Price Discovery of Index Futures Across Markets*

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Abstract

The trading of foreign index futures by the Singapore Exchange (SGX) offers an ideal opportunity to study price discovery and information of trading across different markets. We examine four popular indices - Nikkei 225 Index, MSCI Taiwan Index, CNX Nifty Index and the FTSE China A50 Index traded in SGX and compare them with their home market trading. In contrary to standard theory and evidence, we show that smaller bid-ask spread, lower minimum lots and cheaper transaction cost do not necessary improve information efficiency. These results may shed some light on the usefulness of the role of an international financial centre on the price discovery of foreign indices.

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1 Introduction

Exchanges play important role in trading of securities and financial products which facilitate price discovery and improve information efficiency. Studies (Boehmer and Kelley (2009);Seasholes (2000)) show that institutional investors drive information efficiency. Studies on exchanges' role in establishing new financial services and products to improve information efficiency is however limited. Methods to attract trading of institutional investors include, but not limited to, creating innovative exchange traded products, reducing trading transaction cost, lengthening trading time to 24 hours and increasing market depth. In this paper, we try to fill the gap in the literature by examining the importance role of exchanges regard to their price discovery and information role due to trading activities provided.

Supporters of financial market integration and globalization argue that benefits of such include increased economic growth and the development of local stock markets (Bekaert, Harvey, and Lundblad (2001),Bekaert, Harvey, and Lundblad (2005),2009; Gupta and Yuan, 2004;Mitton (2006)), risk-sharing between domestic and foreign investors (Merton (1987); Karolyi and Stulz (2003);Han Kim and Singal (2000)), and improvement of corporate governance and the information environment (Li, Moshirian, Pham, and Zein (2006); Cumming, ImadEddine, and Schwienbacher (2014)). The emerging and growing trading of foreign index futures provided by the Singapore Exchange (SGX) offers an ideal opportunity to systematically study the price discovery and information efficiency role of securities traded in different markets. SGX successfully launched a few foreign index futures whose fundamentals are the same as their domestic index futures that are traded in home exchanges, including Japan Nikki 225 index futures, MSCI Taiwan Index, CNX Nifty Index and the FTSE China A50 Index. For instance, the trading by SGX of the Japanese Nikkei 225 index futures has flourished in SGX instead of Osaka Exchange (OSE) during the late 1990s. Policy makers consider differences in institutional characteristics and trading in the SGX are more attractive and informative than in the OSE because of lower transaction cost and less trading restrictions therefore resulting in better price discovery.

Fleming, Ostdiek, and Whaley (1996) proposed that low transaction cost in trading helps new information to be incorporated into the market faster. We directly test Fleming et al. (1996)s prediction in the cross markets of index futures by relating price discovery to trading cost. Implicitly, we hypothesize that by lowering transaction cost, market can improve price efficiency therefore leading to greater price discovery. Although researchers do not think that foreign institutions have advantage over domestic counterparties since local investors possess an information advantage due to close proximity and greater accessibility to local information (Hau (2001); Dvořák (2005); Brennan and Cao (1997); Parwada (2008)). We hypothesize that trading of foreign index futures at SGX convey more information and lead to better price discovery. This prior is consistent with the findings that foreign institutions are more sophisticated than domestic ones due to their investment experience and expertise (Seasholes (2000); Grinblatt and Keloharju (2000); Froot and Ramadorai (2001)).

The trading of index futures with same fundamentals offers a perfect setting to test our hypothesis since arbitrage trading should correct any significant mispricing in the lagged market. However, it is hard to believe that price discovery of a country's domestic market index is coming from foreign exchange market instead of its own domestic exchange market. Unless there exist some form of barriers in the domestic exchange market that is hindering price discovery, most would expect the domestic exchange market to be the informational superior one.

In this paper, we establish empirical evidence on price discovery in either domestic or foreign exchanges by investigating four different indexes futures traded concurrently in their domestic market and SGX. This research thus try to answer an important question in the literature - Where and why price discovery occurs. As a globally recognized financial exchange with regulations and standards equal or exceed most exchanges in the world, SGX is believed to facilitate the price discovery of indexes futures and information efficiency. We use the four most liquid index futures traded on SGX[1]: The Singapore Exchanges CNX Nifty Index Futures, FTSE China A50 Index Futures, Nikkei 225 Index Futures, MSCI Taiwan Index Futures. In order to study the price discovery of these indices, the corresponding equity-index futures are also included respectively: CNX

[1]Total value of offshore futures traded in 2013: China US$170 billion, India US$190 billion, Japan US$2.8 trillion, Taiwan US$530 billion. Detailed information can be found on http://www.sgx.com/wps/portal/sgxweb/home/products/derivatives/overview.

Nifty Index Futures listed on the National Stock Exchange of India (NSE), China Security Index 300 Futures listed on China Financial Future Exchange (CFFEX), Nikkei 225 Index Futures listed on the Osaka Stock Exchange (OSE), and Taiwan Stock Index Futures listed on the Taiwan Futures Exchange (TAIFEX). These futures share the same or similar underlying as those futures in SGX.[2] These indexes allow us to compare the effects of having a well-establish exchange trading an emerging market's index, versus a developed market's index. Other than the exception of Japan's Nikkei 225, the underlying of Taiwan's Index futures traded in SGX is the MSCI Taiwan Index instead of the TAIEX Index, and the underlying of China Index traded in SGX is the FTSE China A50 Index instead of China's CSI 300 index. As for the India's the CNX Nifty Index, the futures trading on SGX are denominated in US dollars whereas in India, the futures are denominated in Indian Rupees. These differences are time varying and therefore controlling for these are important.

We follow the information share method proposed by Hasbrouck (1995) and Lien and Shrestha (2009). We find that the information share of CNX Nifty Index Futures in SGX accounts for about 63% which is consistently larger than that in NSE. Similarly, the information share of Nikkei 225 Index Futures in SGX accounts for about 61%. On the other hand, the SGXs information shares of MSCI Taiwan Index Futures and FTSE China A50 Index Futures are around 25% and 21% respectively lower than the information share of their domestic index futures. This evidence suggests that the price discovery of local securities can actually happen in a foreign exchange far away. This is the first study that shows (foreign) traders in foreign markets are more informed than those in local exchanges.

