Information Transmission between NASDAQ and Asian Second Board Markets

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Abstract

In Asia, NASDAQ's success has helped prompt Singapore (SESDAQ), Japan (JASDAQ), Taiwan (TAISDAQ) and South Korea (KOSDAQ) to set up or formalize their own second board markets in the 1980s and early 1990s. In 1999, Malaysia (MESDAQ) and Hong Kong (GEM) also set up their second board markets. Given the growing importance of these second board markets, we examine whether there is any evidence of spillovers from NASDAQ returns and volatilities to Asian second board market returns and volatilities and whether the cross-country spillovers are strong relative to domestic spillovers from the corresponding main board markets. For this purpose, we employ EGARCH models, dynamic causality tests, and VAR-based forecast error decompositions using daily data of a recent sample period that includes the Asian financial crisis of 1997 and up to April 20, 2001.

We find that, first, there is strong evidence of lagged returns and volatility spillovers from the NASDAQ market to the Asian second board markets when we exclude contemporaneous main board market returns. Second, there is strong evidence of contemporaneous and lagged returns and volatility spillovers from the local main board markets to the corresponding second board markets. However, even in the presence of contemporaneous main board market returns, there remain substantial spillovers from the lagged NASDAQ returns and volatilities to Asian second board market returns and volatilities. These findings are not sensitive to whether we use U.S. dollar-based data or local currency-based data.

Given the difference in the trading hours between the NASDAQ and Asian stock markets, we attempt to alleviate this concern by using some available intra-day return data and Canadian return data. The findings seem quite robust: There is substantial information spillover from the NASDAQ to Asian and Canadian second board markets. These findings indicate the existence of substantial cross-country industry effect (or meteor shower effect) as well as domestic market effect (or heat wave effect) and imply that both country diversification and industry diversification are important.

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Information Transmission between NASDAQ and Asian Second Board Markets

I. Introduction

NASDAQ (National Association of Securities Dealers Automated Quotation) was founded in 1971 as the first entirely electronic, or over-the-counter, stock market in the world. Now, the NASDAQ is the leading second board market and ranks second among the world's securities markets in terms of dollar trading volume and market capitalization.[1] The success of NASDAQ prompted the development of second board markets around the world. In Asia, Singapore, Japan, Taiwan, and South Korea set up or formalized their own over-the-counter markets in the 1980s and early 1990s. In 1999, Malaysia and Hong Kong also set up their secondary markets, consecutively. In Europe, EASDAQ, a Brussels-based system that trades stocks from across Europe, was founded in 1996. Most recently, NASDAQ-JAPAN was launched in June 2000, and NASDAQ-CANADA was commenced in November 2000.

The main reason that many stock exchanges have established their own second board markets is to provide a place for fund-raising for small firms and venture capitals, most of which are high-tech related and have the potential for high growth. The second board markets also provide a new venue for investors so that they can adopt a broader investment strategy and enjoy business opportunities outside the main board market. NASDAQ has become an important source of information for stock markets around the world. In the absence of appropriate benchmarks, investors around the world look to NASDAQ to set valuations for home-grown technology and Internet issues. Global companies like Microsoft Corporation, Oracle Corporation, Intel Corporation, Cisco Systems, Inc., and Sun Microsystems, Inc. are all listed on the NASDAQ market and play the role of benchmarks for similar companies or industries in other countries.

Previous studies of the NASDAQ have concentrated on its market structure and spread patterns (Chan et al. (1995), Kandel and Marx (1997)), quotation systems and market making activities (Christie and Schultz (1994), Porter and Weaver (1998)), and return, volatility and volume relationships (Chan and Fong (2000), Schwert (2001)). Given the growing importance of the second board markets, we build on the recent literature of stock market linkages and examine the information transmission mechanism between the NASDAQ and the Asian second board markets.

Existing research on cross-market information transmission has focused on the main board stock markets. For example, Hamao, Masulis, and Ng (1990) study the short-run interdependence of prices and price volatilities across the Tokyo, London, and New York stock markets. They provide evidence of price and price volatility spillovers from New York to Tokyo, London to Tokyo, and New York to

[1] By September 2001, NASDAQ ranked second in both dollar volume and market capitalization and ranked first in share volume.

London. Engle and Susmel (1993) investigate whether international stock markets share the same volatility process, and they observe that the second moments of stock returns are related for some of the 18 countries in their sample. Koutmos and Booth (1995) find that volatility spillovers in a given market are much stronger when the news arriving from the last market to trade is bad.

Evidence of spillover effects across the two markets is consistent with the meteor shower hypothesis, while the lack of spillover effects is consistent with the heat wave hypothesis. These hypotheses are proposed by Engle et al. (1990). The heat wave hypothesis is that volatility has only location-specific autocorrelation. This means that a volatile day in NASDAQ is likely to be followed by another volatile day in NASDAQ, while typically not causing a volatile day in Asian markets. The alternative meteor shower hypothesis is that volatility spills over from one trading center to another so that a volatile day in NASDAQ is likely to be followed by a volatile day in Asian markets.

Grinold, Rudd, and Stefek (1989) study the decomposition of local currency-denominated individual stock returns into a local market factor, an industry factor, and a certain common factor based on company attributes such as size, yield and success. They find that both industry and country factors explain part of the typical stock's return behavior. Roll (1992) finds that each country's industrial structure plays a major role in explaining stock price behavior. However, Heston and Rouswnchorst (1994) show that industry differences and country specialization by industry cannot explain the degree to which country stock markets co-move. They find that country effects dominate industrial explanations.

The objective of the paper is to investigate the information transmission between NASDAQ and Asian second board markets. Since a majority of stocks traded on the NASDAQ and the Asian second board markets engage in high-tech or computer related industries, they may share common industry characteristics. We focus on whether there are returns and volatility spillovers from the NASDAQ to five Asian second board markets: namely, the GEM of Hong Kong, the JASDAQ of Japan, the KOSDAQ of South Korea, the SESDAQ of Singapore, and the TAISDAQ of Taiwan.[2] If we find that the Asian second board markets are influenced by both the NASDAQ and their own main board markets, we examine the relative importance of each market. Main board and second board market returns are highly correlated for the countries in our sample. Table 2 shows that the contemporaneous correlation between the returns on the main board market index and the second board market index is 0.54 for Hong Kong, 0.42 for Japan, 0.51 for South Korea, 0.58 for Singapore, and 0.75 for Taiwan, respectively. Since different companies are listed on the main board and second board markets, a large correlation suggests that a common factor may drive both markets. Given these correlations, we also examine whether the returns and volatilities on each of the Asian second board market indexes are mainly affected by the domestic market effect (the

[2] We do not include the MESDAQ in this study because the market is inactive and has too short a history. By the end of October 2000, there were only three firms traded on the MESDAQ with the total market capitalization of only US$37.73 million.

corresponding main board market index) or the cross-country industry effect (the NASDAQ market index).[3] The contributions of the study are as follows: First, to our knowledge, this is the first paper to examine the spillover effect among second board markets that are becoming increasingly important. Second, by using both intra-day and Canadian data as well as close-to-close return data, we fully take into account the effects of non-synchronous trades that have been ignored in previous studies. Third, this paper may shed some light on the issue of cross-country industry effect (or meteor shower effect) versus domestic market effect (or heat wave effect).

The paper is organized as follows. Section II introduces the characteristics of the NASDAQ and the Asian second board markets. Section III presents data and empirical methodologies used to examine information spillovers between the NASDAQ and Asian second board markets. Section IV presents and discusses the empirical results. Section V provides further analyses of the timing issue using intra-day data and Canadian market data. Section VI concludes the paper.

II. Characteristics of the NASDAQ and the Asian Second Board Markets

NASDAQ (National Association of Securities Dealers Automated Quotation) was founded in 1971 as the first over-the-counter stock market in the world to provide venture capitalists with a place to sell their stakes in the start-ups. In contrast to traditional floor-based stock markets, the NASDAQ is a screen-based market, operating in a highly competitive electronic trading environment without specialists. This allows multiple market participants to trade stock on the NASDAQ with no geographic boundaries. Two separate markets comprise the NASDAQ Market: the NASDAQ National Market and the NASDAQ SmallCap Market. The National market refers to those most actively traded securities, which include some of the largest, best known companies in the world. The SmallCap market is for emerging growth companies. When SmallCap companies become more established, they often move up to the National market.

As mentioned at the outset, the success of the NASDAQ prompted the development of second board markets in Asia. Table 1 gives a summary of the listing requirements on the NASDAQ and Asian second board markets.

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TABLE 1 HERE

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SESDAQ (Stock Exchange of Singapore Dealers and Automated Quotation) was the first second board market in Asia. It was established in February 1987 to aid smaller companies in raising funds from the stock market, as these companies do not meet the requirements for a Main Board listing. Like the

[3] Lessard (1976) regresses individual stock returns on global, industry, and national factors and concludes that national factors

other Asian markets, there are few quantitative criteria for a listing on SESDAQ. SESDAQ companies can be transferred to the Main Board later if they comply with the Main Board listing requirements. Singapore is competing closely with Hong Kong for the position of the second most important financial center in Asia after Japan. However, in spite of being the first second board market in Asia, the development of the SESDAQ has been rather slow. Table 2 shows that SESDAQ is one of the smallest Asian second board markets in the sample in terms of market capitalization.

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Japan has witnessed an economic slowdown since the early 1990s. To stimulate the weak economy, the Japanese government has been working hard to create a favorable environment for venture businesses by introducing necessary legislation and measures. In 1991, JASDAQ (Japan Association of Securities Dealers Automated Quotation) opened in Tokyo and has quickly attracted a new breed of investors. JASDAQ is currently the second largest board market in Asia, with the highest number of listed firms (889 by the end of October 2000) and the largest amount of capitalization (US$114.6 billion). In order to protect potential investors, the government imposes strict screening rules for OTC's listing.[4]

Taiwan established its over-the-counter market ROSE (R.O.C. Over-the-Counter Securities Exchange) on November 1, 1994. In July 1995 ROSE opened to foreign investors and was renamed TAISDAQ in June 2000 to emphasize the nature of high-tech stocks listed in the market. Starting from 2000, the Securities and Futures Commission of Taiwan required that any public company that trades on the TAISDAQ and meets the listing requirements of the Taiwan Stock Exchange be listed on the Exchange directly. The goal behind this policy from the government is the decision to enlarge the scale of the securities market by increasing the number of listed companies on the main board market.[5]

The KOSDAQ (Korea Securities Dealers Automated Quotation) market was born in July 1996. Before the establishment of KOSDAQ, an over-the-counter intermediary floor was set up in October

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dominate the explained part of stock price variances.

[4] For example, it takes five years on average after establishment for companies before enlisting in NASDAQ, whereas it takes 25 years in Japan. This general listing criterion of the OTC market was relaxed in December 1998. For example, it takes less than 21 months for Yahoo Japan to be listed in the OTC market from its inception compared to the 25-year restriction in the past. Recently, the two largest exchanges in Japan, the Tokyo Stock Exchange (TSE) and Osaka Securities Exchange (OSE), have launched two alternative markets. On December 22, 1999, the TSE launched a new parallel market called "Mothers", i.e., Market for High-growth and Emerging Stocks. It is designed to provide an easier, faster and cheaper listing venue for companies in expanding sectors with high potential. With relaxed listing criteria, 'Mothers' does not require ventures a certain time limitation until listing after their inception. The other is NASDAQ-Japan Market, a business partnership of Japan's IT giant Softbank and U.S. NASD. It commenced trading on June 19, 2000, as a section of the OSE. So far the securities trading of both markets are inactive.

[5] Actually, the scale of the OTC market in Taiwan is already the second largest in Asia. However, Hong Kong's GEM benefits from the proximity to Mainland China. According to the present regulations of Taiwan's Exchange, subsidiary companies cannot be listed on the stock market if their capital exceeds 20% of their parent companies. This means that many operations in Mainland China owned by Taiwan companies cannot be listed in Taiwan. Moreover, until now, an OTC trader is not allowed to purchase or sell stocks for residents of Mainland China. A new OTC second board market named Taiwan Innovative Growing Entrepreneurs or "Tiger" was launched in March 2000. The "Tiger" targets companies with smaller capital and shorter business

1991. The market provides opportunities for information-based, high value creating, high-tech start-ups and small enterprises to raise funds and for investors seeking high risk-high return investment opportunities. Although the KOSDAQ market suffered a severe crisis in 1997 due to the economic recession that followed the currency crisis, it has grown to a market size of 10% of the 45-year-old Korea Stock Exchange in just a few years. For the promotion of the nation's economic restructuring to mitigate unemployment and achieve industrial reform, the government of South Korea has diversified requirements for listing on the KOSDAQ market and relaxed regulations so that large telecommunication firms and other similar companies can be easily listed on the market. In addition, tax incentives are extended to small venture firms listed on the KOSDAQ market. KOSDAQ stocks are categorized into three sectors consisting of non-venture companies, venture business, and securities investment companies. Venture companies account for only 22 % of total companies traded on the KOSDAQ market. Now KOSDAQ ranks as the 14th largest stock market in the world, and is competing to be the No.1 venture stock market exchange in Asia.

The GEM (Growth Enterprise Market) was established by the Stock Exchange of Hong Kong (SEHK) on November 25, 1999. GEM aims at providing fund-raising opportunities for enterprises that have good growth potential from all industries and does not require companies to have a solid record of profitability for listing.[6] GEM offers investors the alternative of investing in "high growth, high risk" businesses. Because of the high risk involved, GEM is more stringent in its listing requirements than other Asian markets such as SESDAQ.[7] Unlike other Asian countries, Hong Kong has no tax or other government incentives for venture capital, but companies can benefit from tax exemption in capital gains and offshore profits. Although GEM imposes no restriction on the applicant's business nature, many of GEM companies are from IT or Internet-related fields, including some spin-off companies of main board listed issuers.

In sum, although the NASDAQ and the Asian second board markets differ from their size, length of history, listing and information disclosure requirements, and other administrative regulations, they share the same important features, as follows:

a. NASDAQ and Asian second board markets are all over-the-counter markets, and the basic objective of these markets is to provide a trading place for small firms and venture capitals;

b. The firms traded on these markets are mostly high-tech-related and have the potential of high-speed growth. In other words, most of the firms have the same or similar industrial characteristics;

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history.

[6] However, GEM companies must have had active business pursuits for the 24 months before listing (or 12 months by way of a wavier granted by the SEHK) and under substantially the same management and ownership during that period.

[7] For example, GEM companies require a two-year lock-up of the shares held by management, while SESDAQ companies need to wait only for six months, and NASDAQ shareholders can sell at any time. Furthermore, GEM requires listed companies to have at lease two non-executive directors, a qualified accountant and an audit committee on board.

c. Given the size and characteristics of the firms traded on these markets, these markets would be more volatile than the main board markets.

