return and volatility spillover indexes for the three-month periods before (first week of August to second week of November 2014) and after the liberalization (third week of November 2014 to fourth week of February 2015). We focus on spillovers from all other markets to AHA and SHCOMP net of cross effects between the two markets. The values are shown in the bottom row of Table 5 or 6. We compare the results of AHA in Table 5 to those of SHCOMP in Table 6. The return spillover for SHCOMP is 14.58% before liberalization ($S_{UP,before}$) and 19.71% after liberalization ($S_{UP,after}$). The proportion of $S_{UP,after} / S_{UP,before}$ is merely 1.35, indicating a small increase. On the other hand, the return spillover for AHA is 13.27% before liberalization ($S_{P,before}$) and 29.16% afterwards ($S_{P,after}$). The proportion of $S_{P,after} / S_{P,before}$ indicates a 2.2-fold increase in the index. Therefore, the rise in the return spillover index for stocks that became accessible because of the liberalization is much greater than the rise for stocks that remained inaccessible. SHCOMP includes all the stocks included in the AHA index. If we could

[15] Stocks that became accessible to foreigners number 577 firms and account for about 55.5% of the total.

use a price index purely composed of inaccessible stocks, the rise in the spillover index would have been much smaller than the proportion of 1.35 observed with SHCOMP. In any case, Hypothesis 2C, with a proposition that $S_{UP,after} / S_{UP,before} < S_{P,after} / S_{P,before}$, is supported. However, the change in volatility spillovers was not clear-cut, and Hypothesis 2C regarding volatility is not supported as in the case of Hypotheses 2A and 2B.

In summary, the return spillover effects from other markets to mainland China increased after the market liberalization to foreign investors, vindicating Hypotheses 2A, 2B, and 2C. These results imply that transactions by international investors are the cause of stock price comovements.

5. Conclusion

In this study, we have endeavored to answer whether international stock price comovements are influenced by investor behavior by focusing on how cross-listed stocks in mainland China and Hong Kong markets are impacted by foreign markets. Stocks listed at the Hong Kong Stock Exchange are tradable by foreign investors, but stocks listed in mainland China are not. If stock prices are driven only by fundamentals, shocks arising in other stock markets should affect Chinese stock prices by exactly the same amount, because the underlying fundamentals are identical, whether they adjust to foreign shocks or not. If, on the other hand, stock prices are driven by transactions of investors, stock prices in Hong Kong must be more responsive to foreign shocks than those in mainland China, because foreign investors will adjust their international portfolios in the presence of new shocks elsewhere. We tested these two hypotheses by applying the spillover index proposed by Diebold and Yilmaz (2012, 2014). An innovation of this study lies in the use of cross-listed stocks on both an accessible and an inaccessible market, enabling us to examine the possible cause of stock market spillover effects. The results generally indicate that spillovers are stronger in Hong Kong than in mainland China, implying that the investor-induced hypothesis is valid. Our estimation also reveals that return spillovers between mainland China and major foreign markets are stronger than volatility spillovers.

During the sample period we have adopted for this study, the Chinese government implemented the Shanghai-Hong Kong Stock Connect Program, which partly opened the mainland stock market to foreign investors. Therefore, this policy change provides another opportunity to test the appropriateness of either the fundamentals-based or the investor-induced hypothesis on price comovements by comparing spillover effects before and after the change. The result indicates that the return spillovers became stronger in the mainland Chinese market. However, volatility spillovers remained constant, which is understandable because spillovers were mainly observed in returns rather than in volatilities. Consequently, our results tend to support the investor-induced hypothesis.

Nonetheless, not all stocks traded in mainland China became accessible to foreign investors after liberalization, but only part of them, including stocks cross-listed in Shanghai and Hong Kong. Therefore, if the investor-induced hypothesis is correct, the stocks cross-listed in Shanghai and Hong Kong are likely to generally exhibit stronger spillovers after liberalization than the stocks in Shanghai. This has been verified by our empirical analysis.