This paper is the first to investigate the intra-day price discovery of index futures across different markets. Unlike equity that requires access to the depository during settlements, futures are purely cash settled. Therefore trading of foreign indexes through index futures does not require any regulatory agreement from the domestic country. This paper also contributes to the price discovery literature by comparing the beneficial effect on developing foreign index futures in developed markets where investors can benefit from trading in foreign exchanges and domestic market.

[2]The correlation of FTSE China A50 Index and China Security Index 300 is. The correlation of MSCI Taiwan Index and Taiwan Stock Index is.

2 Literature Review

Base on the efficient markets hypothesis (see Fama (1970)), all security prices in the market adjust quickly towards their efficient price, eliminating any available arbitrage profits. However in practice we do not know how this process is actually being carried out. Some suggested the existence of arbitrageurs that profit from price inefficiency which in return provide an upward or downward pressure on prices to reverse towards the efficient price. One main reason why this economic question is still unanswered is because the efficient price is not observable, but instead, we observed the traded prices, bid prices and ask prices. The law of one price do not necessary hold in reality. In this section, we shall review some papers on the price discovery process by the futures contracts traded on different markets with similar underlyings.

2.1 Does Futures lead Spot?

The literature on whether futures prices help the price discovery process of its underlying (the spot price), gains lots of attention during the late 1990s. Using the S&P500 stock index and the futures on the stock index, Dwyer, Locke, and Yu (1996), Fleming et al. (1996), and Martens, Kofman, and Vorst (1998) showed that the futures price changes lead the spot market price change by 5 to 45 minutes. In contrast, the evidence that spot market price change lead futures price changes is weak. Tse (1999) studied the Dow Jones Industrial Average (DJIA) spot and futures price and found that most of the price discovery takes place in the futures market. In contrast, Booth, So, and Tse (1999) analysed the Germany DAX index spot, futures and options market and showed that the price discovery role is equally shared by the spot and futures market only. Although the international evidence on futures market leading the spot market is still mixed, there seemed to be a consensus that in general futures prices lead its underlying spot price.

The following are papers that investigate the price dicovery process of the Japanese Nikkei 225 Index. Shyy and Shen (1997) used both daily and intra-day data to study the price transmission of Nikkei 225 futures between SIMEX in Singapore and TSE/OSE in Japan. They did not find a significant evidence of the price discovery process for both SIMEX and TSE/OSE market. Booth, Lee, and Tse (1996) used daily closing prices of Nikkei 225 Index futures from OSE, SGX and CME but found none of them can be considered the main source of information flow. Covrig, Ding, and Low (2004) examined the price discovery process using Nikkei 225 index in domestic spot market (Tokyo Stock Exchange), domestic futures market (Osaka Exchange Market) and foreign futures market (Singapore Exchange). They showed evidence that price discovery occured in both markets and suggested that a satellite market can co-exist with another home market by providing a significant role in the price discovery process.

In relation to the price discovery process of the Taiwan Index, Chou and Lee (2002) studied the period during tax reduction in Taiwan Futures Exchange (TAIFEX) and compared the trading costs and information transmissions between SGX and TAIFEX. They found this reduction of market friction had a great impact on the relative efficiencies of price execution of TAIFEX to SGX and the better price execution was mainly driven by the larger base of market participants and less costs of intermediation. Huang and Chou (2007) compared the difference between TAIFEX order-driven call market and SGX quote-driven continuous trading system and found the spread is minimized in TAIFEX when order imbalance is high while the spread is highest in SGX when order imbalance is high.

On the other hand little studies have been carried out on the process of prices discovery on India's Nifty Index and China's CSI 300 index. Kumar (2014) examined the impact of foreign institutional investor's investments on Nifty index futures that are both tradable on National Stock Exchange of India (NSE) and Singapore Exchange (SGX). He found that SGX futures are do not influence Nifty futures. On the other hand, Nifty futures is a significant explanatory variable in SGX futures returns. Guo, Han, Liu, and Ryu (2013) studied the intraday price discovery and volatility transmission processes between Singapore Exchange (SGX) and China Financial Futures Exchange (CFFE). They found that China's CSI 300 index futures dominate FTSE A50 index futures in SGX in both intraday price discovery and intraday volatility transmission processes.

3 SGX's Institutional Details

Singapore Exchanges derivatives market (SGX-DT) is an order driven market that uses a continuous auction system for regular intra-day trading. It provides a platform for a suite of globally tradable products, including equity index futures and options, interest rates futures and option, and dividend index futures contract. For Singapores equity-index futures market, trading takes place during the day (T session) and during the evening (T+1 session). During the opening hours of these sessions, investors can submit orders, make amendments or cancel orders at no extra cost. SGX-DT allows investors to submit limit orders, market orders and stop orders. These orders are matched according to the price and time priority rule. SGX derivatives market face three explicit transaction costs: exchange fees, brokerage fees and taxes. Investors pay a 0.04% of the contract value as a clearing fee and 0.0075% access fee once the order is submitted. A GST of 7% is also charged on both clearing and brokerage fees.

In addition to providing derivatives clearing and settlement, Singapore Exchange Derivatives Clearing Limited (SGX-DC) also provides a mutual offset system with Chicago Mercantile Exchange (CME). This facility allows investors to initiate positions in one exchange for allocation to the other on a real-time basis. Currently, only three index futures products are eligible for mutual offset with CME (1) Nikkei 225 Index futures (Yen denominated), (2) Nikkei 225 Index futures (USD denominated), and (3) S&P CNX Nifty Index futures.

In order to prevent excessive price volatility in the derivatives market, SGX-DT adopts price limits for the majority of its derivatives contracts. These price limits are designed to provide a cooling off period so as to restrict trading temporarily when the market is volatile. Price limits are set as a percentage of the maximum permitted movement a price can advance or decline from the previous trading days settlement price during a trading session. This specified percentage varies from contract to contract. When a price hits any of its price limits, SGX-DT will signal a cooling off period. The cooling off period is a specified duration of time where the affected contract may be traded at or within its price limits. The specified duration also varies from contract to contract. Once the cooling off period ends, normal trading resumes for the remainder of the trading day. In regards to options contracts, trading in the options contracts will be halted when their underlying futures contracts hit its price limits and enter into a cooling off period. Subsequently, normal trading for both options contracts and their underlying futures contracts will resume once the cooling off period is lifted.