Due to these similarities among the NASDAQ and the Asian second board markets, presumably one may expect that the Asian second board markets move more closely with the NASDAQ, the largest second board market in the world, than with the NYSE, the largest main board market in the world. This expectation has been manifested by Table 2: The cross correlation coefficient between the returns on each of the Asian second board market index with the NASDAQ index is higher than that with the S&P500 index. Since a majority of stocks traded on the NASDAQ and the Asian second board markets belong to high-tech electronic or computer related "global" industries, this may at least partly explain the relatively higher degree of price co-movement between the NASDAQ and Asian second board market indices.

III. Data and the Methodology

A. Data and Notation

We use daily main board and second board market indices in the U.S. and five Asian economies: Hong Kong, Japan, South Korea, Singapore, and Taiwan. The sample period starts from each second board market's launching date to April 20, 2001. The index prices of SESDAQ, JASDAQ, and GEM are obtained from the *Dow Jones Interactive*, and those of TAISDAQ and KOSDAQ are obtained directly from the Exchanges' officials. NASDAQ index prices are obtained from the finance section of Yahoo.com. The main board markets' indices -- the Hang Seng Index (HSI) of the Stock Exchange of Hong Kong, the Nikkei 225 Index of the Tokyo Stock Exchange, the Composite Price Index of the Korea Stock Exchange (KOSPI), the Strait Times Composite Index (STCI) of the Singapore Stock Exchange, and the Taiwan Composite Index (TCI) of the Taiwan Stock Exchange -- are extracted from *Datastream*. Exchange rates between the U.S. dollar and each market's local currency are also obtained from *Datastream*.

To identify the possible effects of exchange rate changes on the test results, daily index prices in both local currency and U.S. dollars are used. To reduce the effect of non-synchronous trading between the NASDAQ and the Asian second board markets, it would be ideal to use both the open and close prices in this study. However, due to the availability of the data, we can only use close prices in our analysis for most of the sample markets. For the KOSDAQ and NASDAQ, however, we use both the open and close prices. The close-to-close returns on the *i*th second board market index are defined as: $R_{it} = lnP_{it} - lnP_{it-1}$, i = *GEM, JASDAQ, KOSDAQ, SESDAQ,* and *TAISDAQ.*

Figure 1 illustrates the chronological sequence of the trading hours on the NASDAQ and the Asian second board markets. Note that the trading hours of all the Asian second board markets overlap, but they do not overlap with the NASDAQ.

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FIGURE 1 HERE
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Table 2 reports some basic statistics for daily close-to-close return series for the five Asian second board markets and corresponding main board markets. Most of the return series in the sample have significant skewness and kurtosis, which indicate that their empirical distributions have heavy tails relative to the normal distribution. As we expect for the OTC markets, most of the second board markets are more volatile than their counterparts, and they also tend to have stronger skewness and excess kurtosis. The Ljung-Box (1978) test statistics, $LB(k)$ and $LB^2(k)$ for k = 4 and k = 8 lags, are used to test for serial correlation in the return and squared-return series. The null hypothesis of no serial correlation is rejected at the 5 percent level for most of the return series and the squared-return series. These results indicate that most of the return series exhibit conditional heteroskedasticity and that a GARCH type model will be an appropriate specification.

B. Methodology

B.1. EGARCH model

In this paper, we use a two-stage procedure to investigate the information transmission from the NASDAQ to the Asian second board markets. In the first stage, we estimate the unexpected returns for the NASDAQ and each Asian main board market that cannot be predicted based on public information. In the second stage, we use the estimated unexpected returns to investigate the interdependence of returns and volatilities between the NASDAQ, the Asian main board markets, and the Asian second board markets. During the trading hours of the NASDAQ and the Asian main board markets, information or trading noise is incorporated into the prices of the sample stocks. Since there are no overlapping trading hours between the NASDAQ and the Asian markets, the estimation of the means and variances in each market is assumed to be conditional on each one's own past information as well as information generated from the other market.[8]

The standard GARCH model is symmetric in its response to past innovations. However, there are theoretical arguments that suggest a differential response in conditional variance to past positive and negative innovations. One of the main arguments is related to information arrival. Several alternative GARCH model specifications have been proposed in an attempt to capture the asymmetric nature of

[8] See, for example, Koutmos and Booth (1995).

volatility responses. Engle and Ng (1993), in a test of volatility models on Japanese stock return data, find strong support for the GJR-GARCH model that explicitly incorporates the potential for asymmetry in the conditional variance equation. Kim and Kon (1994) find that the GJR-GARCH model is the most descriptive for individual stocks, while Nelson's (1991) EGARCH is the most appropriate for stock indices.

In this study, we express the returns on the NASDAQ and each Asian second board market by the following ARMA(1,1)-EGARCH(1,1) model:

$$\begin{cases} Nasdaq_t = c_0 + c_1 Nasdaq_{t-1} + c_2 AD_t + \eta u_{Nasdaq,t-1} + u_{Nasdaq,t} \\ \ln v_{Nasdaq,t} = a_0 + a_1 \left(\dfrac{|u_{Nasdaq,t-1}| + \lambda u_{Nasdaq,t-1}}{\sqrt{v_{Nasdaq,t-1}}} \right) + b \ln v_{Nasdaq,t-1} + \phi AD_t \end{cases}$$

$$\begin{cases} MR_{it} = c_{i,0} + c_{i,1} MR_{it-1} + c_{i,2} AD_t + \eta_i u_{i,t-1} + u_{i,t} \\ \ln v_{it} = a_{i,0} + a_{i,1} \left(\dfrac{|u_{it-1}| + \lambda u_{it-1}}{\sqrt{v_{it-1}}} \right) + b_i \ln v_{it-1} + \phi_i AD_t \end{cases} \quad (1)$$

where $Nasdaq_t$ is the return on the NASDAQ index; MR_{it} is the return on ith main board market index, i = *Hang Seng Index*, *Nikkei225*, *KOSPI*, *Strait Times*, and *Taiwan CI.* Variables $u_{Nasdaq,t}$ and $u_{i,t}$ are the unexpected returns for the NASDAQ and the ith main board that cannot be predicted based on public information, respectively.

The major financial market crisis during the sample period of our study was the sudden collapse of currency values and equity prices in Southeast Asia in the second half of 1997. The Asian financial crisis began to emerge on July 2, 1997, when Thailand abandoned its currency (Baht) peg to the U.S. dollar. When the financial market opened the same day, the Baht plunged 15% against the U.S. dollar and led to a currency devaluation panic, which spreads over the rest of Southeast Asia, especially Malaysia, Indonesia, the Philippines, and South Korea. Southeast Asia's turmoil gradually rolled into north Asian financial markets and other emerging markets. In order to study the impact of the Asian financial market crisis on the market index returns, we include a binary dummy variable AD_t which takes value of unity between October 23, 1997, when the Hang Seng Index dropped significantly, and October 28, 1997 (Hong Kong time), when the Dow Jones Index declined sharply [see Wang et al. (2001)]:

$$AD_t = \begin{cases} 1, & \text{if } t = 971023 \text{ to } 971028, \\ 0, & \text{otherwise.} \end{cases} \quad (2)$$

In the second stage of the test procedure, we estimate two types of ARMA(1,1)-EGARCH(1,1) models that allow for the interdependence of returns and volatilities between the NASDAQ and the Asian second board markets. First, to allow for a contemporaneous spillover effect from the ith main board market to the ith second board market, we estimate the following model:

$$
\begin{cases}
R_{it} = \gamma_{i,0} + \gamma_{i,1} R_{it-1} + \sum_{l=0}^{1} \gamma_{i,2,l} \hat{u}_{i,t-l} + \sum_{l=1}^{2} \gamma_{i,3,l} \hat{u}_{Nasdaq,t-l} + \gamma_{i,4} AD_t + \theta_i \varepsilon_{i,t-1} + \varepsilon_{i,t} \\
\ln h_{it} = \alpha_{i,0} + \alpha_{i,1} \left(\frac{|\varepsilon_{it-1}| + \lambda \varepsilon_{it-1}}{\sqrt{h_{t-1}}} \right) + \beta_i \ln h_{it-1} + \sum_{l=0}^{1} \psi_{i,1,l} \hat{u}_{i,t-l}^2 + \sum_{l=1}^{2} \psi_{i,2,l} \hat{u}_{Nasdaq,t-l}^2 + \psi_{i,3} AD_t
\end{cases}
\quad (3)
$$

where R_{it} is the return on the ith second board market index. Variables $\hat{u}_{i,t-l}$ (l =0, 1) with the coefficients $\gamma_{i,2,0}$ and $\gamma_{i,2,1}$ are included in the regression equation (3) to capture the contemporaneous and one-period-lagged return spillover effect from the ith main board market to the ith second board market. Similarly, variables $\hat{u}_{Nasdaq,t-l}$ (l = 1,2) with the coefficients $\gamma_{i,3,1}$ and $\gamma_{i,3,2}$ are also included in the regression to capture the one-period and two-period lagged return spillover effect from the NASDAQ to the ith Asian second board market. Given the timing of the trade on the NASDAQ and Asian markets, we cannot consider the contemporaneous effects of the NASDAQ on Asian second board markets.

Following Engle et al. (1990) and Hamao et al. (1990), we include variables $\hat{u}^2_{i,t-1}$ and $\hat{u}^2_{Nasdaq,t-1}$ in the conditional variance equation for the returns on the ith Asian second board market to capture the potential volatility spillover effect from the ith Asian main board market and the NASDAQ to the corresponding Asian second board market. The EGARCH specification in (3) captures the asymmetric effects of ε_{it-1} on the conditional variance. It allows the impact of the residual on conditional volatility to be different when the lagged residual is negative and when the lagged residual is positive.

The EGARCH model in (3) may give unfairly strong weight to main board markets because their contemporaneous returns are included, whereas only lagged NASDAQ returns are included. Since the contemporaneous returns of Asian main board markets may have incorporated the information of lagged NASDAQ returns, it would be difficult to distinguish between the cross-country industry effect (or meteor shower effect) and domestic market effect (or heat wave effect). In an attempt to provide a fair comparison between spillovers from main board market returns and from NASDAQ returns to second board markets, we allow for only the unexpected one-and two-period lagged return spillover effect from the ith main board market to the ith second board market. Therefore, in a second model, we include variables $\hat{u}_{i,t-l}$ and $\hat{u}_{Nasdaq,t-l}$, for l = 1 and 2, in the return regression, and the squared-residuals $\hat{u}^2_{i,t-1}$ and $\hat{u}^2_{Nasdaq,t-1}$ for l = 1 and 2, in the volatility regression:

$$
\begin{cases}
R_{it} = \gamma_{i,0} + \gamma_{i,1} R_{it-1} + \sum_{l=1}^{2} \gamma_{i,2,l} \hat{u}_{i,t-l} + \sum_{l=1}^{2} \gamma_{i,3,l} \hat{u}_{Nasdaq,t-l} + \gamma_{i,4} AD_t + \theta_i \varepsilon_{i,t-1} + \varepsilon_{i,t} \\
\ln h_{it} = \alpha_{i,0} + \alpha_{i,1} \left(\frac{|\varepsilon_{it-1}| + \lambda \varepsilon_{it-1}}{\sqrt{h_{t-1}}} \right) + \beta_i \ln h_{it-1} + \sum_{l=1}^{2} \psi_{i,1,l} \hat{u}_{i,t-l}^2 + \sum_{l=1}^{2} \psi_{i,2,l} \hat{u}_{Nasdaq,t-l}^2 + \psi_{i,3} AD_t
\end{cases}
\quad (4)
$$

B.2. Causality Tests

Related to the information spillover, an interesting issue in dynamic relations among these different market prices would be whether one market price helps better predict another market price. If a stock market were efficient, it would be very difficult to predict the stock market returns using publicly available information. We explore this issue using Granger causality tests [see Granger (1969)]: [9]

Given the difference in trading hours between the NASDAQ and Asian second board markets, we examine the Granger-causality from NASDAQ returns to Asian second board markets returns taking into account the fact that when the NASDAQ opens on date *t*, Asian second board markets on date *t* have already closed so that the information about Asian second board market returns of the same day is already available to the NASDAQ investors. Following the EGARCH models above, we consider the following two trivariate auto-regressions to test for causality between NASDAQ returns and Asian second board returns: We allow for the contemporaneous effect from main board markets in equation (5) and then remove the contemporaneous effect in equation (6), respectively.

$$R_{it} = \alpha + \sum_{j=0}^{4} \beta_j MR_{it-j} + \sum_{j=1}^{5} \chi_j Nasdaq_{t-j} + \sum_{j=1}^{5} \delta_j R_{it-j} \,, \qquad (5)$$

$$R_{it} = \alpha + \sum_{j=1}^{5} \beta_j MR_{it-j} + \sum_{j=1}^{5} \chi_j Nasdaq_{t-j} + \sum_{j=1}^{5} \delta_j R_{it-j} \qquad (6)$$

If in equation (5) the χ_j coefficients are statistically significant, inclusion of past values of NASDAQ returns, in addition to the past history of the *i*th second board returns and the *i*th contemporaneous and past main board returns, yields a better forecast of the *i*th second board returns, and we say NASDAQ returns Granger-cause the *i*th second board returns. If a standard *F*-test does not reject the hypothesis that χ_j = 0 for all *i*, then NASDAQ returns do not Granger-cause the *i*th second board returns. Similarly, if in equation (6) the χ_j coefficients are statistically significant, inclusion of past values of NASDAQ returns, in addition to the past history of the *i*th second board returns and past main board returns, yields a better forecast of the *i*th second board returns, and we say NASDAQ returns Granger-cause the *i*th second board returns.[10]

[9] The notion behind causality testing in Granger (1969) is based on the premise that the future cannot cause the present or the past. Formally, if the prediction of *y* using past *x* is more accurate than the prediction without using past *x* in the mean square error sense [i.e., if $\sigma^2(y_t \mid I_{t-1}) < \sigma^2(y_t \mid I_{t-1} - x_t)$, where I_t is the information set], *x* Granger-causes *y.*

[10] We do not report the results about whether Asian second board market returns affect NASDAQ returns or volatilities because the focus of the paper is to investigate the cross-country industry effect as well as the domestic market effect.