The above results support the investor-induced hypothesis, which implies that international stock market comovements are caused by international investor behavior. As increases in international portfolio investments are expected to continue, we expect to see stronger stock market comovements.

Our paper has limitations as well. First, the factual evidence we provided was obtained by focusing on two specific markets during a limited time period. We need to confirm these results with other markets and extended sample periods. Furthermore, the results need to be verified by other methods as follows. Although we utilized weekly data and computed spillover indexes, it is desirable to use other frequencies, such as monthly, daily, or even intraday high-frequency data. Other estimation methods regarding stock market comovements are also necessary, such as cross correlation functions. Second, one of the contributions of this paper is that fundamentals are controlled for by analyzing stocks cross-listed in accessible and inaccessible markets. This feature enabled us to focus on investor behavior. However, it also means we cannot observe the effects of changes in fundamentals. As such, devising a methodology whereby we can compare the effect of international investors and that of changing fundamentals would be useful. Third, our analysis was based on the premise that there are only two possible causes of stock market comovements, namely investor behavior and fundamentals. However, news on stock price changes in other countries may affect investor sentiment significantly, resulting in comovement. This possibility needs to be examined. Even if this were the case, the main conclusion of this paper would hold valid, if the effects of news are the same across accessible and inaccessible markets. Addressing these problems provides scope for future research.

Appendix A. Spillover Index of Diebold and Yilmaz (2012, 2014)

The spillover index, proposed by Diebold and Yilmaz (2012, 2014), is based on the variance decompositions of a generalized VAR system. The forecast error matrix with an H-period horizon, $D^H = [d_{ij}^H]$, is defined by:

$$d_{ij}^H = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' \Theta_h \Sigma_\varepsilon e_j)^2}{\sum_{h=0}^{H-1} (e_i' \Theta_h \Sigma_\varepsilon \Theta_h' e_i)}, \tag{A.1}$$

where Σ_ε is a variance-covariance matrix of the error term ε, σ_{jj} is the *j*-th term on the diagonal of Σ_ε, e_i (e_j) is a selection vector which has an *i*-th (*j*-th) element equal to unit and zero otherwise. The error terms are not orthogonal to each other, thus making the row sums of d_{ij}^H not necessarily equal to 1 ($\sum_{j=1}^N d_{ij}^H \neq 1$). In order to compare magnitudes of the spillovers between different markets, Diebold and Yilmaz (2012, 2014) normalize the elements of D^H as follows:

$$\tilde{d}_{ij}^H = \frac{d_{ij}^H}{\sum_{j=1}^N d_{ij}^H}. \tag{A.2}$$

This normalization produces properties such as $\sum_{j=1}^N \tilde{d}_{ij}^H = 1$ and $\sum_{i,j=1}^N \tilde{d}_{ij}^H = N$, which provide comparability between markets. Note that $\tilde{d}_{ij}^H$ measures spillovers from the *j*-th to the *i*-th market.

The total spillover index, S_{total}^H, which measures return (volatility) spillovers in the entire global markets is defined as:

$$S_{total}^H = \frac{\sum_{\substack{i,j=1 \\ i\neq j}}^N \tilde{d}_{ij}^H}{\sum_{i,j=1}^N \tilde{d}_{ij}^H} \times 100 = \frac{1}{N} \sum_{\substack{i,j=1 \\ i\neq j}}^N \tilde{d}_{ij}^H \times 100. \tag{A.3}$$

The total spillover index defined above can measure spillovers in global markets. We are further interested in measuring return (volatility) spillovers between cross-listed Chinese stocks and other non-Chinese stocks. Such spillover indexes are defined as follows:

$$S_{i\leftarrow\bullet}^{H} = \sum_{\substack{j=1 \\ j\neq i}}^{N} \tilde{d}_{ij}^{H} \times 100, \tag{A.4}$$

$$S_{\bullet\leftarrow i}^{H} = \sum_{\substack{j=1 \\ j\neq i}}^{N} \tilde{d}_{ji}^{H} \times 100, \tag{A.5}$$

where $S_{i\leftarrow\bullet}^{H}$ measures spillovers from all other markets to the *i*-th market, and $S_{\bullet\leftarrow i}^{H}$ measures spillovers from the *i*-th market to all other markets.