3.1 Foreign Exchanges

This paper use the four most liquid index futures traded on SGX: The Singapore Exchanges CNX Nifty Index Futures, FTSE China A50 Index Futures, Nikkei 225 Index Futures, MSCI Taiwan Index Futures. In order to study the price discovery of these indices, the corresponding equity-index futures are also included respectively: CNX Nifty Index listed on the National Stock Exchange of India (NSE), China Shanghai Nifty Index listed on China Financial Future Exchange (CFFEX), Nikkei 225 Index Futures listed on the Osaka Stock Exchange (OSE), and Taiwan Stock Index listed on the Taiwan Futures Exchange (TAIFEX). These futures share the same or similar underlying as those futures traded on SGX. Appendix B shows the differences between each exchanges such as the trading time, trading cost, minimum lot sizes and the multiplier. These differences affects the cost of trading in a particular exchange and the difference in cost of trading may indirectly determine the type of traders trading in the exchange. For example high-frequency speculators may want to trade in the exchange that is the cheapest to trade and the smallest size, whereas large institutional traders may not be interested in these as these factors do not affect them.

In all cases, the trading time of the four indices in their domestic exchanges is always a subset of the trading time in SGX. For the purpose of the paper, we are only interested in futures quotes and trades prices within the trading period where both the domestic and singapore exchanges open. In singapore time, this means that for the Nikkei 225 prices between 0800hrs-1415hrsare used, 0845hrs-1345hrs for the Taiwan futures index and 1145hrs-1800hrs for Nifty Index. As for the China's index futures, two sessions, 0915hrs-1130hrs and 1300hrs-1515hrs, are extracted. All futures prices not within these time interval are truncated away.

4 Data and Summary Statistics

The intra-day tick, time-stamped market traded, bid and ask quotes for all the index futures trading in both SGX and their home markets are obtained from Bloomberg. Our sample period span from 1st August 2014 to 31th January 2015. Intra-day foreign exchange rate data are also obtained from Bloomberg. As the time-stamped data are accurate up the seconds, for every second, we take the lastest price to represent the price observed in that time stamped. If there are no trades or quotes in a particular second, the price in the previous time period is used instead. Trade prices, Bid and Ask prices are stored separately as individual price interval.

Appendix 3 reports the relative percentage of transacted index futures by the size of the lot in each exchange. For example in column 2 for the Nifty Index futures traded on SGX, 27.92% means that 27.92% of all the transacted futures contract traded on SGX have lot sizes less than 2. For comparison purposes, all lots sizes are approximately measured as a multiple of SGX lot sizes. This means that if 1 lot in Japan OSE cost twice as much as 1 lot in SGX, than we would measure the 1 lot transacted in OSE as 2 lots. Lot Ratios measures the relative cost of the smallest size lots in each exchange. For example, the cost of 1 lot in NSE is $\frac{1}{5}$ the cost of 1 lot in SGX. It cost 15.68 times more expensive to trade on CFFE than SGX, 2 times more expensive to trade on OSE than SGX and 1.76 times more expensive to trade on TFE than SGX. In conclusion, other than the Nifty Index futures on NSE, it is always cheaper to trade on SGX. Therefore what are some evidence of the consequences of having a lower minimum cost lots? From appendix 3, we find evidence that exchanges having a cheaper minimum lot have more smaller transactions. This may suggest that the cheaper minimum lot size is attacting certain type of global traders, traders that can trade across country borders. Whether attacting these types of traders would have a positive effect on the exchange still remains an open question. In terms of information share, due to our small international cross-sectional sample size, we are unable to test this relation. However if we were to just compare, we find no consistent relation between cheaper minimum lost size and greater information share.

From appendix 4 the time-weighted spread ratio (as a percentage of futures price) is greater in

SGX except for the Nikkei 225 index futures. The negative relation between cheaper minimum lot size and smaller spread does not always hold true in our sample. The both the China and Taiwan Index futures are cheaper to trade on SGX but the spread ratio is relatively higher.

5 Price Discovery

Testing where price dicovery occurs is an econometric problems and many previous papers have done do in many ways. In this paper, we shall use the information share measure contructed in Hasbrouck (1995) as our only measure. In this section, we describe briefly the information share methodology of Hasbrouck (1995) and some computational constrains used. The univariate results on information share is subsequently presented at the end of this section.

5.1 Methodology

Suppose there are n price variables related to a single security. Examples of these observable related price variables are the transaction, bid and ask prices of a traded security. In this paper, the single security of concern is an index, and the price variables related to this security are the transaction, bid and ask futures prices such that the futures underlying is the index itself. If we were to assume a fixed interest rate r over a fixed time period τ such that τ also corresponds exactly to the futures contract's time to maturity, then there exist a no arbitrage equation that relates the futures price to its underlying price: $F_\tau = S_0 e^{r\tau}$, here F_τ is the futures price with maturity τ, and S_0 is the price of the underlying at time 0. Suppose each price series is integrated of order one, $I(1)$, which implies that their price changes are covariance stationary then this means that they can be modelled using a vector moving average model (VMA):

$$\Delta p_t = \Phi(L) e_t \tag{1}$$

where e_t has $E[e_t] = 0$ and variance covariance matrix Σ. Φ is a polynomial in the lag polynomial.

Although each price is non-stationary, we know that the prices in different market do not diverge from each other significantly. Therefore we can assume that the difference between any two price is stationary, inparticular, the difference between any price variables with the first price variable is stationary. Formally this means that the prices are cointegrated of order $n-1$ with conintegrating matrix β:

$$\text{s.t. } \beta' = [\tau_{n-1}, -I_{n-1}]$$

$$\text{and } \beta' p_t = I(0)$$

here τ_{n-1} is a column unit vector. The requirement that $\beta' p_t$ is stationary implies that $\beta' \Phi(1) = 0$, where $\phi(1)$ is the sum of all the moving average coefficients of equation 1. We can therefore decompose the VMA model into $\delta p_t = \Phi(1)e_t + \Phi * (L)e_t$ where $\phi(1)e_t$ intuitively measures the long-run impact of a disturbance on each price variables. Given the unique structure of β, it can be shown that all the rows of $\phi(1)$ are identical which suggest a common long-run price impact on each of the price variables. Measuring the contribution from each of the price variables towards this common long-run price impact serve as a measure of information share of a market.