B.3. Forecast Error Variance Decomposition

We examine the relative importance of main board market returns and NASDAQ returns in explaining forecast error variance in second board market returns based on a VAR framework. We consider a 3-by-1 vector x_t consisting of three return variables: MR_t, $Nasdaq_t$, and R_t, i.e., x_t = [MR_t, $Nasdaq_t$, and R_t] ' for each Asian stock market. By the Wold theorem, x_t has the following three-variable moving average representation (MAR):

$$x_t = B(L)\, e_t, \tag{7}$$

where e_t is a 3x1 vector of innovations consisting of e_{1t}, e_{2t}, and e_{3t}. We interpret e_{1t}, e_{2t}, and e_{3t} as shocks (i.e., disturbances or innovations) to MR_t, $Nasdaq_t$, and R_t, respectively; L is the lag operator (i.e., $L^n x_t = x_{t-n}$); $B_{ij}(L)$ for i, j = 1, 2, 3 is a polynomial in the lag operator L (i.e., $B_{ij}(L) = \sum_{k=0}^{\infty} b_{ij}(k) L^k$); and the innovations e_t are orthonormalized such that var(e_t) = I.[11]

The MAR allows us to examine dynamic relations because the MAR coefficients of B(L) (i.e., $b_{ij}(k)$) represent responses of the i-th variable (x_{it}) to the j-th type of shock (e_{jt}) after k periods. Since e_t is, by orthonormalization, serially and contemporaneously uncorrelated with var(e_t) = I, one can allocate the variance of each element in x to sources in elements of e. For example,

$$\sum_{k=0}^{t-1} b_{ij}(k)^2 \Big/ \sum_{j=1}^{3} \sum_{k=0}^{t-1} b_{ij}(k)^2 \tag{8}$$

provides the forecast error decompositions: the components of error variance in the t-step ahead forecast of x_i, which is accounted for by innovations (or disturbances) in x_j (i.e., e_j).[12]

B.4. The Effect of Exchange Rate

Some previous studies suggest that changes in exchange rates may affect the behavior of index returns and volatilities in a majority of national financial markets. Roll (1992) raises a number of important issues relevant to studies of inter-market linkages using equity indices. He suggests that equity index behavior is affected by two factors: the technical procedure of index construction and the composition and role of exchange rates. When returns of indices are expressed in a nation's own (local) currency, part of the index's return volatility is induced by monetary phenomena such as changes in anticipated and actual inflation rates. Hamao et al. (1990) report that their results remain essentially unchanged after conversion to a common currency. In order to control for the possible effect that changes in exchange rates would have on cross-market information transmission, we use both local currency-based and U.S. dollar-based data in our study. Results in terms of U.S. dollars are especially relevant to

[11] For the VAR framework, see Sims (1980). See also Lee (1992).
[12] In fact, the above three-variable MAR coefficients B(L) (= [B_{ij}(L)]) are derived by inverting a three-variable vector autoregression (VAR). For details, for example, see Lee (1992).

international investors. Historically, Asian markets have experienced relatively high inflation, leading to interpretation problems in using stock indexes denominated in the local currency.

IV. Empirical Results using Close-to-Close Returns

A. EGARCH Model

Panel A of Table 3 reports the estimates of the first-stage model for the NASDAQ and the five Asian main board market indices. The estimates show that most of the GARCH coefficients are significant at the 5% level for all markets in the sample except for Hong Kong, whose sample includes the shortest sample period among the five Asian markets. The coefficient of the leverage term (λ) is significant for all markets, except for Hong Kong. The Asian financial crisis had significant impacts on most of the return volatilities. i.e., ϕ is significant except for Taiwan. The null hypothesis of no serial correlation is not rejected at the 5 percent level for all the return residuals and squared-return residuals. This indicates that the EGARCH(1,1) model specification for this study seems reasonable. Since the main purpose of the first-stage models is to estimate the residual terms for the return series, we concentrate our analysis on the estimates of the second-stage models.

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TABLE 3 HERE
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Panel B of Table 3 reports the estimates of the second-stage model in equation (3) for the five Asian second-board market index return series. As expected from Table 2, where the index returns of the main board and the second board markets in each country have a strong positive correlation, Panel B of Table 3 shows strong contemporaneous returns and volatility spillovers from the main-board market to the second-board market as indicated by the significant estimates of $\gamma_{2,0}$ and $\psi_{1,0}$. For all the Asian markets in the sample, the unexpected returns of each main board market index have a significantly positive, contemporaneous effect on the returns of the corresponding second board market. The volatility of each main board market also has a significantly positive contemporaneous effect on the volatility of the corresponding second board market. There is also strong evidence of one-period lagged return and volatility spillover effects from most of the main board markets to the corresponding second board markets, as indicated by the significant estimates of $\gamma_{2,1}$ and $\psi_{1,1}$.

In this paper, our main focus is on the information transmission mechanism between the NASDAQ and the Asian secondary board markets. In particular, we are interested in whether there are return and volatility spillovers from the NASDAQ to the Asian second board markets in the sample. Panel B of Table 3 provides empirical evidence that there are significantly positive one-period lagged return spillovers from the NASDAQ to the GEM, JASDAQ and TAISDAQ, as indicated by the significant coefficients of $\gamma_{3,1}$. There are also significantly negative two-period lagged return spillovers from the NASDAQ to the GEM, JASDAQ, SESDAQ, and TAISDAQ, as indicated by the significant negative estimates of $\gamma_{3,2}$. We also observe a significant one-period lagged volatility spillover from the NASDAQ to the SEADAQ and TAISDAQ, and a two-period lagged volatility spillover from the NASDAQ to the SESDAQ.

In addition, it is noted that the estimates of $\gamma_{2,0}$, $\gamma_{2,1}$, $\psi_{1,0}$, and $\psi_{1,1}$ are relatively larger than the estimates of $\gamma_{3,1}$ $\gamma_{3,2}$, $\psi_{2,1}$, and $\psi_{2,2}$. This indicates that the contemporaneous local main board markets have stronger return and volatility spillover effects than the previous day's NASDAQ market on the local second board markets. This implies that although local main board markets and the corresponding second board markets list and trade different companies while the NASDAQ and Asian second board markets tend to list companies in similar industries, local domestic common factors seem to exert a stronger effect than cross-country industry-common factors when we allow for the contemporaneous local domestic main board market returns. However, we cannot conclude that the domestic effect dominates the cross-country industry effect because Asian second board markets open after the NASDAQ closes.

Panel C of Table 3 reports the estimates of the second-stage model in equation (4) for the Asian second-board market index return series. The panel shows that in the absence of a contemporaneous effect of the local main board market on the corresponding second board market, the NASDAQ has stronger returns and volatility spillovers to the second board markets than the main board markets do. That is, the estimates of $\gamma_{2,1}$, $\gamma_{2,2}$, $\psi_{1,1}$, and $\psi_{1,2}$ are relatively smaller or less significant than the estimates of $\gamma_{3,1}$ $\gamma_{3,2}$, $\psi_{2,1}$, and $\psi_{2,2}$ except for the KOSDAQ.

In short, the findings in Panels B and C of Table 3 indicate that in the presence of contemporaneous main board market returns, the NASDAQ still has returns and volatility spillovers to some Asian second board markets. In the absence of contemporaneous main board market returns, the NASDAQ has even stronger returns and volatility spillovers to Asian second board markets than the main board markets do. These findings imply that first, the timing of the trades does matter for returns and volatility spillovers. Second, regardless of the timing of the trades, the NASDAQ seems to exert substantial spillover effects on Asian second board markets.

B. The Effect of Exchange Rate

To identify the potential effect of exchange rate changes on the test results, we convert all the Asian main board and second board markets' home currency-based price indices to U.S. dollars. Table 3 provides the estimates of the second-stage models for the Asian second-board market indices in both U.S. dollars and domestic currencies. Compared with the estimates using domestic currency, there is no significant difference between the two sets of estimates. Although the local main board markets have strong return and volatility spillover effects on their corresponding second board markets, unexpected returns on the NASDAQ index still have significant effects on the returns of the JASDAQ and the TAISDAQ in Panel B and on the returns of all the Asian second board markets in Panel C. Regarding the volatility spillover, NASDAQ volatility has significant spillover effects on the volatilities of the SESDAQ and the TAISDAQ in Panel B and on the volatilities of the JASDAQ, SESDAQ and TAISDAQ in Panel C. That is, whether we use the local currency-based data or the U.S. dollar-denominated data, the estimates remain very similar. In summary, the above results indicate that after controlling for changes in the exchange rates and information transmission from the local main board markets, the unexpected returns of the NASDAQ index still have significant effects on Asian second board markets' returns and volatilities.

C. Causality Tests

Table 4 presents Granger-causality test results based on equations (5) and (6) for the three stock exchange returns and volatilities: second board markets, main board markets, and NASDAQ. Panel A shows that in the presence of contemporaneous local main board market returns, NASDAQ returns Granger-cause only JASDAQ and KOSDAQ markets' returns regardless of whether the returns are measured in local currencies or U.S. dollars. Given the difference in trading hours between the NASDAQ and Asian stock exchanges, we also examine the Granger-causality among second boards, main boards, and NASDAQ, taking into account the contemporaneous effect of main board markets. Panel B shows that in the absence of contemporaneous main board market returns, NASDAQ returns are Granger-causally prior to all the Asian second board market returns regardless of whether the returns are measured in local currencies or U.S. dollars. Again, the findings in Panels A and B indicate that the causality results are sensitive to the timing of trades, and the results are very consistent with those of the spillover effects in Table 3 obtained by using EGARCH models.

Panels C and D present the causality tests using return volatilities. Variables R_{it}, MR_{it}, and $Nasdaq_t$ denote the *i*th second board, main board return volatilities, and NASDAQ return volatilities, respectively. Panel C shows that in the presence of contemporaneous local main board return volatilities, NASDAQ volatility Granger-causes only JASDAQ and KOSDAQ volatilities. Panel D shows that in the absence of contemporaneous main board volatility, NASDAQ volatilities are Granger-causally prior to all the Asian second board market volatilities. These findings of volatility spillovers are strongly consistent with those of return spillovers in Panels A and B.

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TABLE 4 HERE
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D. Sub-sample Analysis

Financial market crises can lead to dramatic changes in investment behavior, and thus it is important to study the dynamic interdependence of stock markets before and after any significant economic shock. For example, Arshanapalli and Doukas (1993) find that the degree of international co-movements among stock prices has substantially increased since the 1987 crash. Arshanapalli, Doukas, and Lang (1995) show that the cointegration structure that ties the U.S. and Asian stock markets together has substantially increased since October 1987. Masih and Masih (1997) find that the crash does not appear to have affected the relative leading role by the U.S. market over other markets.

To examine whether the returns and volatility spillover patterns are different before and after the October 1997 Asian financial crisis**,** we split the whole sample period into the pre- and post-crisis sub-sample periods. The sub-sample results, available from the authors, are very similar to those of the whole-sample estimation.[13]

E. Forecast Error Variance Decomposition

In investigating the relative explanatory power of the NASDAQ and domestic main board markets based on the forecast error variance, a potentially important issue would be the ordering of the variables in the VAR model. We estimate the VAR using two orderings: first, $x_t = [MR_{it}, Nasdaq_t, R_{it}]'$, and second, $x_t = [Nasdaq_t, MR_{it}, R_{it}]'$. In explaining forecast error variance in the *i*th second board market return, R_{it}, the former model may potentially have more explanatory power for the *i*th main board market return, MR_{it}, while the latter model may give the NASDAQ return, $Nasdaq_t$, more explanatory power. Since we want to explain variations in the *i*th second board market returns, R_{it}, it is ordered at the bottom.

The results are presented in Panel A of Table 5 (using domestic currency) and Panel B (using U.S. dollars). When we estimate the models using the two different orderings, we find the results are not at all sensitive to the ordering of the variables. This implies that there is little correlation between the residuals of MR_{it} and $Nasdaq_t$ regression equations. As such, we only report and discuss the results of the forecast error decompositions using the ordering of $x_t = [MR_{it}, Nasdaq_t, R_{it}]'$. It is noted that when only past values of main board market returns and NASDAQ returns are considered (i.e., if we do not include the contemporaneous effect from the main board market), innovations in the NASDAQ returns account for a significantly larger fraction of the second board market forecast error variance than those in the corresponding main board returns do for all five Asian markets. For example, Nikkei innovations explain 0.01 ~ 0.69% of JASDAQ return forecast error variance, whereas NASDAQ innovations explain 10.27 ~ 11.32% of the variance, depending on forecasting horizons. This implies that the NASDAQ contains

[13] For example, there are significant lagged return spillovers from the NASDAQ to the JASDAQ and TAISDAQ in both the pre-

more information than domestic main board markets in explaining variations in Asian second board market return variations.

Once we include the contemporaneous effect from the main board markets in the VAR system, the explanatory power of the main board markets becomes greater than that of the NASDAQ. However, the NASDAQ still preserves substantial explanatory power for the second board market return variations even in the presence of contemporaneous main board market returns. For example, Nikkei innovations explain 13.82 ~ 14.67% of JASDAQ return forecast error variance, whereas NASDAQ innovations explain 10.13 ~ 11.20% of the variance, depending upon forecasting horizons, respectively. We observe similar results using U.S. dollar-denominated returns from Panel B of Table 5. These results are again consistent with those of the Granger-causality tests and of the EGARCH models.[14]

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TABLE 5 HERE
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V. Further Analysis

A. Intra-day Return Analysis

To reduce the effect of non-synchronous trading between the NASDAQ and the sample Asian second board markets, it would be ideal to use both the open and close prices in this study. Lin, Engle and Ito (1994), using a signal extraction model with GARCH processes, find that Tokyo (New York) daytime returns are in general significantly correlated with New York (Tokyo) overnight returns. They also observe that, except for a lagged return spillover from New York to Tokyo for the period after the crash, there are no significant lagged spillovers in returns or volatility. Dividing daily close-to-close index returns into daytime and overnight returns, Hamao, Masulis, and Ng (1990) study the short-run interdependence of prices and price volatilities across the Tokyo, London, and New York stock markets. They provide evidence of price volatility spillovers from New York to Tokyo, London to Tokyo, and New York to London. Susmel and Engle (1994) use hourly data to estimate a modified ARCH model to study the relation between the New York and London stock markets. They find no evidence of mean spillovers if no overlapping periods are included but note some weak evidence of volatility spillovers.

Due to the availability of the data, we can only use both the open and close prices for the KOSDAQ and the NASDAQ. Let OP_t and CP_t be the market index's opening price and closing price on date t, respectively. We define the overnight (close-to-open) returns, RN_{it}, and the daytime (open-to-close) returns, RD_{it}, on the second board market index as follows: $RN_t = lnOP_t - lnCP_{t\text{-}1}$ and $RD_t = lnCP_t -$

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and post-crisis periods. There is no return spillover from the NASDAQ to the KOSDAQ in either sub-sample period.

[14] When we implement the forecast error variance decompositions using return volatilities, the results are very similar to those of Granger-causality tests reported in Panels C and D of Table 4. As such, to save space, we do not report the results.