Appendix B. Compilation of A-share and H-share Cross-Listed Stock Index

We retrieve prices at five-min frequency for 86 stocks cross-listed in mainland China (A-shares) and Hong Kong (H-shares) and compute capitalization-weighted average of those prices. This index on day *t* and at time *i* is computed as

$$Index_{t(i)}^{m} = \sum_{l=1}^{86} \delta_{t(i)}^{l(m)} p_{t(i)}^{l(m)} ,$$

where

$$\delta^{l(m)} = \frac{V_t^{l(m)} p_{t(i)}^{l(m)}}{\sum_{l=1}^{86} V_t^{l(m)} p_{t(i)}^{l(m)}} .$$

In the expressions above, $p_{t(i)}^{l}$ is the price of stock *l* in market *m* (*m* = China, Hong Kong) at time *i* on day *t*, V_t^l is the number of shares of stock *l* in market *m* on day *t*. Prices of A-shares were retrieved from FoxTrader and those of H-shares from Stock Exchange of Hong Kong, Ltd. The number of shares was retrieved from the Wind database. Five-min data are available for mainland China, but only tick data are available for H-shares. As such, we retrieved five-min data from these tick data.

[Insert Table A about here]

Figures and Tables

Table 1. Descriptive Statistics, Global Stock Market Weekly Returns
Sample period: January 2, 2012 to February 27, 2015 (*T* = 165)

	AHA	AHH	USA	GBR	JPN
Mean	0.320	0.227	0.312	0.134	0.484
Std. dev	3.530	3.432	1.539	1.656	2.785
Skewness	0.647	0.456	-0.262	-0.636	-0.340
Kurtosis	4.122	3.427	3.288	4.641	3.132
	DEU	FRA	TWN	IND	AUS
Mean	0.398	0.272	0.177	0.380	0.231
Std. dev	2.261	2.178	1.636	1.934	1.532
Skewness	-0.279	-0.434	-0.153	0.161	-0.597
Kurtosis	2.794	3.405	4.031	2.458	4.202

Table 2. Descriptive Statistics, Global Stock Market Weekly Log Volatility

Sample period: January 2, 2012 to February 27, 2015 (T = 165)

	AHA	AHH	USA	GBR	JPN
Mean	0.481	0.761	-0.880	-0.705	0.202
Std. dev	0.730	0.417	0.623	0.557	0.657
Kurtosis	1.254	0.170	-0.104	0.220	0.538
Skewness	5.399	3.387	3.221	2.541	4.081
	DEU	FRA	TWN	IND	AUS
Mean	-0.181	-0.087	-0.709	-0.321	-0.852
Std. dev	0.625	0.604	0.460	0.470	0.464
Kurtosis	-0.112	0.200	0.168	0.388	0.152
Skewness	2.685	2.491	2.523	2.969	2.811

Table 3. Full-Sample Return Spillover Table
Sample period: January 2012 to February 2015