Since the price variables are cointegrated, there exists an error correction model (VECM) of the form:

$$\Delta p_t = \alpha(\beta' p_{t-1} - \mu) + \Gamma_1 \Delta p_{t-1} + \Gamma_2 \Delta p_{t-2} + ... + \Gamma_K \Delta p_{t-K} + e_t \tag{2}$$

The α in equation 2 measures the speed of adjustments towards the long-run mean, μ is the long-run mean and Γ is an nxn coefficient matrix. After estimating the parameters of the VECM model in equation 2, we can then estimate the equivalent VMA model in equation 1 using the parameter of the VECM model which will be discuss in more details in the next section.

Finally, the j^{th} market information share on the single security relative to the total variance of the common random walk component can be measured as:

$$S_j = \frac{\phi_j^2 \Sigma_{jj}}{\phi \Sigma \phi'} \tag{3}$$

Here ϕ denote the common row of Φ and ϕ_j denote the j^{th} element of ϕ.

5.2 Estimation

Given observable price samples P_t, we transform it by taking natural log and define $p_t = ln(P_t)$. Therefore the change in p_t can be the continuously compounded returns of the price samples P_t. We estimate μ in equation 2 separately from the other parameters, and estimating it as the sample mean of $\beta' p_t$. The remaining parameters in equation 2 can then be estimated via ordinary least squares. For the purpose of this paper, we specify the VECM model to have 300 lags to account for possible autocorrelation up to 5 minutes due to uninformative trades such as trades due to inventory control purposes[3].

To estimate parameters of the VMA model in equation 1, we "forecast" the VECM system subsequent to a unit perturbation. A recursive loop can then be formulated to estimate the coefficients of the VMA model. Details of this recursive formula can be found in the Appendix. We than compute $\phi(1)$ to the sum of all the moving average coefficient. In theory, $\phi(1)$ is equal to $\sum_{i=0}^{\infty} \Gamma_i$. However for the purpose of this paper, we stop the summation if:

$$||\phi_{k+1} - \phi_k||_1 < 0.0001 \tag{4}$$

ϕ_k denote $\sum_{i=0}^{k} \Gamma_i$ and $||M||_1$ is the matrix 1-norm. This is to ensure that convergence is reached and the system is stable. The Information Share measure in equation 5 is uniquely define if the variance-covariance matrix Σ is diagonal otherwise the order of the price vector will affect the information share measure, i.e. the information share measure is different if we place SGX futures price as the first element as oppose if we place it as the second element in the n-vector price variable. Therefore following an invariant information share method by Lien and Shrestha (2009), we shall use the correlation matrix instead of the covariance matrix. Let Σ^* represent the innovation correction matrix which is also a product of the above estimation procedure. Let Λ represent the diagonal matrix with diagonal elements being the eigenvalue of Σ^* ang G be the corresponding eigenvector matrix where the columns are the eigenvectors. Finally, let V be a diagonal matrix containing the innovation standard deviation on the diagonal, $V = diag(\sqrt{\Sigma_{1,1}}, \sqrt{\Sigma_{2,2}}, ..., \sqrt{\Sigma_{n,n}})$.

[3]Since computing technology has improved, unlike Hasbrouck (2003) we do not use any polynomial approximation of the Γ coeffients, but instead estimate all the coefficients of the Γ matrix.

Denote $F^* = [G\Lambda^{-1/2}G^TV^{-1}]^{-1}$

and under this factor structure instead of the Cholesky factorization used by Hasbrouck (1995):

$$S_j = \frac{\phi_j^{*2}}{\phi\Sigma\phi'} \tag{5}$$

Here, $\phi^* = \phi F^*$ and ϕ_j^* is the jth element. Proof of the invariance information share can be found in Lien and Shrestha (2009).

5.3 Univariate analysis: Information Share

To compute the information Share result in table 1, both the traded price and bid-ask middle point are used as separate price variables that are cointegrated. The average information share for both price variables is later combined to compute the information share of the exchange.

[Place Table 1 about here]

From table 1, information share is greater in SGX for the Nifty index and Nikkei index. However the information share is lower in SGX for the China Index and Taiwan Index. It means that there are more information contain in SGX for both Nifty and Nikkei 225, but less information for FTSE China A50 and MSCI Taiwan Index. All these differences are statistically significant.

6 Multivariate analysis: Factors affecting Information Share

The univariate test only compares the mean information share in the two exchanges without controlling for other factors. Thus, we are interested to know whether the information is persistent and also the determinants of information share. Table 2 shows the key variable we use in the multivariate regression, and Panel A to Panel D show the detailed information for the four index futures. Information share is the same variable used for the univariate test. Most of the time SGX traded futures have larger spread, higher mean-adjusted price volatility, lower depth and lower traded volume. But there is exceptions: for example, the spread in OSE is twice that of SGX and the volatility is slightly larger in OSE. Unlike other exchange, CFFEX in China owns much smaller depth than SGX, suggesting a potential illiquid futures market in China. As for the traded volume, local exchanges usually demand more futures contracts than SGX with exception of OSE. The order imbalance (total buy trades minus total sell trades) tends to be more positive in SGX with exception of CFFEX.

[Place Table 2 about here]

Table 3 reports the multivariable regression results on the determinants of information share. All the controls are the ratio of variable in SGX divided by the corresponding variable in the foreign derivative market. We introduce lagged information share in SGX, controlling for the momentum/reversal effect of the price discovery. We also control of the day-of-the-week effect and index fixed effect to rule out the potential time variant and individual effect.