$lnOP_t$. Similarly, we define the main board market index's overnight returns, MRN_t, and the daytime returns, MRD_t, as follows: $MRN_t = lnMOP_t – lnMCP_{t\text{-}1}$, and $MRD_{it} = lnMCP_{it} – lnMOP_{it}$. To investigate the intra-day returns and volatility spillovers between the NASDAQ and the KOSDAQ, we estimate the following EGARCH(1,1) model:[15]

$$\begin{cases} RD_t = \gamma_0 + \gamma_1 RD_{t-1} + \gamma_2 RN_t + \gamma_3 MRN_t + \gamma_4 NasdaqD_{t-1} + \gamma_5 NasdaqN_{t-1} + \varepsilon_t \\ \ln h_t = \alpha_0 + \alpha_1 \left(\dfrac{|\varepsilon_{t-1}| + \lambda \varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right) + \beta \ln h_{t-1} + \varphi_1 RD_{t-1}^2 + \varphi_2 RN_t^2 + \varphi_3 MRN_t^2 + \varphi_4 NasdaqD_{t-1}^2 + \varphi_5 NasdaqN_{t-1}^2 \end{cases} \quad (9)$$

In model (9), the coefficient γ_3 indicates the effect of KOSPI overnight returns on KOSDAQ daytime returns. The coefficients γ_4 and γ_5 indicate the spillovers from NASDAQ's one-period lagged daytime and one-period lagged overnight returns to KOSDAQ daytime returns. The coefficient φ_3 indicates the KOSPI's overnight volatility "surprises" on KOSDAQ daytime volatilities. The coefficients φ_4 and φ_5 measure the possible spillovers from daytime and overnight volatilities of NASDAQ to KOSDAQ daytime volatilities, respectively. Evidence of spillover effects across the two markets is consistent with the meteor shower hypothesis, while the lack of spillover effects is consistent with the heat wave hypothesis, as proposed by Engle et al. (1990). Panel A of Table 6 reports the estimates for Equation (9). The significant estimates of γ_3 and γ_5 indicate the existence of return spillovers from KOSPI's and NASDAQ's overnight returns to KOSDAQ's daytime returns. In particular, it is noted that $\gamma_3 < \gamma_5$, which implies that NASDAQ's overnight returns have a larger effect than KOSPI's overnight returns. Although similar spillover effects are observed for the return volatilities, the estimates are not significant.

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TABLE 6 HERE
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To estimate the contemporaneous relation between main board and second board markets in Korea, we add MRD_t and MRD^2_t terms to equation (9) and estimate the following EGARCH model:

$$\begin{cases} RD_t = \gamma_0 + \gamma_1 RD_{t-1} + \gamma_2 RN_t + \gamma_3 MRN_t + \gamma_4 NasdaqD_{t-1} + \gamma_5 NasdaqN_{t-1} + \gamma_6 MRD_t + \varepsilon_t \\ \ln h_t = \alpha_0 + \alpha_1 \left(\dfrac{|\varepsilon_{t-1}| + \lambda \varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right) + \beta \ln h_{t-1} + \varphi_1 RD_{t-1}^2 + \varphi_2 RN_t^2 + \varphi_3 MRN_t^2 + \varphi_4 NasdaqD_{t-1}^2 + \varphi_5 NasdaqN_{t-1}^2 + \varphi_6 MRD_t^2 \end{cases} \quad (10)$$

Panel B of Table 6 shows that after including KOSPI's daytime returns into the model, the spillover effect from KOSPI's overnight returns disappears (i.e., $\gamma_3 = 0.0687$ and is insignificant). It is not surprising to

[15] Note that we do not include the MA term in Model (9) because model specification tests show that the MA term is not significant for this intra-day analysis. Due to the availability of the data, the sample period of this intra-day analysis starts from May 18, 1998, and ends on June 30, 2001, which does not include the Asian crisis period.

find that the spillover from the contemporaneous KOSPI's daytime returns dominate the lagged spillovers from NASDAQ's overnight returns. However, NASDAQ overnight returns still exert spillover effects on KOSDAQ daytime returns (i.e., γ_5 = 0.1514 and is significant). This suggests that KOSPI's daytime returns have not fully incorporated all the information emanated from the NASDAQ overnight returns.

Panels C and D of Table 6 document the results using five-variable and six-variable Granger-causality tests using Korea's intra-day return data. Panel C shows that, in addition to KOSPI overnight returns, NASDAQ daytime and overnight returns Granger-cause KOSDAQ daytime returns, when we do not include contemporaneous KOSPI daytime returns. In particular, NASDAQ overnight returns are more significant than KOSPI overnight returns. Once we include contemporaneous KOSPI daytime returns in the regression, only overnight NASDAQ returns, besides the KOSPI daytime returns, remain Granger-causally prior to KOSDAQ daytime returns.

Panels E and F of Table 6 present the results using five-variable and six-variable Granger-causality tests using Korea's intra-day return volatility data. Panel E shows that among other things, NASDAQ daytime return volatilities Granger-cause KOSDAQ daytime return volatilities when we do not include contemporaneous KOSPI daytime return volatilities. However, NASDAQ overnight return volatilities do not Granger-cause KOSDAQ daytime return volatilities, which indicates that NASDAQ overnight volatilities do not contain much information compared to NASDAQ daytime volatilities. Once we include contemporaneous KOSPI daytime volatilities in the regression, we make a similar observation. That is, NASDAQ daytime return volatilities remain Granger-causally prior to KOSDAQ daytime return volatilities.

These findings are consistent with the findings using the above EGARCH model. Again our findings using the intra-day returns confirm what we find using close-to-close return data in Section IV: The timing of the trading matters in the information spillovers, and the NASDAQ returns remain a significant source of spillovers to Asian second board market returns.

B. Analysis using Canadian data

In an attempt to reduce the effect of non-synchronous trading between the NASDAQ and the sample Asian second board markets, we have used the intra-day returns for Korea's main and second board markets. As an additional means of checking the robustness of our findings from the perspective of trading timing, we employ Canadian main and second board market returns in this section. This is because both the main and second board markets in the U.S. and Canada open and close at the same time so that the results should not be affected by the non-synchronous trading between the two markets.

The Toronto Stock Exchange (TSE) was established on October 25, 1861. In 1977, TSE launched the world's first Computer Assisted Trading System (CATS). That same year the TSE 300 Composite

Index was launched. In April 1997 the TSE became the largest stock exchange in North America to choose a floorless, electronic environment. On April 3, 2000, TSE became TSE Inc., a pro-profit company. Now TSE is Canada's premier market for senior equities, accounting for about 95% of all equities trading in Canada. TSE ranks 7th in the World for domestic market capitalization (June 2001), and is the fourth most active stock exchange in North America after NYSE, NASDAQ and Chicago (September 2001). The average daily trading volume in October 2001 is 147.3 million shares, and the average daily trading value is 2.9 billion Canadian dollars. Currently, the TSE has the following major indices: TSE 300 Composite Index, TSE 300 Capped Composite Index, TSE 200 Index, and TSE 100 Index. The TSE 300 Composite Index, introduced in 1977, is a market-value weighted broad market index that represents 300 of the largest traded companies.

The Canadian Venture Exchange (CDNX) is Canada's public venture capital marketplace, providing emerging companies with access to capital. The CDNX was established in November 1999 by the merger of two former Canadian venture capital markets, the Vancouver Stock Exchange and the Alberta Stock Exchange. The CDNX is a wholly-owned subsidiary of TSE Inc. The CDNX has offices in Calgary, Vancouver, Winnipeg and Toronto. The CDNX has four indices: a main index (CDNX) and three sector indexes (mining, oil & gas, and technology). It is equally weighted and represents 80% of the total market capitalization of all index-eligible securities. A new index, the S&P/CDNX Composite Index, is being developed as a broad market indicator for the Canadian venture capital market and will replace the existing CDNX index on December 10, 2001. The new index will be a market value-weighted index and will include 500 companies. In this paper, we use the VSE index for the sample period between January 1, 1986, and November 28, 1999, and the CDNX index for the sample period between November 29, 1999, and October 31, 2001.

We estimate the following three EGARCH models for Canadian returns:

$$\begin{cases} R_t = \gamma_0 + \gamma_1 R_{t-1} + \sum_{l=1}^{2} \gamma_{2,l}\hat{u}_{t-l} + \sum_{l=1}^{2} \gamma_{3,l}\hat{u}_{Nasdaq,t-l} + \theta\varepsilon_{t-1} + \varepsilon_t \\ \ln h_t = \alpha_0 + \alpha_1 \left(\frac{|\varepsilon_{t-1}| + \lambda\varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right) + \beta \ln h_{t-1} + \sum_{l=1}^{2} \psi_{1,l}\hat{u}^2_{i,t-l} + \sum_{l=1}^{2} \psi_{2,l}\hat{u}^2_{Nasdaq,t-l} \end{cases} \tag{11.1}$$

$$\begin{cases} R_t = \gamma_0 + \gamma_1 R_{t-1} + \sum_{l=0}^{1} \gamma_{2,l}\hat{u}_{t-l} + \sum_{l=0}^{1} \gamma_{3,l}\hat{u}_{Nasdaq,t-l} + \theta\varepsilon_{t-1} + \varepsilon_t \\ \ln h_t = \alpha_0 + \alpha_1 \left(\frac{|\varepsilon_{t-1}| + \lambda\varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right) + \beta \ln h_{t-1} + \sum_{l=0}^{1} \psi_{1,l}\hat{u}^2_{i,t-l} + \sum_{l=0}^{1} \psi_{2,l}\hat{u}^2_{Nasdaq,t-l} \end{cases} \tag{11.2}$$

$$\begin{cases} R_t = \gamma_0 + \gamma_1 R_{t-1} + \sum_{l=0}^{1} \gamma_{2,l} \hat{u}_{t-l} + \sum_{l=1}^{2} \gamma_{3,l} \hat{u}_{Nasdaq,t-l} + \theta\varepsilon_{t\text{-}1} + \varepsilon_t \\ \ln h_t = \alpha_0 + \alpha_1 \left(\frac{|\varepsilon_{t-1}| + \lambda\varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right) + \beta \ln h_{t-1} + \sum_{l=0}^{1} \psi_{1,l} \hat{u}_{i,t-l}^2 + \sum_{l=1}^{2} \psi_{2,l} \hat{u}_{Nasdaq,t-l}^2 \end{cases} \quad (11.3)$$

In equation (11.1), both one- and two-period lagged main board and NASDAQ returns and volatilities are included; in equation (11.2), both contemporary and one-lagged main board and NASDAQ returns and volatilities are included; in equation (11.3), contemporary and one-lagged main board returns and volatilities are included, whereas contemporary NASDAQ return and volatility are not included.

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TABLE 7 HERE
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Estimates of the models (11.1) – (11.3) are presented in Panel A of Table 7. Throughout the three models, it is evident that in addition to main board market returns and volatilities, NASDAQ returns and volatilities also have significant spillover effects on Canadian second board market (CDNX) returns. In particular, in model (11.3), even in the presence of contemporaneous main board returns and volatilities, NASDAQ returns and volatilities continue to have spillover effects on the Canadian second board market (CDNX) returns and volatilities.

Panels B- D of Table 7 contain causality test results for Canadian returns. In the presence of contemporaneous TSE returns, Panel B shows that NASDAQ returns still remain Granger-causally prior to Canadian second board (CDNX) returns. Panel C shows that in the absence of contemporaneous Canadian main board (TSE) market returns, NASDAQ returns more strongly Granger-cause Canadian second board (CDNX) returns than Canadian main board (TSE) returns. In Panel D of Table 7, we include both contemporaneous Canadian main board (TSE) returns and contemporaneous NASDAQ returns in the regression. NASDAQ returns still remain Granger-causally prior to Canadian second board (CDNX) returns.[16]

VI. Concluding Remarks

Given the increasing importance of second board markets and the paucity of rigorous studies on the relations between second board markets, we have examined whether there is any evidence of information spillovers from NASDAQ, the largest OTC market in the world, to emerging Asian second board markets and whether the cross-country spillovers are strong relative to domestic spillovers from the corresponding main board markets. For this purpose, we employ EGARCH models, dynamic causality

[16] When we implement causality tests using Canadian return volatilities, Canadian second board return volatilities appear to be Granger-causally prior. I.e., Neither TSE nor NASDAQ volatilities Granger-cause CDNX volatilities. As such, to save space,

tests, and VAR-based forecast error decomposition methods.

We use daily close-to-close return data for a recent sample period that includes the Asian financial crisis of 1997 and ends on April 20, 2001. Given the difference in trading hours between the NASDAQ and Asian main board markets, we are not allowed to fully resolve the timing issue. However, we have attempted to alleviate this concern as much as possible by employing some available intra-day return data and Canadian return data that do not suffer from non-synchronous trades. Our findings are quite robust: There is substantial information spillover from the NASDAQ to Asian second board markets as well as from the local main board markets. These results indicate the existence of substantial cross-country industry effect (or meteor shower effect) as well as domestic market effect (or heat wave effect) and imply that both country diversification and industry diversification are important.

More specifically, our findings can be summarized as follows. First, there is strong evidence of lagged returns and volatility spillovers from the NASDAQ to the Asian second board markets when we exclude contemporaneous main board market returns. Second, there is strong evidence of contemporaneous and lagged returns and volatility spillovers from the local main board market to the corresponding second board markets. However, even in the presence of contemporaneous main board market returns, the lagged NASDAQ returns and volatilities still exert substantial spillovers to Asian second board market returns and volatilities. These findings are not sensitive to whether U.S. dollar-based data or local currency-based data are used in our estimation. Third, when we employ the intra-day returns and volatility analyses between the NASDAQ and the KOSDAQ to check the robustness of our findings, we confirm the above findings in that even in the presence of contemporaneous main board market returns, the lagged overnight NASDAQ returns and volatilities still exert substantial spillovers to Asian second board market returns and volatilities. Fourth, when we employ Canadian returns data to further control for the different timing of trades, we again confirm the above findings.

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we do not report the results, which are available from the authors upon request.

References

Arshanapalli, A., and J. Doukas. "International stock market linkage: evidence from the pre and post-October 1987 period." *Journal of Banking and Finance* 17, (1993), 193-208.

Arshanapalli, A., Doukas, J., and L.H.P. Lang. "Pre- and post-October 1987 stock market linkages between U.S. and Asian markets." *Pacific-Basin Finance Journal* 3, (1995), 57-73.

Chan, K., and W. Fong. "Trade Size, Order Imbalance, and the Volatility-Volume Relation." *Journal of Financial Economics* 57, (2000), 247-273.

Chan, K.C., W.G. Christie, and P.H. Schultz. "Market Structure and the Intraday Pattern of Bid-ask Spreads for Nasdaq Securities." *Journal of Business* 68, (1995), 35-60.

Christie, W.G., and P.H. Schultz. "Why did Nasdaq Market Makers Avoid Odd-eighth Quotes." *Journal of Finance* 49, (1994), 1813-1840.

Engle, R.F., T. Ito, and W. Lin. "Meteor Showers or Heatwaves? Heteroskedastic Intra-Day Volatility in the Foreign Exchange Market." *Econometrica* 58, (1990), 525-542.