	AHA	AHH	USA	GBR	JPN	DEU	FRA	TWN	IND	AUS	Directional FROM others
AHA	56.22	25.09	1.83	3.34	0.73	3.38	2.68	3.87	1.54	1.32	43.78 (18.68)
AHH	19.30	43.24	3.81	4.68	3.30	5.36	4.78	5.16	6.50	3.88	56.76 (37.46)
USA	0.59	2.01	26.61	16.24	7.06	14.78	16.14	4.56	5.11	6.91	73.39
GBR	1.29	2.44	14.35	23.59	6.65	15.01	16.71	5.00	6.56	8.40	76.41
JPN	0.54	3.12	10.35	10.55	37.59	7.94	10.04	6.10	6.05	7.71	62.41
DEU	0.56	2.85	14.23	16.27	5.11	25.58	20.95	3.88	5.52	5.05	74.42
FRA	0.78	2.50	14.60	16.94	6.18	19.54	23.91	4.27	5.79	5.49	76.09
TWN	2.38	4.14	9.08	10.08	6.47	7.85	9.23	35.03	9.77	5.94	64.97
IND	0.97	5.63	7.84	11.00	5.12	8.60	9.64	8.34	38.91	3.97	61.09
AUS	0.85	3.43	10.02	13.49	7.61	7.69	8.97	6.07	4.46	37.40	62.60
Directional TO others	27.26 (7.96)	51.22 (26.12)	86.10	102.59	48.23	90.16	99.14	47.24	51.29	48.67	*Total spillover*
TO-FROM	-16.52 (-10.72)	-5.54 (-11.34)	12.72	26.18	-14.17	15.73	23.05	-17.73	-9.79	-13.92	
TO+FROM	71.03 (26.64)	107.97 (63.58)	159.49	178.99	110.64	164.58	175.23	112.20	112.38	111.27	65.19

Note: The underlying variance decomposition is based upon a VAR of order 1, and the predictive horizon is 2. The *ij*-th entry of the upper-left 10×10 market submatrix gives the *ij*-th pairwise directional spillover index (i.e., spillover from *j* market to *i* market). The rightmost (FROM) column gives the total directional spillover index (FROM); that is, row sums (from all others to *i*). The bottom (TO) row gives the total directional spillover Index (TO); that is, column sums (to all others from *j*). Values in parentheses are the directional spillover indexes net of cross effects between mainland China and Hong Kong.

Table 4. Full-Sample Volatility Spillover Table

Sample period: January 2012 to February 2015

	AHA	AHH	USA	GBR	JPN	DEU	FRA	TWN	IND	AUS	Directional FROM others
AHA	82.65	9.83	0.12	0.50	0.81	0.05	0.17	0.19	4.39	1.30	17.35 (7.53)
AHH	13.41	53.02	4.20	8.32	3.21	5.03	4.44	2.06	0.46	5.85	46.98 (33.57)
USA	0.05	1.99	28.74	19.31	6.25	15.55	16.69	3.87	1.04	6.49	71.26
GBR	0.24	2.61	15.26	25.58	4.30	17.90	19.15	4.39	1.34	9.23	74.42
JPN	0.69	1.33	10.01	9.31	61.72	4.38	4.96	2.58	0.04	4.97	38.28
DEU	0.02	1.82	14.15	21.11	2.35	27.56	23.37	4.00	0.59	5.04	72.44
FRA	0.03	1.90	14.64	21.48	2.56	22.65	25.79	4.33	0.68	5.95	74.21
TWN	0.47	0.64	6.71	11.91	2.55	10.27	11.62	52.98	1.41	1.46	47.02
IND	1.23	1.22	3.20	4.73	0.37	2.28	2.13	3.50	79.03	2.31	20.97
AUS	1.86	5.32	10.14	12.66	5.84	7.35	8.69	2.30	0.78	45.07	54.93
Directional TO others	18.00 (0.57)	26.66 (2.10)	78.41	109.32	28.24	85.46	91.20	27.24	10.73	42.60	*Total spillover*
TO-FROM	0.65 (-6.96)	-20.33 (-31.47)	7.16	34.90	-10.03	13.03	16.98	-19.79	-10.24	-12.33	
TO+FROM	35.35 (8.1)	73.64 (35.67)	149.67	183.74	66.52	157.90	165.41	74.26	31.70	97.54	51.79

Note: The underlying variance decomposition is based upon a VAR of order 1 and the predictive horizon is 2. The *ij*-th entry of the upper-left 10×10 market submatrix gives the *ij*-th pairwise directional spillover index (i.e., spillover from *j* market to *i* market). The rightmost (FROM) column gives the total directional spillover index (FROM); that is, row sums (from all others to *i*). The bottom (TO) row gives total directional spillover index (TO); that is, column sums (to all others from *j*). Values in parentheses are the directional spillover indexes net of cross effects between mainland China and Hong Kong.