The first column only control for lagged information share in SGX, using the fixed effect model. The coefficient on the lagged information share is positive, showing a momentum effect of information share. This means that the price discovery is usually consistently dominant in one market. It also suggests that a one percent increase of last days information share leads to an increase in todays information share by about 0.135%. Additional market microstructure as independent variables are investigated and reported in Column 2 to Column 6 in Table 3. The coefficients of lagged information share in SGX are slightly lower comparing with previous model but they are still significant. It shows that spread ratio and volatility ratio are significantly negative with the information share. Higher spread in SGX may slow down information transmission comparing with foreign market while greater volatility usually means greater market uncertainty which arbitrage traders do not want to take. We fail to find any relation between information share and depth ratio or volume ratio. Mostly interestingly we find that the order imbalance ratio is positive and significant with the information share and the magnitude of the coefficient shows that one unit more buy order traded uplift about 0.1% increase in information share. Column 7 reports the result by including all the variables and we see that the result is still unchanged. All standard errors are adjusted using the Newey-West estimator.

[Place Table 3 about here]

Table 4 and Table 5 report the robustness test for multivariate test. In Table 4 we winsor all variable at 1% and 99% percent level to avoid the extreme values. The result become even stronger and most of the magnitudes are unchanged. In Table 5, we construct the dummy variable of SGX IS Dummy to be one if the information share in SGX is more than 60%, zero if less than 40%. We do not use the information share around 50% since it may not be very clear which market is actually the dominant market. We adopt logit regression in which the dependent variable is censored at one or zero. From Table 5, it shows that the magnitude of lagged information share dummy is around 80% suggesting that the dominance of one market is very persistent. Besides, the significance level of all exchange variables has dropped but the spread ratio, volatility ratio and order imbalance ratio are still marginally significant.

[Place Table 4 and Table 5 about here]

7 Testing Cross-markets efficiency

The evidence that price discovery occurs in SGX for Japan's Nikkei and India's Nifty maybe a surprise from an academic view point. Information superiority from one market implies that a less informational superior market is lagging, and therefore this may lead to possible cross-market arbitrage. However in the long-run these arbitrage opportunities should not exist. Micro-structure differences such as transaction costs and bid-ask spread may lead one market to lag continuously from the other market. Literature on limits on arbitrage may explain why such lead and lag relationships maybe exist. For examples short selling constrains or expensive trading costs maybe preventing arbitrageurs from correcting the current price towards to the true price. Therefore understanding reasons why one market lead or lagged the other have strong economic and policy implications. In this section, we attempt to search for empirical evidence of market inefficiency by constructing trading portfolios following certain trading strategy in-line with the information share results in section 4 and 6.

The trading strategy used in this paper is derived from a special-case model:

$$\begin{aligned} P_{1,t} &= P_{1,t-1} + \epsilon_{1,t} \\ P_{2,t} &= P_{1,t-2} + \epsilon_{2,t} \\ P_{2,t} &= P_{1,t-1} - \epsilon_{1,t-1} + \epsilon_{2,t} \end{aligned} \tag{6}$$

The VECM model used to derive the information share measure is quite general, in particular the above model 6 is a special case of the VECM, we could use information share results to construct trading strategies to exploit our main results. From model 6, we can observe that the price of a security in one market,$P_{1,t}$, follows a random walk and therefore unpredictable. However, the price of the same security in the second market is tracking the price of the first market lagged two periods. We can therefore exploit this relationship as long as we can identify which market is leading and which market is lagging. From table 3 we can infer that the daily information share of one market is very sticky and hardly change through time. Using this information, we shall use the random walk model on the time-series information share dynamics whereby the best predictor of future date $t + 1$ information share the last date t information share. For comparison, we also include the result on perfect information, whereby we know the true information share. Given this, our trading strategy shall be the following:

Let $P_{1,t}^{Last}$ be the last futures price of the leading market at time interval t, $P_{1,t}^{First}$ be the first futures price of the leading market at time interval t, $P_{2,t}^{Last}$ be the last futures price of the lagging market at time interval t and $P_{1,t}^{First}$ be the first futures price of the lagging market at time interval t. Information in time interval t refers to all the price information within the interval $(t-1, t]$. In this paper, trading is carried out every minute[4] from opening to closing. A buy signal is generated if the price in the leading market is higher than the price in the lagging market. This translate to $P_{1,t-1}^{Last} > P_{2,t-1}^{Last}$ and a sell signal is generated if $P_{1,t-1}^{Last} < P_{2,t-1}^{Last}$. We then compute our trading profit at the lagging market as $\pi_t = P_{2,t+1}^{First} - P_{2,t}^{First}$ if it is a buy signal and $\pi_t = P_{2,t}^{First} - P_{2,t+1}^{First}$ if it is a sell signal. This means that at time $t-1$ after we know the trading signal, we trade the first

[4]Other time intervals are used and the results are stronger if we used smaller time interval. Since some markets are not that liquid to have trades every other second, using a 1 minute trading frequency gives a more realistic test. The lead and lagged effects diminished as we use longer time interval.

available futures price at time t and clear our position at time $t+1$ regardless whether we incur a profit or loss. For the case of China and Taiwan where the underlying index is numerically different, index prices cannot used. Instead we use their first difference, which is returns to determine the buy or sell signal. Table 6 reports the results for both the perfect information case and the predictive random walk case.

[Place Table 6 about here]

From Table 6 the statistics for the perfect information and the random walk case are very similar, supporting our previous results that the information share time-series dynamics of all the countries in our sample is rather persistent. The portfolio strategy produces positive average daily returns ranging from 0.08% to 0.62%. The portfolio returns are negatively skewed and tails fatter than the normal distribution (kurtosis value greater than 3). Using the portfolio analysis, we show that empirically the is a lead and a lag market supporting our multivariate analysis results. Since our portfolio strategy assumes that we are able to trade at the bid-ask mid-point, this may not be a evidence that the lagging market is inefficient. Transaction cost, trading at the spread and feasibility has to be shown to conclude that the lagging market is indeed inefficient. However for the purpose of our paper, showing the existence of a lagging market is sufficient and conclusive.