Engle, R. F., and V. K. Ng. "Measuring and Testing the Impact of News on Volatility." *Journal of Finance* 48, (1993), 1749-1778.

Engle, R. F., and P. Susmel. "Common Volatility in International Equity Markets." *Journal of Business and Economic Statistics* 11, (1993), 167-176.

Grinold, R., A. Rudd, and D. Stefek. "Global Factors: Fact or Fiction?" *Journal of Portfolio Management* Fall, (1989), 79-88.

Hamao, Y., R.W. Masulis, and V. Ng. "Correlations in Price Changes and Volatility across International Stock Markets." *Review of Financial Studies* 3, (1990), 281-307.

Heston, S.L., and L.G. Rousenhorst. "Does Industrial Structure Explain the Benefits of International Diversification?" *Journal of Financial Economics* 36, (1994), 3-27.

Kandel, E., and L.M. Marx. "Nasdaq Market Structure and Spread Patterns." *Journal of Financial Economics* 45, (1997), 61-89.

Kim, D., and S.J. Kon. "Alternative Models for the Conditional Heteroskedasticity of Stock Returns." *Journal of Business* 67, (1994), 563-598.

Koutmos, G., and G. G. Booth. "Asymmetric Volatility Transmission in International Stock Markets." *Journal of International Money and Finance* 14, (1995), 747-762.

Lau, S. T., and J. D. Diltz. "Stock Returns and The Transfer of Information Between The New York And Tokyo Stock Exchanges." *Journal of International Money and Finance* 13, (1994), 211-222.

Lee, B. S. , "Causal relations among stock returns, interest rate, real activity, and inflation," *Journal of Finance* 47, (1992), 1591-1604.

Lessard, D.R. “World, country and industry relationships in equity returns.” *Journal of Finance* 29 (1976), 379-391.

Lin, W., R.F. Engle, and T. Ito. “Do Bulls and Bears Move across Borders? International Transmission of Stock Returns and Volatility.” *Review of Financial Studies* 7, (1994), 507-538.

Ljung, G. M., and G.E.P. Box. “On a Measure of Lack of Fit in Time Series Models.” *Biometrika* 65, (1978), 297-303.

Masih, A.M.M., and R. Masih. "Dynamic Linkages and the Propagation Mechanism Driving Major International Stock Markets: An Analysis of the Pre- and Post-Crash Eras." *Quarterly Review of Economics and Finance* 37, (1997), 859-885.

Nelson, D.B. “Conditional Heteroskedasticity in Aasset Returns: A New Approach.” *Econometrica* 59, (1991), 347-370.

Poter, D. C., and D. G. Weaver. “Post-trade Transparency on Nasdaq’s National Market System.” *Journal of Financial Economics* 50, (1998), 231-252.

Roll, R. “Industrial Structure and the Comparative Behavior of International Stock Market Indices.” *Journal of Finance* 47, (1992), 3-42.

Schwert, G.W. “Stock Volatility in the New Millennium: How Wacky is Nasdaq?” NBER Working Paper Series #8346, (2001).

Sims, C. A., “Macroeconomics and reality,” *Econometrica* 48, (1980), 1-48.

Susmel, R., and R.F. Engle. "Hourly volatility spillovers between international equity markets" *Journal of International Money and Finance* 13, (1994), 3-25.

Wang, S., O. Rui, and M. Firth. “Return and Volatility Behavior of Dually-listed Stocks: The Case of Hong Kong.” *Journal of International Money and Finance*, forthcoming (2001).

Figure 1. Trading Hours of the NASDAQ and Asian Second Board Markets

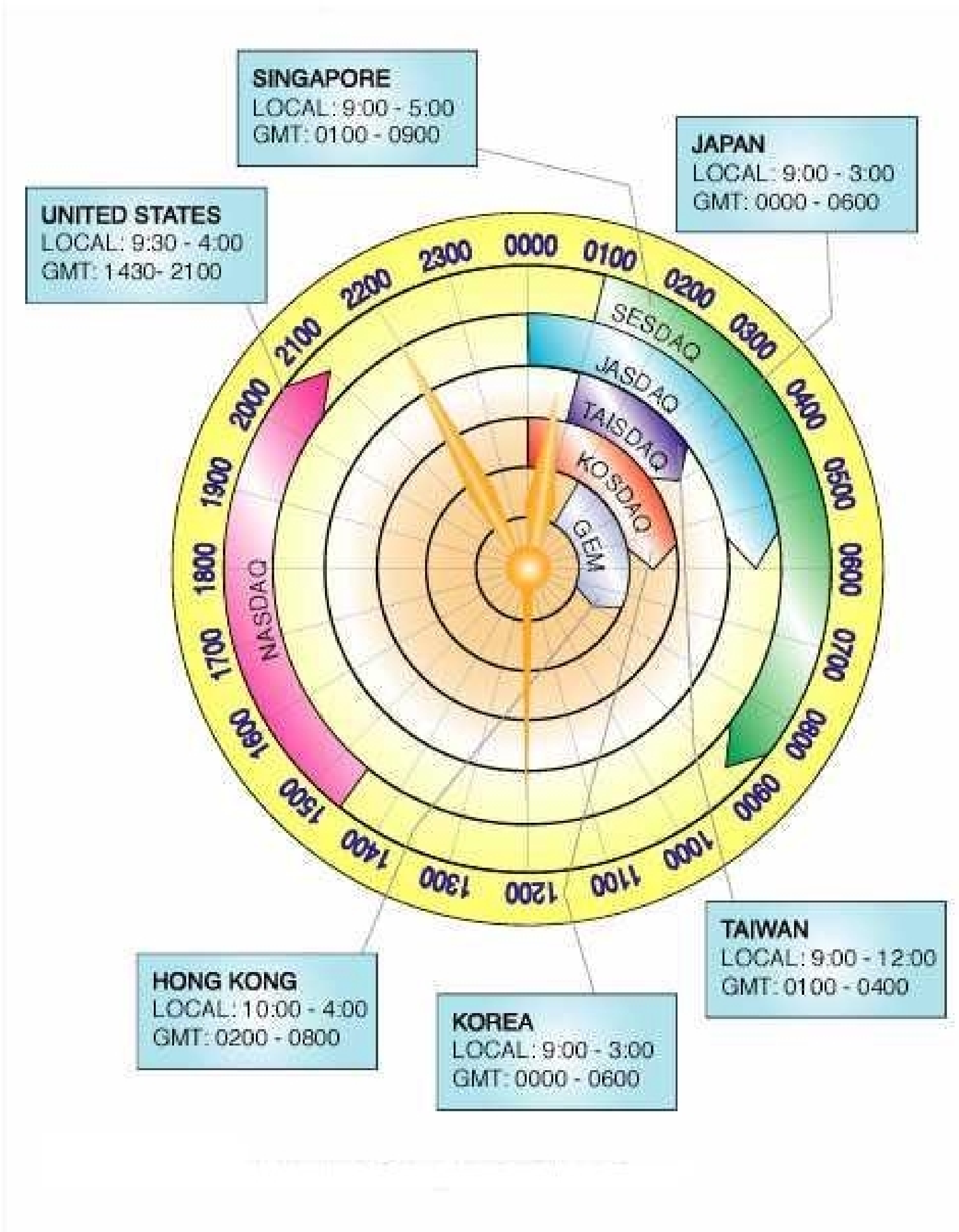

TABLE 1
Listing Requirements in NASDAQ and Asian Secondary Board Markets

Market	Market Capitalization[1]	Last year or 2 of last 3 fiscal years	Public Float (shares)[2]	Operating History
NASDAQ National Market				
-Standard 1	N/A	$1 million	1.1 million	N/A
-Standard 2	N/A	N/A	1.1 million	2 years
-Standard 3	N/A	N/A	1.1 million	2 years
NASDAQ SmallCap Market	$50 million	$750,000	1 million	1 year
SESDAQ				
	N/A	Nil[3]	15% of issued shares at least 500,000 shares in the hands of 500 shareholders	N/A[4]
JASDAQ				
	>JPY 500 million at listing	Profit for the previous fiscal year is positive	>300 shareholders, <10mil shares >400 shareholders, 10-20mil shares >500 shareholders, >20mil shares	Establishment Co. in last 10 years OR cost of incorporation is more than 3% of sales figure
TAISDAQ				
	>NT$50 million	Exceeds 4% of paid-in capital and no accumulated losses for latest fiscal year	10% of total no. of shares issued or 5 million shares	3 years
KOSDAQ				
	500 million won(1 billion Won in case of construction business)	Positive Net Income before Extra items	30% of total shares outstanding or 10% & more than 5 million shares	3 years(5 years in case of construction business)
GEM				
	-Share: ->HK$46 million -Options, warrants or similar rights -HK$6 million	N/A	-MC<HK$1 billion - 20% of shares / HK$30 million -MC>HK$1 billion -15% of shares / HK$200 million - 15% - 20% of warrants issued	2 years under substantially the same mgt. & ownership
MESDAQ				
-Technology Co.	>RM2 million	Not required	N/A	Not required
-Non-technology Co.	>RM2 million	Not required	N/A	1 year

1. For initial listing under Standard 3, or continued listing under Standard 2, a company must satisfy one of the following compliance: a) the market capitalization requirement or b) the total assets and the total revenue requirement.
2. Public float is defined as shares outstanding less any shares held by officers, director, or beneficial owners of the company.
3. Company is expected to be profitable and viable, with good growth prospects.
4. A company with no track record has to demonstrate that it requires funds to finance a project or develop a product, which must have been fully researched.

TABLE 2
Basic Statistics of the Sample Asian Main Board and Second Board Markets

Market	Hong Kong		Japan		South Korea		Singapore		Taiwan	
Index	Hang Seng	GEM	Nikkei225	JASDAQ	KOSPI	KOSDAQ	Strait Times	SESDAQ	Taiwan CI	TAISDAQ
Establish Date	Apr., 1986	Nov., 1999	May, 1878	1991	Mar., 1956	July, 1996	May, 1973	Feb.,1987	Oct., 1961	Nov., 1994
Number of Firms	736	49	2406	889	704	591	321	90	437	284
Market Capitalization	$343.5bn	$9,156.mil	$2,495.6bn	$114,674mil	$114.6bn	$40,351mil	$94.5bn	$2,761mil	$288.2bn	$40,351.83
Sample Period	(03/21/2000 - 04/20/2001)		(01/11/1995 - 04/20/2001)		(07/01/1996 - 04/20/2001)		(12/15/1987- 4/20/2001)		(11/01/1995 - 04/20/2001)	
Number of Obs.	255	255	1478	1478	1146	1146	3088	3088	1291	1291
Mean Return	-0.1101	-0.5077	-0.0237	-0.0050	-0.0353	-0.0269	0.0312	0.0162	0.0119	0.0304
Standard Deviation	0.0185	0.0287	0.0151	0.0164	0.0272	0.0252	0.0142	0.0200	0.0179	0.0230
Skewness	-0.2270	-0.5899*	0.1170	-0.3490*	0.0002	-0.3124*	0.1626*	0.4359*	-0.0507	-0.0814
Kurtosis	1.692*	7.687*	2.366*	7.410*	1.767*	3.134*	10.112*	7.826*	2.666*	9.822*
LB(4)	3.25	2.83	7.86	245.52*	16.19*	62.95*	70.49*	64.15*	6.56	5.15
LB(8)	11.66	13.97	16.54*	264.17*	27.92*	78.18*	75.62*	89.95*	14.42	12.59
$LB^2(4)$	0.93	36.48*	84.08*	617.54*	100.21*	383.63*	350.44*	313.54*	110.53*	218.59*
$LB^2(8)$	5.69	67.68*	137.12*	845.44*	156.67*	595.03*	456.63*	409.00*	152.58*	220.30*
ρ_1	0.0190	0.0888	-0.0268	0.4014*	0.0940*	0.1811*	0.1473*	0.0958*	0.0118	0.0311
$\rho_{SP500,i}$	0.1116	0.0511	0.1046	0.1027	0.1115	0.0300	0.1735	0.0727	0.0619	0.0615
$\rho_{Nasdaq,i}$	0.1404	0.1428	0.1011	0.1099	0.1339	0.0954	0.1863	0.1186	0.0938	0.0798
$\rho_{MB,SB}$	0.5441		0.4217		0.5133		0.5807		0.7534	

Note: Market capitalization is in million U.S. dollars. Data for the market capitalization and number of firms are the figures at October 31, 2000. * indicates significance at the 5% level. LB(k) and $LB^2(k)$ denote the Ljung-Box test of significance of autocorrelations of k lags for returns and squared returns respectively. ρ_1 is the first order auto-correlation coefficient. $\rho_{Nasdaq,i}$ is the correlation between NASDAQ index return and the *i*th Asian second board market index return. $\rho_{SP500,i}$ is the correlation between SP500 return and the *i*th Asian main board market index return. $\rho_{MB,SB}$ is the correlation between *i*th market's main board and second board index returns.