Table 5. Return and Volatility Spillover Index of AHA and AHH before and after the Shanghai-Hong Kong Stock Connect Program

	Return Spillover Index				Volatility Spillover Index			
	AHA		AHH		AHA		AHH	
	before	after	before	after	before	after	before	after
AHA	53.27	45.64	26.50	23.32	62.88	65.95	11.58	18.69
AHH	33.46	25.20	42.59	46.77	18.75	14.15	49.19	43.96
USA	1.31	2.26	4.90	3.78	0.71	3.83	3.22	3.73
GBR	1.53	5.20	3.05	2.34	3.39	2.65	6.82	8.66
JPN	0.62	0.68	4.77	2.10	7.36	4.01	13.30	2.55
DEU	2.58	6.19	5.68	6.95	0.98	0.43	1.58	3.18
FRA	3.11	5.88	4.25	4.10	0.78	0.38	4.23	3.66
TWN	1.66	4.38	3.35	3.45	1.29	0.67	0.83	1.08
IND	1.72	1.61	3.06	3.94	1.21	5.22	2.24	4.71
AUS	0.74	2.96	1.85	3.25	2.65	2.71	7.00	9.78
FROM exclude AHA & AHH	13.27	29.16	30.91	29.91	18.37	19.90	39.24	37.35

Notes: The rolling estimation window width is 52 weeks, and the predictive horizon for the underlying variance decomposition is 2. The "before" column presents mean values between the first week of August 2014 and the third week of November 2014. The "after" column presents mean values between the third week of November 2014 and the fourth week of February 2015.

Table 6. Return and Volatility Spillover Index of SHCOMP before and after the Shanghai-Hong Kong Stock Connect Program

	Return Spillover Index		Volatility Spillover Index	
	before	after	before	after
SHCOMP	60.36	55.71	68.92	53.09
AHH	25.06	24.58	9.87	18.37
USA	2.92	1.96	1.05	1.71
GBR	1.96	2.87	5.42	6.42
JPN	0.89	0.62	4.00	4.66
DEU	2.64	4.45	1.18	1.43
FRA	2.96	4.22	1.54	1.18
TWN	0.72	2.41	0.73	0.51
IND	1.23	1.30	3.00	6.20
AUS	1.24	1.88	4.29	6.42
FROM exclude SHCOMP & AHH	14.58	19.71	21.21	28.53

Notes: The rolling estimation window width is 52 weeks, and the predictive horizon for the underlying variance decomposition is 2. The “before” column presents mean values between the first week of August 2014 and the third week of November 2014. The “after” column presents mean values between the third week of November 2014 and the fourth week of February 2015.

Table A. List of Companies Included in the AH Cross-Listed Index.