8 Conclusion

In this paper we explore the process of price discovery of four different Indices, India's Nifty Index, China's Index, Japan's Nikkei 225 Index and Taiwan's Index. These country indices are available for trading in each of their respective domestic exchanges and in Singapore's exchange (SGX). We then investigative how the SGX contributed in the process of price discovery for each of the four indices though it index futures trading. Our results suggest that it is possible for the price discovery process to be occurring in a foreign country's exchange from the evidence of Nifty Index and Nikkei index. In addition, we construct portfolios to check if the measure is truly capturing a leading and lagging relation and show that positive profits is possible if we are able to trade at the bid-ask middle point. Although we are unable to reject the efficient market hypothesis from the negative profit evidence of our second portfolio where we have to buy at the ask and sell at the bid, we are still able to show that one market is truly leading the other. We attempt to find factors that may affect information share but at the moment most factors do not explain much.

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Table 1: This table reports the univariate results on the daily information share ratio. The price vector is used to compute the information share is traded price and bid-ask middle point by one second. Daily information share is computed and the one sided T test is used. ***, **, and * denotes statistical significance at the 1%, 5%, and 10% levels respectively.

	CNX Nifty(SGX)	CNX Nifty(NSE)	Difference
Mean	63.12%	36.88%	26.23%***
Std. Error	2.51%	2.51%	0.00%
Obs	118	118	
	FTSE China A50 Index Futures (SGX)	CSI 300 Index Futures (CFFEX)	Difference
Mean	21.25%	78.75%	-57.49%***
Std. Error	2.10%	2.10%	0.00%
Obs	118	118	
	Nikkei 225 (SGX)	Nikkei 225 (OSE)	Difference
Mean	61.80%	38.20%	23.61%***
Std. Error	1.92%	1.92%	0.00%
Obs	94	94	
	MSCI Taiwan Index Futures (SGX)	TAIEX Index Futures (TAIFEX)	Difference
Mean	24.72%	75.28%	-50.55%***
Std. Error	2.21%	2.21%	0.00%
Obs	125	125	

Table 2: This table report the summary statistics for the key variables used for each future indexes. IS is the information share calculated by the trades and midquotes. Spread is the difference between ask and bid. Volatility is the mean-adjusted 5-minute index future price volatility. Depth is the total number of ticks by each second. Traded Volume is the total number of lots in thousand. Order imbalance is the number of buy order minus the number of sell order within each day. ***, **, and * denotes statistical significance at the 1%, 5%, and 10% levels respectively. Panel E shows the ratio of SGX market divided by the foreign exchange market.

Panel A: CNX Nifty Index Futures(SGX) / CNX Nifty Index Futures(NSE)					
	SGX	NSE	Difference	T-statistics	
IS	0.631	0.369	0.262	5.227	***
Spread	0.014	0.008	0.006	26.961	***
Volatility	0.025	0.025	0.000	4.907	***
Depth	8.900	31.386	-22.486	-23.545	***
Traded Volume(thousand lots)	38.737	329.734	-290.997	-18.182	***
Order Imbalance	90.864	-134.025	224.890	1.902	*
Panel B: FTSE China A50 Index Futures(SGX) / CSI 300 Index Futures(CFFEX)					
	SGX	CFFEX	Difference	T-statistics	
IS	0.213	0.787	-0.575	-13.683	***
Spread	0.062	0.010	0.052	40.219	***
Volatility	0.075	0.065	0.010	5.110	***
Depth	376.048	133.758	242.290	5.950	***
Traded Volume(thousand lots)	174.919	985.613	-810.694	-20.546	***
Order Imbalance	-121.356	54.822	-176.178	-1.484	
Panel C: Nikkei 225 Index Futures(SGX) / Nikkei 225 Index Futures(OSE)					
	SGX	OSE	Difference	T-statistics	
IS	0.618	0.382	0.236	6.146	***
Spread	0.032	0.061	-0.029	-140.000	***
Volatility	0.029	0.029	0.000	-3.412	***
Depth	54.721	585.495	-530.774	-30.526	***
Traded Volume(thousand lots)	67.237	66.507	0.730	0.547	
Order Imbalance	198.755	-148.266	347.021	3.443	***
Panel D: MSCI Taiwan Index Futures(SGX) / TAIEX Index Futures(TAIFEX)					
	SGX	TAIFEX	Difference	T-statistics	
IS	0.247	0.753	-0.506	-11.438	***
Spread	0.031	0.012	0.019	192.549	***
Volatility	0.027	0.024	0.003	6.355	***
Depth	65.509	302.249	-236.740	-29.644	***
Traded Volume(thousand lots)	38.619	107.199	-68.580	-23.698	***
Order Imbalance	121.216	-633.264	754.480	4.877	***
Panel E: Ratio					
	Obs	Mean	Std.Dev.		
Spread Ratio	455	2.928	2.296		
Volatility Ratio	455	1.103	0.234		
Depth Ratio	455	1.253	2.279		
Volume Ratio	455	0.418	0.401		
Order Imbalance Ratio	455	0.811	22.846		

Table 3: The table examines the determinants of information share. The dependent variable is SGX information share, which is the proportion of information share calculated from VECM. Subscript t denotes trading day. Spread Ratio is the spread of the index futures traded on SGX divided by the spread of the index futures traded on its domestic exchange. Price $\sigma *$ is the mean-adjusted 5-minutes index futures price volatility. Volume Ratio is the daily traded volume of the index futures on SGX divided by the daily traded volume of its corresponding foreign index futures. Depth Ratio is the Depth of SGX index futures divided by the Depth of its corresponding foreign index futures. Depth is measured as the average 1-second bid and ask total volume. Volume is measured as the number of lots multiply by the exchange respective lot ratio found in Table **??**. All standard errors are adjusted by Newey-West using the maximum of five order. ***,**,and * denotes statistical significance at the 1%, 5%, and 10% levels, respectively and the t-statistics are shown in parenthesis