TABLE 3

Panel A: Estimates of the First Stage Model for the NASDAQ and the Asian Main Board Markets

$$\begin{cases} Nasdaq_t = c_0 + c_1 Nasdaq_{t-1} + c_2 AD_t + \eta u_{Nasdaq,t\text{-}1} + u_{Nasdaq,t} \\ \ln v_{Nasdaq,t} = a_0 + a_1\left(\dfrac{|u_{Nasdaq,t-1}| + \lambda u_{Nasdaq,t-1}}{\sqrt{v_{Nasdaq,t-1}}}\right) + b \ln v_{Nasdaq,t-1} + \phi AD_t \end{cases} \quad (1)$$

$$\begin{cases} MR_{it} = c_{i,0} + c_{i,1} MR_{it-1} + c_{i,2} AD_t + \eta_i u_{i,t\text{-}1} + u_{i,t} \\ \ln v_{it} = a_{i,0} + a_{i,1}\left(\dfrac{|u_{it-1}| + \lambda u_{it-1}}{\sqrt{v_{it-1}}}\right) + b_i \ln v_{it-1} + \phi_i AD_t \end{cases}$$

	NASDAQ Index	Hong Kong Hang Seng	Japan Nikkei 225	South Korea KOSPI	Singapore Strait Times	Taiwan Composite
c_0	0.0005*	-0.0011	-0.0004	-0.0009	0.0002	0.0000
c_1	-0.0019	0.1231	-0.6908	-0.0501	0.0795	0.5233†
c_2	-0.0252*	0.0434	-0.0308	-0.0374	-0.0334	-0.0105
η	-0.1495		-0.6874	-0.1492	-0.1070	0.4735
a_0	-0.1457*	0.00015	-0.1767*	-0.0530	-0.4700*	-0.7682*
a_1	0.1832*	0.0000	0.0932*	0.1475*	0.2571*	0.2241*
b	0.9831*	0.4545	0.9790*	0.9922*	0.9450*	0.9051*
λ	0.2999*	0.2103	0.7819*	0.2011*	0.2171*	0.5140*
ϕ	0.5872*		0.4324*	0.3089*	0.5213†	0.1968
LL	9614.37	653.51	4143.73	2623.12	9266.38	3454.58
LB(4)	0.65	3.42	1.01	1.06	4.45	2.98
LB(8)	1.45	11.56	7.02	8.03	5.58	9.45
$LB^2(4)$	2.29	1.25	3.58	3.47	0.70	5.22
$LB^2(8)$	3.11	4.02	7.45	4.22	1.40	6.46
Joint	3.59*	1.01	0.27	0.31	0.16	0.66

Panel B: Estimates of the Second Stage Model for the Asian Second Board Markets

$$\begin{cases} R_{it} = \gamma_{i,0} + \gamma_{i,1} R_{it-1} + \sum_{l=0}^{1} \gamma_{i,2,l} \hat{u}_{i,t-l} + \sum_{l=1}^{2} \gamma_{i,3,l} \hat{u}_{Nasdaq,t-l} + \gamma_{i,4} AD_t + \theta_i \varepsilon_{i,t-1} + \varepsilon_{i,t} \\ \ln h_{it} = \alpha_{i,0} + \alpha_{i,1} \left(\frac{|\varepsilon_{it-1}| + \lambda \varepsilon_{it-1}}{\sqrt{h_{t-1}}} \right) + \beta_i \ln h_{it-1} + \sum_{l=0}^{1} \psi_{i,1,l} \hat{u}_{i,t-l}^2 + \sum_{l=1}^{2} \psi_{i,2,l} \hat{u}_{Nasdaq,t-l}^2 + \psi_{i,3} AD_t \end{cases} \quad (3)$$

	GEM		JASDAQ		KOSDAQ		SESDAQ		TAISDAQ	
	Local Currency	US Dollar	Local Currency	US Dollar	Local Currency	US Dollar	Local Currency	US Dollar	Local Currency	US Dollar
γ_0	0.0000	-0.0068*	-0.0001	-0.0004**	-0.0002	-0.0002	-0.0003*	-0.0003*	0.0002	0.0000
γ_1	0.9940*	-0.8640**	0.4549*	0.2857*	0.3170*	0.4320*	0.5200*	0.5685*	0.3301*	0.4064
$\gamma_{2,0}$	0.0076*	0.0091*	0.0036*	0.0083*	0.0041*	0.0052*	0.0075*	0.0080*	0.0163*	0.0152*
$\gamma_{2,1}$	-0.0075*	0.0081*	0.0012*	0.0000	0.0007	-0.0003	-0.0017*	-0.0024*	-0.0037	-0.0054
$\gamma_{3,1}$	0.0022*	0.0014	0.0012*	0.0011*	0.0003	0.0002	-0.0001	-0.0002	0.0006**	0.0010*
$\gamma_{3,2}$	-0.0025*	0.0011	-0.0010*	-0.0005	0.0004	0.0006	-0.0005*	-0.0003	-0.0010*	-0.0004
γ_4			-0.0081	-0.0105	-0.0060	-0.0126	-0.0113	-0.0089	0.0083	-0.0107
θ	1.0060*	-0.8710**	0.1314*	0.1001	0.1994**	0.3291*	0.4394*	0.4983*	0.2649**	0.3423
α_0	-0.2990*	-0.3310*	-0.1650*	-0.1801*	-0.1080*	-0.1801*	-0.9562*	-0.9076*	-0.0688*	-1.2198*
α_1	0.0091	0.0006	0.2571*	0.1350*	0.2107*	0.2442*	0.4022*	0.3980*	0.0649*	0.4241*
β	0.9660*	0.9610*	0.9835*	0.9851*	0.9927*	0.9882*	0.8868*	0.8925*	0.9907*	0.8597*
λ	0.3770	0.0660	0.0098	-0.0612	0.0221	0.0792	-0.1484*	-0.1243*	-0.7324*	0.1256*
$\psi_{1,0}$	0.1350*	0.1810*	0.0818*	0.1167*	0.1622*	0.2432*	0.0805*	0.0979*	0.1397*	0.1088*
$\psi_{1,1}$	-0.0996*	-0.1490**	-0.0384*	-0.0815*	-0.1270*	-0.1792*	-0.0427*	-0.0600*	-0.1181*	0.0013
$\psi_{2,1}$	0.0146	-0.0558	-0.0005	-0.0169	0.0289	0.0329	0.0306*	0.0333*	-0.0076	-0.0514*
$\psi_{2,2}$	-0.0547	0.0159	-0.0218	0.0323	-0.0131	-0.0094	-0.0348*	-0.0354*	-0.0255	-0.0063
ψ_4			0.6773*	0.3781*	0.2842	0.4433**	0.6689**	0.6454	0.9929*	0.0765
LL	672	674	4768	4451	3159	2977	8679	8642	3701	3679
LB(4)	3.37	4.42	6.75	5.65	6.09	4.47	1.90	2.10	3.16	2.08
LB(8)	7.45	7.85	10.59	6.34	11.34	10.88	8.86	10.28	9.08	8.83
$LB^2(4)$	5.40	5.63	7.61	6.65	3.82	4.84	4.40	4.95	3.87	0.87
$LB^2(8)$	8.84	9.94	12.00	8.89	6.72	9.74	6.14	6.89	4.14	1.82
Joint	1.39	0.81	1.62	1.94	0.09	0.29	1.62	0.92	1.92	0.19

Panel C: Estimates of the Second Stage Model for the Asian Second Board Markets

$$\begin{cases} R_{it} = \gamma_{i,0} + \gamma_{i,1} R_{it-1} + \sum_{l=1}^{2} \gamma_{i,2,l} \hat{u}_{i,t-l} + \sum_{l=1}^{2} \gamma_{i,3,l} \hat{u}_{Nasdaq,t-l} + \gamma_{i,4} AD_t + \theta_i \varepsilon_{i,t-1} + \varepsilon_{i,t} \\ \ln h_{it} = \alpha_{i,0} + \alpha_{i,1} \left(\frac{|\varepsilon_{it-1}| + \lambda \varepsilon_{it-1}}{\sqrt{h_{t-1}}} \right) + \beta_i \ln h_{it-1} + \sum_{l=1}^{2} \psi_{i,1,l} \hat{u}^2_{i,t-l} + \sum_{l=1}^{2} \psi_{i,2,l} \hat{u}^2_{Nasdaq,t-l} + \psi_{i,3} AD_t \end{cases} \quad (4)$$

	GEM		JASDAQ		KOSDAQ		SESDAQ		TAISDAQ	
	Local Currency	US Dollar	Local Currency	US Dollar	Local Currency	US Dollar	Local Currency	US Dollar	Local Currency	US Dollar
γ_0	-0.0016	-0.0015	-0.0005*	-0.0006	-0.0001	-0.0003	-0.0003*	-0.0002	-0.0002	-0.0003
γ_1	0.5730*	0.5910*	0.3996*	0.1416	0.6449*	-0.9695*	0.5435*	0.5300*	0.6970*	0.7082*
$\gamma_{2,1}$	-0.0008	-0.0005	0.0012*	0.0005	0.0017*	0.0026*	0.0014*	0.0011*	0.0010	0.0014*
$\gamma_{2,2}$	0.0014	0.0014	-0.0001	0.0007	-0.0011*	0.0023*	0.0001	0.0005	0.0001	-0.0001
$\gamma_{3,1}$	0.0056*	0.0054*	0.0020*	0.0028*	0.0006**	0.0008*	0.0021*	0.0023*	0.0029*	0.0029*
$\gamma_{3,2}$	-0.0018	-0.0020	-0.0008*	-0.0005	-0.0002	0.0009*	-0.0011*	-0.0011*	-0.0014**	-0.0015**
γ_4			-0.0075	-0.0104	-0.0034	-0.0030	-0.0087	-0.0080	-0.0012	-0.0041
θ	0.6560*	0.6900*	0.0597	-0.0651	0.5253*	-0.9639*	0.4809*	0.4746*	0.7341*	0.7382*
α_0	-0.4480*	-0.4690*	-0.1217*	-0.1598*	-0.1383*	-0.1818*	-0.7992*	-0.5860*	-1.1533*	-1.0517*
α_1	0.0009	0.0009	0.2498*	0.1045*	0.2444*	0.3596*	0.3901*	0.3168*	0.4701*	0.4255*
β	0.9510*	0.9460*	0.9850*	0.9855*	0.9871	0.9797*	0.8994*	0.9251*	0.8436*	0.8594*
λ	0.4740	0.3660	0.0503	0.0137	0.0714	0.1276*	-0.0802*	-0.0546*	0.0975*	0.0784
$\psi_{1,1}$	0.0138	-0.0097	0.0331	0.0062	0.0305	0.0469	0.0190*	0.0221*	-0.0459*	-0.0367*
$\psi_{1,2}$	0.0134	0.0231	-0.0210	0.0108	-0.0289	-0.0601*	-0.0140*	-0.0145*	0.0451*	0.0559*
$\psi_{2,1}$	0.0771	0.0714	0.0338**	0.0539*	0.0408	0.0409	0.0560*	0.0516*	-0.0299	-0.0325**
$\psi_{2,2}$	-0.0664	-0.0565	-0.0493*	-0.0292	-0.0005	0.0109	-0.0483	-0.0528*	0.0053	0.0094
ψ_4			0.6423*	0.4130*	-0.0128	0.1465	0.5371	0.5093*	0.1419	0.0895
LL	635	636	4605	4115	3044	2801	8278	8182	3160	3131
LB(4)	4.52	5.17	8.03	1.35	1.36	2.79	9.60	1.60	7.38	6.71
LB(8)	9.71	9.79	16.60	5.02	6.28	3.11	19.34	3.11	12.04	13.48
$LB^2(4)$	2.84	4.63	16.22	9.49	1.35	3.91	1.81	2.37	0.78	1.32
$LB^2(8)$	7.63	9.49	22.11	11.59	8.09	9.35	2.90	3.94	1.16	2.48
Joint	0.23	0.37	1.93	0.77	0.39	0.30	2.04	1.48	0.75	1.48

Note: R_{it}, is the Second Board close-to-close returns of the *i*th stock market index. $\hat{u}_{MR,it-l}$ and $\hat{u}_{Nasdaq,t-l}$ are estimates of the *i*th main board market and the NASDAQ close-to-close return residuals respectively. The sample period for the GEM starts after the Asian financial crisis so that the dummy variable for the Asian crisis is not included in the estimation model for the GEM. *AD* is a dummy variable for the Asian financial crisis. For all estimates, * and **indicate significance at the 5% and the 10% level respectively. LB(*k*) and $LB^2(k)$ denote the Ljung-Box test of significance of autocorrelations of *k* lags for return residuals and squared-return residuals respectively. Autocorrelations are computed for standard residuals. *Joint* is the Engle and Ng (1993) joint sign bias test statistic.

Table 4. Three-variable Granger-causality Tests

Panel A: Using Returns

$$R_{it} = \alpha + \sum_{j=0}^{4} \beta_j MR_{it-j} + \sum_{j=1}^{5} \chi_j Nasdaq_{t-j} + \sum_{j=1}^{5} \delta_j R_{it-j} \qquad (5)$$

	Local Currency		US Dollar	
	$\beta_j = 0$	$\chi_j = 0$	$\beta_j = 0$	$\chi_j = 0$
	F-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)
GEM	HANG SENG* 14.448 (0.000)	NASDAQ 0.568 (0.725)	HANG SENG* 14.449 (0.000)	NASDAQ 0.569 (0.724)
JASDAQ	NIKKEI 225* 53.283 (0.000)	NASDAQ* 25.106 (0.000)	NIKKEI 225* 129.655 (0.000)	NASDAQ* 15.256 (0.000)
KOSDAQ	KOSIP* 67.815 (0.000)	NASDAQ* 8.577 (0.000)	KOSIP* 186.994 (0.000)	NASDAQ* 5.593 (0.000)
SESDAQ	STRAIT TIMES* 288.840 (0.000)	NASDAQ 1.213 (0.300)	STRAIT TIMES* 342.803 (0.000)	NASDAQ 1.193 (0.310)
TAISDAQ	TAIWAN CI* 325.445 (0.000)	NASDAQ 0.846 (0.517)	TAIWAN CI* 362.508 (0.000)	NASDAQ 0.857 (0.509)

Panel B: Using Returns

$$R_{it} = \alpha + \sum_{j=1}^{5} \beta_j MR_{it-j} + \sum_{j=1}^{5} \chi_j Nasdaq_{t-j} + \sum_{j=1}^{5} \delta_j R_{it-j} \qquad (6)$$

	Local Currency		US Dollar	
	$\beta_j = 0$	$\chi_j = 0$	$\beta_j = 0$	$\chi_j = 0$
	F-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)
GEM	HANG SENG 0.895 (0.485)	NASDAQ* 5.758 (0.000)	HANG SENG 0.891 (0.478)	NASDAQ* 5.754 (0.000)
JASDAQ	NIKKEI 225* 2.722 (0.019)	NASDAQ* 46.208 (0.000)	NIKKEI 225* 5.985 (0.000)	NASDAQ* 33.083 (0.000)
KOSDAQ	KOSIP† 2.001 (0.076)	NASDAQ* 20.805 (0.000)	KOSIP† 3.323 (0.006)	NASDAQ* 16.203 (0.000)
SESDAQ	STRAIT TIMES* 2.709 (0.019)	NASDAQ* 17.410 (0.000)	STRAIT TIMES* 3.474 (0.004)	NASDAQ* 14.956 (0.000)
TAISDAQ	TAIWAN CI* 2.829 (0.015)	NASDAQ* 8.167 (0.000)	TAIWAN CI* 3.0671 (0.009)	NASDAQ* 8.186 (0.000)

Note: R_{it}, and MR_{it}, are the Second Board and the Main Board close-to-close returns of the *i*th stock market index, respectively. $Nasdaq_t$ is the NASDAQ close-to-close return. * and † indicate significance at the 5% and the 10% level respectively. *p*-values are in parentheses.