Company Name	A-share Code	H-share Code	Company Name	A-share Code	H-share Code
China Vanke Co., Ltd.	000002.SZ	2202.HK	Tianjin Capital Environmental Protection Group Co., Ltd.	600874.SH	1065.HK
China International Marine Containers (Group) Co., Ltd.	000039.SZ	2039.HK	Dongfang Electric Corporation Limited	600875.SH	1072.HK
ZTE Corporation	000063.SZ	0763.HK	Luoyang Glass Co., Ltd.	600876.SH	1108.HK
Zoomlion Heavy Industry Science and Technology Co., Ltd.	000157.SZ	1157.HK	Chongqing Iron and Steel Company Limited	601005.SH	1053.HK
Weichai Power Co., Ltd.	000338.SZ	2338.HK	First Tractor Company Limited	601038.SH	0038.HK
Shandong Chenming Paper Holdings Limited	000488.SZ	1812.HK	China Shenhua Energy Company Limited	601088.SH	1088.HK
Livzon Pharmaceutical Group Inc.	000513.SZ	1513.HK	Sichuan Expressway Company Limited	601107.SH	0107.HK
Northeast Electric Development Company Limited	000585.SZ	0042.HK	Air China Limited	601111.SH	0753.HK
Jingwei Textile Machinery Co., Ltd.	000666.SZ	0350.HK	China Railway Construction Corporation Limited	601186.SH	1186.HK
Shandong Xinhua Pharmaceutical Company Limited	000756.SZ	0719.HK	Guangzhou Automobile Group Co., Ltd.	601238.SH	2238.HK
Angang Steel Company Limited	000898.SZ	0347.HK	Agricultural Bank of China Limited	601288.SH	1288.HK
Hisense Kelon Electrical Holdings Co., Ltd.	000921.SZ	0921.HK	China CNR Corporation Limited	601299.SH	6199.HK
Xinjiang Goldwind Science and Technology Co., Ltd.	002202.SZ	2208.HK	Ping An Insurance (Group) Company of China, Ltd.	601318.SH	2318.HK
Shandong Molong Petroleum Machinery Co., Ltd.	002490.SZ	0568.HK	Bank of Communications Co., Ltd.	601328.SH	3328.HK
BYD Company Limited	002594.SZ	1211.HK	Guangshen Railway Company Limited	601333.SH	0525.HK
Dongjiang Environmental Company Limited	002672.SZ	0895.HK	New China Life Insurance Company Ltd.	601336.SH	1336.HK
Zhejiang Shibao Company Limited	002703.SZ	1057.HK	China Railway Group Limited	601390.SH	0390.HK
Huaneng Power International Co., Ltd.	600011.SH	0902.HK	Industrial and Commercial Bank of China Limited	601398.SH	1398.HK
Anhui Expressway Co., Ltd.	600012.SH	0995.HK	Beijing North Star Company Limited	601588.SH	0588.HK
China Minsheng Banking Corp., Ltd.	600016.SH	1988.HK	Aluminum Corporation of China Limited	601600.SH	2600.HK
China Shipping Development Company Limited	600026.SH	1138.HK	China Pacific Insurance (Group) Co., Ltd.	601601.SH	2601.HK
Huadian Power International Corporation Limited	600027.SH	1071.HK	Shanghai Pharmaceuticals Holding Co., Ltd.	601607.SH	2607.HK
China Petroleum and Chemical Corporation	600028.SH	0386.HK	Metallurgical Corporation of China Ltd.	601618.SH	1618.HK
China Southern Airlines Co., Ltd.	600029.SH	1055.HK	China Life Insurance Company Limited	601628.SH	2628.HK
CITIC Securities Company Limited	600030.SH	6030.HK	Great Wall Motor Company Limited	601633.SH	2333.HK
China Merchants Bank Co., Ltd.	600036.SH	3968.HK	Zhengzhou Coal Mining Machinery Group Co., Ltd.	601717.SH	0564.HK
China Eastern Airlines Corporation Limited	600115.SH	0670.HK	Shanghai Electric Group Company Limited	601727.SH	2727.HK
Yanzhou Coal Mining Company Limited	600188.SH	1171.HK	CSR Corporation Limited	601766.SH	1766.HK
Shanghai Fosun Pharmaceutical (Group) Co., Ltd.	600196.SH	2196.HK	China Communications Construction Company Limited	601800.SH	1800.HK
Guangzhou Baiyunshan Pharmaceutical Holdings Company Limited	600332.SH	0874.HK	China Oilfield Services Limited	601808.SH	2883.HK
Jiangxi Copper Co., Ltd.	600362.SH	0358.HK	China Everbright Bank Company Limited	601818.SH	6818.HK
Jiangsu Expressway Co., Ltd.	600377.SH	0177.HK	Petrochina Company Limited	601857.SH	0857.HK
Shenzhen Expressway Co., Ltd.	600548.SH	0548.HK	China Shipping Container Lines Company Limited	601866.SH	2866.HK
Anhui Conch Cement Company Limited	600585.SH	0914.HK	Dalian Port (PDA) Company Limited	601880.SH	2880.HK
Tsingtao Brewery Co., Ltd.	600600.SH	0168.HK	China Coal Energy Company Limited	601898.SH	1898.HK
Guangzhou Shipyard International Co., Ltd.	600685.SH	0317.HK	Zijin Mining Group Co., Ltd.	601899.SH	2899.HK
Sinopec Shanghai Petrochemical Co., Ltd.	600688.SH	0338.HK	China COSCO Holdings Company Limited	601919.SH	1919.HK
Nanjing Panda Electronics Co., Ltd.	600775.SH	0553.HK	China Construction Bank Corporation	601939.SH	0939.HK
Shenji Group Kunming Machine Tool Co., Ltd.	600806.SH	0300.HK	Datang International Power Generation Co., Ltd.	601991.SH	0991.HK
Maanshan Iron and Steel Co., Ltd.	600808.SH	0323.HK	China CITIC Bank Corporation Limited	601998.SH	0998.HK
Haitong Securities Company Ltd.	600837.SH	6837.HK	BBMG Corporation	601992.SH	2009.HK
Beijing Jingcheng Machinery Electric Company Limited	600860.SH	0187.HK	Bank of China Limited	601988.SH	3988.HK
Sinopec Yizheng Chemical Fibre Co., Ltd.	600871.SH	1033.HK	China Molybdenum Co., Ltd.	603993.SH	3993.HK