SGXIS	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lag SGXIS	0.135***	0.117***	0.137***	0.136***	0.133***	0.132***	0.114***
	(3.38)	(2.89)	(3.45)	(3.44)	(3.38)	(3.29)	(2.85)
Spread Ratio		-0.033***					-0.032***
		(-3.07)					(-2.76)
Volatility Ratio			-0.121***				-0.120***
			(-2.78)				(-2.62)
Depth Ratio				-0.007			-0.008
				(-1.32)			(-1.16)
Volume Ratio					0.022		0.046
					(0.41)		(0.71)
Order Imbalance Ratio						0.001**	0.001***
						(2.36)	(2.63)
mon	-0.044	-0.043	-0.045	-0.046	-0.043	-0.047	-0.048
	(-1.12)	(-1.11)	(-1.17)	(-1.17)	(-1.09)	(-1.19)	(-1.25)
tue	0.031	0.032	0.029	0.029	0.032	0.031	0.030
	(0.91)	(0.95)	(0.83)	(0.85)	(0.95)	(0.91)	(0.86)
wed	-0.001	0.001	-0.003	-0.003	0.000	-0.001	-0.000
	(-0.03)	(0.02)	(-0.08)	(-0.08)	(0.01)	(-0.02)	(-0.01)
thu	0.014	0.017	0.010	0.014	0.016	0.014	0.018
	(0.40)	(0.50)	(0.30)	(0.41)	(0.45)	(0.42)	(0.53)
Constant	0.186***	0.394***	0.335***	0.216***	0.180***	0.187***	0.555***
	(5.60)	(5.58)	(5.53)	(5.62)	(5.07)	(5.63)	(6.30)
Index Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	451	451	451	451	451	451	451

Table 4: The table examines the determinants of information share. All variable is winsored at 1% and 99% level by each future indexes. The dependent variable is SGX information share, which is the proportion of information share calculated from VECM. Subscript t denotes trading day. Spread Ratio is the spread of the index futures traded on SGX divided by the spread of the index futures traded on its domestic exchange. Price $\sigma*$ is the mean-adjusted 5-minutes index futures price volatility. Volume Ratio is the daily traded volume of the index futures on SGX divided by the daily traded volume of its corresponding foreign index futures. Depth Ratio is the Depth of SGX index futures divided by the Depth of its corresponding foreign index futures. Depth is measured as the average 1-second bid and ask total volume. Volume is measured as the number of lots multiply by the exchange respective lot ratio found in Table **??**. All standard errors are adjusted by Newey-West using the maximum of five order. ***,**,and * denotes statistical significance at the 1%, 5%, and 10% levels, respectively and the t-statistics are shown in parenthesis

SGXIS	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lag SGXIS	0.136***	0.118***	0.137***	0.137***	0.131***	0.132***	0.111***
	(3.41)	(2.93)	(3.48)	(3.46)	(3.33)	(3.30)	(2.83)
Spread Ratio		-0.032***					-0.030***
		(-3.04)					(-2.66)
Volatility Ratio			-0.123***				-0.124***
			(-2.81)				(-2.69)
Depth Ratio				-0.006			-0.008
				(-1.21)			(-1.16)
Volume Ratio					0.044		0.074
					(0.68)		(0.92)
Order Imbalance Ratio						0.001***	0.001***
						(2.86)	(2.91)
mon	-0.043	-0.042	-0.045	-0.045	-0.042	-0.046	-0.047
	(-1.11)	(-1.10)	(-1.16)	(-1.16)	(-1.08)	(-1.19)	(-1.23)
tue	0.032	0.033	0.029	0.029	0.033	0.032	0.030
	(0.93)	(0.96)	(0.84)	(0.87)	(0.97)	(0.93)	(0.86)
wed	-0.001	0.001	-0.002	-0.002	0.001	0.000	0.001
	(-0.02)	(0.03)	(-0.07)	(-0.06)	(0.03)	(0.01)	(0.02)
thu	0.014	0.017	0.010	0.014	0.017	0.015	0.019
	(0.41)	(0.49)	(0.30)	(0.41)	(0.49)	(0.43)	(0.57)
Constant	0.185***	0.390***	0.337***	0.213***	0.174***	0.186***	0.546***
	(5.60)	(5.56)	(5.56)	(5.60)	(4.93)	(5.63)	(6.25)
Index Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	451	451	451	451	451	451	451

Table 5: The table examines the determinants of information share. The dependent variable is SGX information share dummy, which equals to one if the information share is higher than 60% and zero if the information share is lower than 40%. The logit model is used in this table. Subscript t denotes trading day. Spread Ratio is the spread of the index futures traded on SGX divided by the spread of the index futures traded on its domestic exchange. Price $\sigma*$ is the mean-adjusted 5-minutes index futures price volatility. Volume Ratio is the daily traded volume of the index futures on SGX divided by the daily traded volume of its corresponding foreign index futures. Depth Ratio is the Depth of SGX index futures divided by the Depth of its corresponding foreign index futures. Depth is measured as the average 1-second bid and ask total volume. Volume is measured as the number of lots multiply by the exchange respective lot ratio found in Table **??**. All standard errors are clustered at indexes level. ***,**,and * denotes statistical significance at the 1%, 5%, and 10% levels, respectively and the t-statistics are shown in parenthesis.

SGXIS Dummy	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lag SGXIS Dummy	0.810**	0.748**	0.862**	0.818**	0.793**	0.817**	0.797**
	(2.17)	(1.97)	(2.33)	(2.20)	(2.14)	(2.18)	(2.11)
Spread Ratio		-0.283					-0.326*
		(-1.60)					(-1.72)
Volatility Ratio			-1.480*				-1.696*
			(-1.76)				(-1.86)
Depth Ratio				-0.026			-0.014
				(-0.34)			(-0.13)
Volume Ratio					0.225		0.154
					(0.52)		(0.21)
Order Imbalance Ratio						0.012	0.017*
						(1.39)	(1.75)
mon	-0.556	-0.509	-0.529	-0.562	-0.539	-0.593	-0.507
	(-0.97)	(-0.88)	(-0.92)	(-0.98)	(-0.94)	(-1.04)	(-0.87)
tue	0.472	0.527	0.517	0.466	0.488	0.482	0.619
	(1.00)	(1.08)	(1.10)	(0.99)	(1.03)	(1.03)	(1.28)
wed	0.055	0.097	0.078	0.050	0.076	0.051	0.133
	(0.11)	(0.19)	(0.15)	(0.10)	(0.15)	(0.10)	(0.26)
thu	0.267	0.311	0.300	0.271	0.291	0.292	0.428
	(0.55)	(0.64)	(0.62)	(0.55)	(0.60)	(0.61)	(0.89)
Constant	-2.199***	-0.489	-0.476	-2.081***	-2.281***	-2.226***	1.715
	(-4.91)	(-0.48)	(-0.49)	(-3.72)	(-4.63)	(-5.15)	(1.21)
Index Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	314	314	314	314	314	314	314