Panel C: Using Volatilities

$$R_{it} = \alpha + \sum_{j=0}^{4} \beta_j MR_{it-j} + \sum_{j=1}^{5} \chi_j Nasdaq_{t-j} + \sum_{j=1}^{5} \delta_j R_{it-j} \qquad (5)$$

	Local Currency		US Dollar	
	$\beta_j = 0$	$\chi_j = 0$	$\beta_j = 0$	$\chi_j = 0$
	F-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)
GEM	HANG SENG*	NASDAQ	HANG SENG*	NASDAQ
	10.600 (0.000)	0.185 (0.968)	10.567 (0.000)	0.186 (0.968)
JASDAQ	NIKKEI 225*	NASDAQ*	NIKKEI 225*	NASDAQ*
	23.786 (0.000)	18.511 (0.000)	49.883 (0.000)	19.751 (0.000)
KOSDAQ	KOSIP*	NASDAQ*	KOSIP*	NASDAQ*
	16.674 (0.000)	9.318 (0.000)	294.400 (0.000)	4.107 (0.001)
SESDAQ	STRAIT TIMES*	NASDAQ	STRAIT TIMES*	NASDAQ
	139.134 (0.000)	0.863 (0.505)	170.397 (0.000)	0.866 (0.503)
TAISDAQ	TAIWAN CI*	NASDAQ	TAIWAN CI*	NASDAQ*
	291.615 (0.000)	0.069 (0.997)	45511.001 (0.000)	11.399 (0.000)

Panel D: Using Volatilities

$$R_{it} = \alpha + \sum_{j=1}^{5} \beta_j MR_{it-j} + \sum_{j=1}^{5} \chi_j Nasdaq_{t-j} + \sum_{j=1}^{5} \delta_j R_{it-j} \qquad (6)$$

	Local Currency		US Dollar	
	$\beta_j = 0$	$\chi_j = 0$	$\beta_j = 0$	$\chi_j = 0$
	F-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)
GEM	HANG SENG	NASDAQ*	HANG SENG	NASDAQ*
	1.037 (0.396)	2.275 (0.048)	1.038 (0.396)	2.275 (0.048)
JASDAQ	NIKKEI 225*	NASDAQ*	NIKKEI 225*	NASDAQ*
	4.324 (0.001)	25.271 (0.000)	3.216 (0.007)	25.309 (0.000)
KOSDAQ	KOSIP	NASDAQ*	KOSIP*	NASDAQ*
	1.572 (0.165)	14.366 (0.000)	6.423 (0.000)	4.893 (0.000)
SESDAQ	STRAIT TIMES*	NASDAQ*	STRAIT TIMES*	NASDAQ*
	13.005 (0.000)	3.760 (0.002)	17.105 (0.000)	3.006 (0.010)
TAISDAQ	TAIWAN CI*	NASDAQ*	TAIWAN CI	NASDAQ
	3.433 (0.004)	3.434 (0.004)	0.834 (0.525)	1.189 (0.312)

Note: Variables R_{it}, MR_{it}, $Nasdaq_t$ denote the *i*th second board, main board return volatilities, and NASDAQ return volatilities, respectively. * and ** indicate significance at the 5% and the 10% level respectively. *p*-values are in parentheses.

Table 5. Decomposition of Forecast Error Variance for Second Board Market Returns

Panel A: Using Local Currency

	$R_{it} = \alpha + \sum_{j=1}^{5} \chi_j MR_{t-j} + \sum_{j=1}^{5} \delta_i Nasdaq_{t-j} + \sum_{j=1}^{5} \beta_j R_{t-j}$					$R_{it} = \alpha + \sum_{j=1}^{5} \beta_j Nasdaq_{t-j} + \sum_{j=0}^{4} \chi_j MR_{t-j} + \sum_{j=1}^{5} \delta_i R_{t-j}$				
Market	Step	Std Err	MR	NASDAQ	R	Step	Std Err	NASDAQ	MR	R
GEM	1	0.03	0.00	0.00	100.00	1	0.03	0.00	21.72	78.28
	2	0.03	0.26	9.94	89.79	2	0.03	9.71	19.62	70.66
	3	0.03	0.60	9.92	89.47	3	0.03	9.72	19.74	70.54
	4	0.03	2.33	10.82	86.86	4	0.03	10.69	20.43	68.88
	5	0.03	2.57	12.59	84.83	5	0.03	12.44	19.93	67.63
	8	0.03	2.70	13.09	84.20	8	0.03	12.98	20.22	66.81
	10	0.03	2.86	13.17	83.96	10	0.03	13.06	20.29	66.66
	15	0.03	2.87	13.22	83.91	15	0.03	13.09	20.29	66.62
	20	0.03	2.87	13.22	83.91	20	0.03	13.09	20.29	66.62
JASDAQ	1	0.01	0.00	0.00	100.00	1	0.01	0.00	14.67	85.33
	2	0.02	0.01	10.27	89.72	2	0.02	10.13	13.79	76.08
	3	0.02	0.16	10.77	89.06	3	0.02	10.64	13.68	75.68
	4	0.02	0.16	11.30	88.53	4	0.02	11.16	13.54	75.30
	5	0.02	0.55	11.26	88.19	5	0.02	11.14	13.74	75.12
	8	0.02	0.69	11.32	87.99	8	0.02	11.20	13.82	74.99
	10	0.02	0.69	11.32	87.99	10	0.02	11.20	13.82	74.98
	15	0.02	0.69	11.32	87.99	15	0.02	11.20	13.82	74.98
	20	0.02	0.69	11.32	87.99	20	0.02	11.20	13.82	74.98
KOSDAQ	1	0.02	0.00	0.00	100.00	1	0.02	0.00	22.45	77.55
	2	0.02	0.74	7.48	91.79	2	0.02	7.25	22.84	69.91
	3	0.02	0.75	7.63	91.62	3	0.02	7.40	22.79	69.81
	4	0.02	1.08	8.27	90.65	4	0.03	8.04	22.60	69.36
	5	0.03	1.06	8.46	90.48	5	0.03	8.22	22.60	69.18
	8	0.03	1.09	8.50	90.41	8	0.03	8.27	22.61	69.12
	10	0.03	1.10	8.50	90.41	10	0.03	8.27	22.63	69.10
	15	0.03	1.10	8.50	90.40	15	0.03	8.27	22.63	69.10
	20	0.03	1.10	8.50	90.40	20	0.03	8.27	22.63	69.10
SESDAQ	1	0.02	0.00	0.00	100.00	1	0.02	0.00	31.74	68.26
	2	0.02	0.23	2.52	97.24	2	0.02	2.42	31.62	65.96
	3	0.02	0.45	2.54	97.01	3	0.02	2.44	31.77	65.79
	4	0.02	0.45	2.77	96.77	4	0.02	2.67	31.70	65.63
	5	0.02	0.65	2.78	96.58	5	0.02	2.67	31.97	65.36
	8	0.02	0.68	2.81	96.51	8	0.02	2.70	31.95	65.35
	10	0.02	0.68	2.82	96.50	10	0.02	2.70	31.95	65.34
	15	0.02	0.68	2.82	96.50	15	0.02	2.70	31.95	65.34
	20	0.02	0.68	2.82	96.50	20	0.02	2.70	31.95	65.34
TAISDAQ	1	0.02	0.00	0.00	100.00	1	0.02	0.00	55.70	44.30
	2	0.02	0.77	2.76	96.48	2	0.02	2.75	54.26	43.00
	3	0.02	1.45	2.79	95.76	3	0.02	2.79	54.40	42.80
	4	0.02	2.15	3.23	94.63	4	0.02	3.27	53.96	42.77
	5	0.02	2.43	3.23	94.34	5	0.02	3.28	53.95	42.77
	8	0.02	2.45	3.24	94.32	8	0.02	3.29	53.94	42.77
	10	0.02	2.45	3.24	94.32	10	0.02	3.29	53.94	42.77
	15	0.02	2.45	3.24	94.32	15	0.02	3.29	53.94	42.77
	20	0.02	2.45	3.24	94.32	20	0.02	3.29	53.94	42.77

Panel B: Using U.S. dollars

	$R_{it} = \alpha + \sum_{j=1}^{5} \chi_j MR_{t-j} + \sum_{j=1}^{5} \delta_i Nasdaq_{t-j} + \sum_{j=1}^{5} \beta_j R_{t-j}$					$R_{it} = \alpha + \sum_{j=1}^{5} \beta_j Nasdaq_{t-j} + \sum_{j=0}^{4} \chi_j MR_{t-j} + \sum_{j=1}^{5} \delta_i R_{t-j}$				
Market	Step	Std Err	MR	NASDAQ	R	Step	Std Err	NASDAQ	MR	R
GEM	1	0.03	0.00	0.00	100.00	1	0.03	0.00	21.73	78.27
	2	0.03	0.26	9.95	89.80	2	0.03	9.72	19.63	70.66
	3	0.03	0.60	9.92	89.48	3	0.03	9.72	19.75	70.53
	4	0.03	2.33	10.82	86.85	4	0.03	10.69	20.44	68.87
	5	0.03	2.57	12.59	84.84	5	0.03	12.44	19.94	67.62
	8	0.03	2.70	13.09	84.21	8	0.03	12.97	20.22	66.80
	10	0.03	2.86	13.17	83.97	10	0.03	13.05	20.30	66.65
	15	0.03	2.87	13.21	83.92	15	0.03	13.08	20.30	66.62
	20	0.03	2.87	13.22	83.92	20	0.03	13.08	20.30	66.62
JASDAQ	1	0.02	0.00	0.00	100.00	1	0.02	0.00	29.35	70.65
	2	0.02	0.81	8.35	90.84	2	0.02	8.57	25.49	65.95
	3	0.02	0.87	8.68	90.45	3	0.02	8.91	25.37	65.72
	4	0.02	0.91	9.30	89.79	4	0.02	9.55	25.06	65.39
	5	0.02	1.77	9.21	89.03	5	0.02	9.49	25.51	65.01
	8	0.02	1.85	9.23	88.92	8	0.02	9.51	25.62	64.87
	10	0.02	1.85	9.23	88.91	10	0.02	9.51	25.62	64.87
	15	0.02	1.85	9.23	88.91	15	0.02	9.51	25.62	64.87
	20	0.02	1.85	9.23	88.91	20	0.02	9.51	25.62	64.87
KOSDAQ	1	0.03	0.00	0.00	100.00	1	0.03	0.00	44.63	55.37
	2	0.03	0.31	5.87	93.82	2	0.03	5.77	43.00	51.22
	3	0.03	0.84	5.92	93.24	3	0.03	5.85	43.03	51.12
	4	0.03	1.63	6.28	92.09	4	0.03	6.25	42.79	50.96
	5	0.03	2.75	6.55	90.70	5	0.03	6.62	42.32	51.07
	8	0.03	2.85	6.58	90.57	8	0.03	6.69	42.32	51.00
	10	0.03	2.89	6.57	90.54	10	0.03	6.69	42.33	50.98
	15	0.03	2.89	6.57	90.53	15	0.03	6.69	42.33	50.98
	20	0.03	2.89	6.57	90.53	20	0.03	6.69	42.33	50.98
SESDAQ	1	0.02	0.00	0.00	100.00	1	0.02	0.00	35.52	64.48
	2	0.02	0.29	2.15	97.57	2	0.02	2.06	35.46	62.48
	3	0.02	0.63	2.16	97.21	3	0.02	2.07	35.70	62.23
	4	0.02	0.63	2.38	96.98	4	0.02	2.29	35.62	62.09
	5	0.02	0.89	2.37	96.74	5	0.02	2.27	35.92	61.80
	8	0.02	0.93	2.41	96.66	8	0.02	2.30	35.91	61.79
	10	0.02	0.93	2.41	96.66	10	0.02	2.30	35.91	61.79
	15	0.02	0.93	2.41	96.66	15	0.02	2.30	35.91	61.79
	20	0.02	0.93	2.41	96.66	20	0.02	2.30	35.91	61.79
TAISDAQ	1	0.02	0.00	0.00	100.00	1	0.02	0.00	58.32	41.68
	2	0.02	0.87	2.81	96.32	2	0.02	2.80	56.88	40.32
	3	0.02	1.85	2.85	95.30	3	0.02	2.86	57.07	40.07
	4	0.02	2.56	3.29	94.15	4	0.02	3.33	56.62	40.05
	5	0.02	2.77	3.28	93.95	5	0.02	3.33	56.60	40.07
	8	0.02	2.80	3.28	93.92	8	0.02	3.33	56.58	40.09
	10	0.02	2.80	3.28	93.92	10	0.02	3.33	56.58	40.09
	15	0.02	2.80	3.28	93.92	15	0.02	3.33	56.58	40.09
	20	0.02	2.80	3.28	93.92	20	0.02	3.33	56.58	40.09

Note: R_{it}, and MR_{it}, are the Second Board and the Main Board close-to-close returns of the *i*th stock market index, respectively. $Nasdaq_t$ is the NASDAQ close-to-close return.

Table 6. Spillovers between the Nasdaq and the Kosdaq: Intra-day Analysis

Panel A:

$$\begin{cases} RD_t = \gamma_0 + \gamma_1 RD_{t-1} + \gamma_2 RN_t + \gamma_3 MRN_t + \gamma_4 NasdaqD_{t-1} + \gamma_5 NasdaqN_{t-1} + \varepsilon_t \\ \ln h_t = \alpha_0 + \alpha_1 \left(\frac{|\varepsilon_{t-1}| + \lambda \varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right) + \beta \ln h_{t-1} + \varphi_1 RD_{t-1}^2 + \varphi_2 RN_t^2 + \varphi_3 MRN_t^2 + \varphi_4 NasdaqD_{t-1}^2 + \varphi_5 NasdaqN_{t-1}^2 \end{cases} \quad (9)$$

γ_0	γ_1	γ_2	γ_3	γ_4	γ_5			
-0.0011**	-0.015	-0.133*	0.159*	-0.009	0.2056*			
α_0	α_1	β	λ	φ_1	φ_2	φ_3	φ_4	φ_5
0.0259	0.2706*	1.0037*	-0.0560	-0.5617	0.3305	-0.3068	0.0349	0.6141
LL	LB(4)	LB(8)	$LB^2(4)$	$LB^2(8)$	Joint			
1783	6.38	12.94	1.70	3.96	0.06			

Panel B:

$$\begin{cases} RD_t = \gamma_0 + \gamma_1 RD_{t-1} + \gamma_2 RN_t + \gamma_3 MRN_t + \gamma_4 NasdaqD_{t-1} + \gamma_5 NasdaqN_{t-1} + \gamma_6 MRD_t + \varepsilon_t \\ \ln h_t = \alpha_0 + \alpha_1 \left(\frac{|\varepsilon_{t-1}| + \lambda \varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right) + \beta \ln h_{t-1} + \varphi_1 RD_{t-1}^2 + \varphi_2 RN_t^2 + \varphi_3 MRN_t^2 + \varphi_4 NasdaqD_{t-1}^2 + \varphi_5 NasdaqN_{t-1}^2 + \varphi_6 MRD_t^2 \end{cases} \quad (10)$$

γ_0	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6			
-0.0011	0.0297	-0.0806	0.0687	-0.0658	0.1544**	0.4530*			
α_0	α_1	β	λ	φ_1	φ_2	φ_3	φ_4	φ_5	φ_6
0.1122	0.2392*	1.0117*	0.0905	-0.5819**	0.2009	-1.0411*	0.1373	0.4803	0.4578*
LL	LB(4)	LB(8)	$LB^2(4)$	$LB^2(8)$	Joint				
1855	4.27	9.93	3.60	4.02	0.18				

Note: RN_t, RD_t, MRN_t, and MRD_t are the overnight and daytime returns of the KOSDAQ index and the KOSPI index in Korea, respectively. $NasdaqD_t$ and $NasdaqN_t$ are the daytime and overnight returns of the NASDAQ. * and ** indicate significance at the 5% and the 10% level respectively. LB(k) and $LB^2(k)$ denote the Ljung-Box test of significance of autocorrelations of k lags for return residuals and squared-return residuals respectively. Autocorrelations are computed for standard residuals. *Joint* is the Engle and Ng (1993) joint sign bias test statistics.