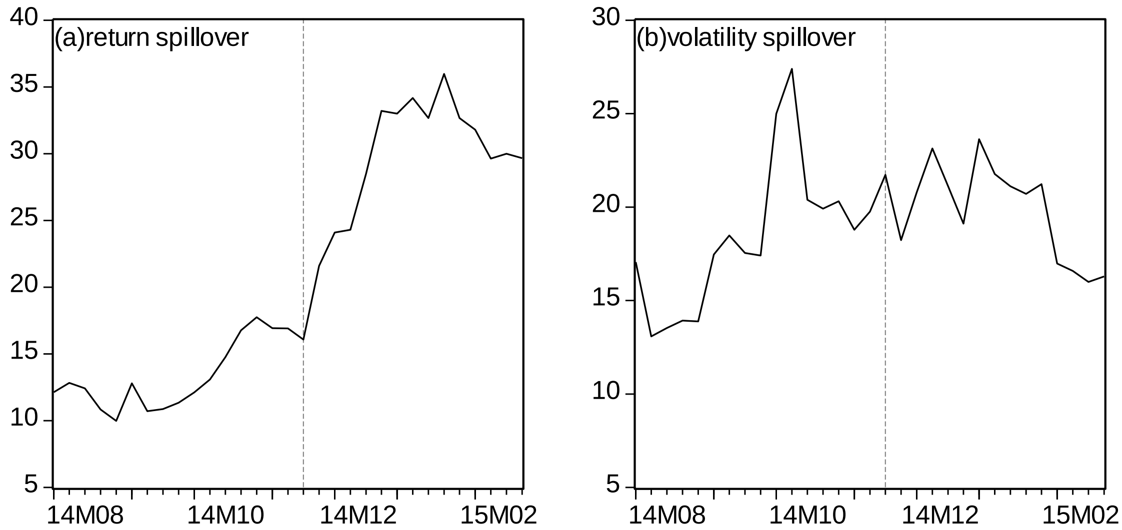

Figure 1. Directional Spillover Plots, A-share market FROM all other markets

Notes: The rolling estimation window width is 52 weeks, and the predictive horizon for the underlying variance decomposition is 2. Panel (a) depicts return spillovers and (b) volatility spillovers. The solid line indicates spillover levels, and the vertical dotted line shows the third week of November 2014, when the Shanghai-Hong Kong Stock Connect Program started.

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