Panel C: Five-variable Granger-causality Tests Using Intra-Day Returns

$$RD_t = \alpha + \sum_{j=1}^{5} \alpha_j RD_{t-j} + \sum_{j=0}^{4} \beta_j RN_{t-j} + \sum_{j=0}^{4} \gamma_i MRN_{t-j} + \sum_{j=1}^{5} \delta_j NasdaqD_{t-j} + \sum_{j=0}^{4} \phi_i NasdaqN_{t-j}$$

	$\alpha_j=0$	$\beta_j=0$	$\gamma_j=0$	$\delta_j=0$	$\phi_j=0$
	F-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)
KOSDAQD	KOSDAQD	KOSDAQN	KOSPIN	NasdaqD	NasdaqN

Local currency	1.704 (0.131)	1.321 (0.253)	3.081 (0.009)	3.057 (0.01)	4.344 (0.001)
US dollar	1.748 (0.121)	1.355 (0.239)	3.490 (0.004)	3.421 (0.005)	4.482 (0.000)

Panel D: Six-variable Granger-causality Tests Using Intra-Day Returns

$$RD_t = \alpha + \sum_{j=1}^{5} \alpha_j RD_{t-j} + \sum_{j=0}^{4} \beta_j RN_{t-j} + \sum_{j=0}^{4} \gamma_i MRN_{t-j} + \sum_{j=1}^{5} \delta_j NasdaqD_{t-j} + \sum_{j=0}^{4} \phi_i NasdaqN_{t-j} + \sum_{j=0}^{4} \eta_j MRD_{t-j}$$

	α_j=0	β_j=0	γ_j=0	δ_j=0	ϕ_j=0	η_j = 0
	F-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)	F-statistic (p-value)
KOSDAQD	KOSDAQD	KOSDAQN	KOSPIN	NasdaqD	NasdaqN	KOSPID
Local Currency	0.640 (0.669)	0.413 (0.840)	0.959 (0.442)	1.918 (0.089)**	2.767 (0.017)*	44.432 (0.000)*
US dollar	0.692 (0.629)	0.606 (0.695)	0.781 (0.563)	1.639 (0.147)	2.848 (0.015)*	43.759 (0.000)*

Note: In Panels C and D, variables RN_t, RD_t, MRN_t, and MRD_t are the overnight and daytime returns of the KOSDAQ index and the KOSPI index in Korea, respectively. $NasdaqD_t$ and $NasdaqN_t$ are the daytime and overnight returns of the NASDAQ. * and ** indicate significance at the 5% and the 10% level respectively.

Panel E: Five-variable Granger-causality Tests Using Intra-Day Volatilities

$$RD_t = \alpha + \sum_{j=1}^{5} \alpha_j RD_{t-j} + \sum_{j=0}^{4} \beta_j RN_{t-j} + \sum_{j=0}^{4} \gamma_i MRN_{t-j} + \sum_{j=1}^{5} \delta_j NasdaqD_{t-j} + \sum_{j=0}^{4} \phi_i NasdaqN_{t-j}$$

	α_j=0	β_j=0	γ_j=0	δ_j=0	ϕ_j=0
	F-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)
KOSDAQD	KOSDAQD	KOSDAQN	KOSPIN	NasdaqD	NasdaqN
Local currency	3.966 (0.001)*	4.497 (0.000)*	2.097 (0.064)**	2.237 (0.049)*	0.415 (0.838)
US dollar	4.185 (0.001)*	4.875 (0.000)*	2.337 (0.040)*	2.953 (0.012)*	0.465 (0.802)

Panel F: Six-variable Granger-causality Tests Using Intra-Day Volatilities

$$RD_t = \alpha + \sum_{j=1}^{5} \alpha_j RD_{t-j} + \sum_{j=0}^{4} \beta_j RN_{t-j} + \sum_{j=0}^{4} \gamma_i MRN_{t-j} + \sum_{j=1}^{5} \delta_j NasdaqD_{t-j} + \sum_{j=0}^{4} \phi_i NasdaqN_{t-j} + \sum_{j=0}^{4} \eta_j MRD_{t-j}$$

	α_j=0	β_j=0	γ_j=0	δ_j=0	ϕ_j=0	η_j = 0
	F-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)
KOSDAQD	KOSDAQD	KOSDAQN	KOSPIN	NasdaqD	NasdaqN	KOSPID
Local Currency	3.895 (0.002)*	4.065 (0.001)*	1.758 (0.119)	2.251 (0.048)*	0.360 (0.876)	5.833 (0.000)*
US dollar	3.921 (0.002)*	4.297 (0.001)*	1.932 (0.087)**	2.986 (0.011)*	0.400 (0.849)	5.582 (0.000)*

Note: In Panels E and F, variables R_{it}, MR_{it}, $Nasdaq_t$ denote the *i*th second board, main board return volatilities, and NASDAQ return volatilities, respectively. * and ** indicate significance at the 5% and the 10% level respectively. *p*-values are in parentheses.

Table 7. Estimates using Canadian returns

Panel A: Thee Second Stage Model for the Canadian Second Board Markets

$$\begin{cases} R_t = \gamma_0 + \gamma_1 R_{t-1} + \sum_{l=1}^{2} \gamma_{2,l} \hat{u}_{t-l} + \sum_{l=1}^{2} \gamma_{3,l} \hat{u}_{Nasdaq,t-l} + \theta \varepsilon_{t-1} + \varepsilon_t \\ \ln h_t = \alpha_0 + \alpha_1 \left(\frac{|\varepsilon_{t-1}| + \lambda \varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right) + \beta \ln h_{t-1} + \sum_{l=1}^{2} \psi_{1,l} \hat{u}_{i,t-l}^2 + \sum_{l=1}^{2} \psi_{2,l} \hat{u}_{Nasdaq,t-l}^2 \end{cases} \quad (11.1)$$

$$\begin{cases} R_t = \gamma_0 + \gamma_1 R_{t-1} + \sum_{l=0}^{1} \gamma_{2,l} \hat{u}_{t-l} + \sum_{l=0}^{1} \gamma_{3,l} \hat{u}_{Nasdaq,t-l} + \theta \varepsilon_{t-1} + \varepsilon_t \\ \ln h_t = \alpha_0 + \alpha_1 \left(\frac{|\varepsilon_{t-1}| + \lambda \varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right) + \beta \ln h_{t-1} + \sum_{l=0}^{1} \psi_{1,l} \hat{u}_{i,t-l}^2 + \sum_{l=0}^{1} \psi_{2,l} \hat{u}_{Nasdaq,t-l}^2 \end{cases} \quad (11.2)$$

$$\begin{cases} R_t = \gamma_0 + \gamma_1 R_{t-1} + \sum_{l=0}^{1} \gamma_{2,l} \hat{u}_{t-l} + \sum_{l=1}^{2} \gamma_{3,l} \hat{u}_{Nasdaq,t-l} + \theta \varepsilon_{t-1} + \varepsilon_t \\ \ln h_t = \alpha_0 + \alpha_1 \left(\frac{|\varepsilon_{t-1}| + \lambda \varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right) + \beta \ln h_{t-1} + \sum_{l=0}^{1} \psi_{1,l} \hat{u}_{i,t-l}^2 + \sum_{l=1}^{2} \psi_{2,l} \hat{u}_{Nasdaq,t}^2 \end{cases} \quad (11.3)$$

	(11.1)		(11.2)		(11.3)	
	Local Currency	US Dollar	Local Currency	US Dollar	Local Currency	US Dollar
γ_0	0.0011*	-0.0007*	0.0003*	-0.0004*	0.0016*	0.0011*
γ_1	0.6420*	-0.0332*	-0.7239*	0.5913*	-0.3707*	-0.3304*
$\gamma_{2,1}$#	-0.0019*	-0.0032*	-0.0007*	0.0076*	0.0019*	0.0033*
$\gamma_{2,2}$#	0.0016*	-0.0010*	0.0002*	-0.0053*	0.0029*	0.0033*
$\gamma_{3,1}$	0.0017*	0.0002*	0.0030*	-0.0017*	-0.0011*	-0.0013*
$\gamma_{3,2}$	-0.0018*	-0.0025*	0.0017*	0.0011*	0.0023*	0.0029*
θ	0.0684*	0.1149*	-0.7382*	0.5648*	-0.3626*	-0.2162*
α_0	-3.1869*	-1.5296*	-3.0163*	-0.8339*	-3.7481*	-4.0516*
α_1	1.4603*	2.6056*	1.4431*	1.3121*	1.4663*	1.5920*
β	0.6380*	0.7154*	0.6512*	0.8980*	0.5716*	0.5338*
λ	-0.5997*	0.4978*	-0.2123*	0.2217*	-0.4551*	-0.4884*
$\psi_{1,1}$#	-0.0134*	-0.0495*	0.0336*	0.1692*	0.0684*	0.0771*
$\psi_{1,2}$#	-0.0938*	-0.0928*	0.0258*	-0.0944*	0.0137	0.0314*
$\psi_{2,1}$	0.0058	0.0889*	-0.0418*	-0.0722*	-0.0345*	-0.0292*
$\psi_{2,2}$	0.3499*	-0.0270*	-0.0752*	0.0118*	0.0783*	0.0737*
LL	12124	10429	12345	12096	12393	12232
LB(4)	10.725	2.476	3.545	3.703	4.570	2.672
LB(8)	14.417	4.964	6.584	6.772	8.954	4.107
$LB^2(4)$	0.354	0.175	0.065	4.309	0.022	0.024
$LB^2(8)$	0.505	0.205	0.078	4.660	0.035	0.042
Joint	2.324	1.245	0.227	2.238	0.143	0.085

Note: R_t, is the CDNX close-to-close returns. $\hat{u}_{MR,t-l}$ and $\hat{u}_{Nasdaq,t-l}$ are estimates of the TSE and the NASDAQ close-to-close return residuals respectively. For all estimates, * and ** indicate significance at the 5% and the 10% level respectively. LB(k) and $LB^2(k)$ denote the Ljung-Box test of significance of autocorrelations of k lags for return residuals and squared-return residuals respectively. Autocorrelations are computed for standard residuals. *Joint* is the Engle and Ng (1993) joint sign bias test statistic. $\gamma_{2,1}$# and $\gamma_{2,2}$# will be $\gamma_{2,0}$ and $\gamma_{2,1}$ in the second and third models. $\psi_{1,1}$# and $\psi_{1,2}$# will be $\psi_{1,0}$ and $\psi_{1,1}$ in the second and third models.

Panel B: Using Returns

$$R_{it} = \alpha + \sum_{j=1}^{4} \beta_j MR_{it-j} + \sum_{j=1}^{5} \chi_j Nasdaq_{t-j} + \sum_{j=1}^{5} \delta_j R_{it-j}$$

	Local Currency		US Dollar	
	$\beta_j = 0$	$\chi_j = 0$	$\beta_j = 0$	$\chi_j = 0$
	F-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)
CDNX	TSE	NASDAQ	TSE	NASDAQ
	21.532 (0.000)	3.786 (0.002)	30.455 (0.000)	3.335 (0.005)

Panel C: Using Returns

$$R_{it} = \alpha + \sum_{j=1}^{5} \beta_j MR_{it-j} + \sum_{j=1}^{5} \chi_j Nasdaq_{t-j} + \sum_{j=1}^{5} \delta_j R_{it-j}$$

	Local Currency		US Dollar	
	$\beta_j = 0$	$\chi_j = 0$	$\beta_j = 0$	$\chi_j = 0$
	F-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)
CDNX	TSE	NASDAQ	TSE	NASDAQ
	2.692 (0.020)	3.607 (0.003)	1.545 (0.172)	3.300 (0.006)

Panel D: Using Returns

$$R_{it} = \alpha + \sum_{j=0}^{4} \beta_j MR_{it-j} + \sum_{j=0}^{4} \chi_j Nasdaq_{t-j} + \sum_{j=1}^{5} \delta_j R_{it-j}$$

	Local Currency		US Dollar	
	$\beta_j = 0$	$\chi_j = 0$	$\beta_j = 0$	$\chi_j = 0$
	F-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)	*F*-statistic (*p*-value)
CDNX	TSE	NASDAQ	TSE	NASDAQ
	8.135 (0.000)	4.826 (0.000)	13.681 (0.000)	3.741 (0.002)

Note: R_{it}, and MR_{it}, are the CDNX and the TSE close-to-close returns, respectively. $Nasdaq_t$ is the NASDAQ close-to-close return. * and ** indicate significance at the 5% and the 10% level respectively. *p*-values are in parentheses.

Information Transmission between NASDAQ and Asian Second Board Markets

Abstract

In Asia, NASDAQ's success has helped prompt Singapore (SESDAQ), Japan (JASDAQ), Taiwan (TAISDAQ) and South Korea (KOSDAQ) to set up or formalize their own second board markets in the 1980s and early 1990s. In 1999, Malaysia (MESDAQ) and Hong Kong (GEM) also set up their second board markets. Given the growing importance of these second board markets, we examine whether there is any evidence of spillovers from NASDAQ returns and volatilities to Asian second board market returns and volatilities and whether the cross-country spillovers are strong relative to domestic spillovers from the corresponding main board markets. For this purpose, we employ EGARCH models, dynamic causality tests, and VAR-based forecast error decompositions using daily data of a recent sample period that includes the Asian financial crisis of 1997 and up to April 20, 2001.

We find that, first, there is strong evidence of lagged returns and volatility spillovers from the NASDAQ market to the Asian second board markets when we exclude contemporaneous main board market returns. Second, there is strong evidence of contemporaneous and lagged returns and volatility spillovers from the local main board markets to the corresponding second board markets. However, even in the presence of contemporaneous main board market returns, there remain substantial spillovers from the lagged NASDAQ returns and volatilities to Asian second board market returns and volatilities. These findings are not sensitive to whether we use U.S. dollar-based data or local currency-based data.

Given the difference in the trading hours between the NASDAQ and Asian stock markets, we attempt to alleviate this concern by using some available intra-day return data and Canadian return data. The findings seem quite robust: There is substantial information spillover from the NASDAQ to Asian and Canadian second board markets. These findings indicate the existence of substantial cross-country industry effect (or meteor shower effect) as well as domestic market effect (or heat wave effect) and imply that both country diversification and industry diversification are important.

JEL classification: G15

Keywords: NASDAQ; Second Board Markets; Spillover; Volatility; EGARCH.