Table 6: This table tabulates the portfolio trading returns for each country indexes. Perfect information assumes that the trader knows the exact information share of the day while random walk implies that the trader uses the previous day information share. Total number of trades is the average number of transactions per day given that the trading frequency is 1 minute. Average Daily Dollar Profits is the average dollar amount a trader would get every trading day by using our strategy. Average Daily Returns is the returns of a fully collateralized futures contract a trader would get every trading day by using our strategy. Return Volatility is the standard deviation of the portfolio daily returns. Return Skewness is the skewness of the portfolio daily returns. Return Kurtosis is the kurtosis of the portfolio daily returns. Max Trade Drawdown is the maximum loss one would suffer from 1 transaction. Max Daily Drawdown is the maximum aggregate loss one would suffer every other trading day. Sharpe Ratio is computed as Average Daily Returns divided by return volatility.

	Perfect Information (1 min)			
	CHINA	INDIA	JAPAN	TAIWAN
Total number of trades	268	373	373	297
Average Daily Dollar Profits	26	7	53	2
Average Daily Returns	0.47%	0.08%	0.31%	0.62%
Return Volatility	2.80%	0.69%	0.90%	0.68%
Return Skewness	-3.229	-0.477	-0.600	-0.309
Return Kurtosis	21.324	3.700	4.195	3.319
Max Trade Drawdown	-91	-43	-140	-10
Max Daily Drawdown	-1830	-185	-428	-4
Sharpe Ratio	0.169	0.120	0.341	0.913

	Random Walk (1 min)			
	CHINA	INDIA	JAPAN	TAIWAN
Total number of trades	268	373	373	297
Average Daily Dollar Profits	27	7	50	2
Average Daily Returns	0.49%	0.09%	0.29%	0.61%
Return Volatility	2.82%	0.69%	0.92%	0.67%
Return Skewness	-3.207	-0.495	-0.567	-0.361
Return Kurtosis	21.019	3.733	3.999	3.359
Max Trade Drawdown	-91	-43	-140	-10
Max Daily Drawdown	-1830	-185	-428	-4
Sharpe Ratio	0.174	0.128	0.318	0.909

A Appendix

Appendix 1: Trading difference for Nikkei 225 Index Futures, MSCI Taiwan Index Futures, CNX Nifty Index Futures and FTSE China A50 Index Futures trading in SGX.

Exchange	SGX		SGX	
Underlying Stock Index	Nikkei 225 Index		MSCI Taiwan Index	
Multiplier	Y500		US$100	
Minimum Price Fluctuation	Outright : 5 index points		0.1 index points	
	Strategy Trades: 1 index point			
Settlement Procedure	Cash Settlement		Cash Settlement	
Contract Months	6 nearest serial months		2 nearest serial months	
	20 nearest quartely months		12 nearest quartely months	
Trading Costs	Clearing Fee	0.04%	Clearing Fee	0.04%
	Trading Access Fee	0.0075%	Trading Access Fee	0.0075%
Trading Hours		T Session:		T Session:
	Pre -Opening	07:30-07:43	Pre -Opening	08:30-08:43
	Non -Cancel Period	07:43-07:45	Non -Cancel Period	08:43-08:45
	Opening	07:45-14:25	Opening	08:45-13:45
	Pre-Closing	14:25-14:29	Pre-Closing	13:45-13:49
	Non-Cancel Period	14:29-14:30	Non-Cancel Period	13:49-13:50
		T+1 Session:		T+1 Session:
	Pre -Opening	15:00-15:13	Pre -Opening	14:20-14:33
	Non -Cancel Period	15:13-15:15	Non -Cancel Period	14:33-14:35
	Opening	15:15-02:00	Opening	14:35-02:00

Exchange	SGX		SGX	
Underlying Stock Index	CNX Nifty Index		FTSE China A50 Index	
Multiplier	US$2		US$1	
Minimum Price Fluctuation	0.5 index points		5 index points	
Settlement Procedure	Cash Settlement		Cash Settlement	
Contract Months	2 nearest serial months		2 nearest serial months	
	4 nearest quartely months		4 nearest quartely months	
Trading Costs	Clearing Fee	0.04%	Clearing Fee	0.04%
	Trading Access Fee	0.0075%	Trading Access Fee	0.0075%
Trading Hours		T Session:		T Session:
	Pre -Opening	08:45-08:58	Pre -Opening	08:45-08:58
	Non -Cancel Period	08:58-09:00	Non -Cancel Period	08:58-09:00
	Opening	09:00-18:10	Opening	09:00-15:55
	Pre-Closing	18:10-18:14	Pre-Closing	15:55-15:59
	Non-Cancel Period	18:14-18:15	Non-Cancel Period	15:59-16:00

Appendix 2: Trading difference for Nikkei 225 Index Futures, MSCI Taiwan Index Futures, CNX Nifty Index Futures and FTSE China A50 Index Futures trading in their home exchanges.

Exchange	Osaka Stock Exchange		Taiwan Futures Exchange	
Underlying Stock Index	Nikkei 225 Index		TAIEX Index	
Multiplier	Y1000		NT$200	
Minimum Price Fluctuation	0.01 index points		1 index points	
Settlement Procedure	Cash Settlement		Cash Settlement	
Contract Months	Jun and Dec: 10 nearest contract months		2 nearest serial months	
	Mar and Sep: 3 nearest contract months		3 nearest quartely months	
Trading Costs	Clearing Fee (Proprietary)	Y20	Trasaction Fee	NT$12
	Clearing Fee (Customer)	Y20	Clearing Fee	NT$8
	Trading Fee (Proprietary)	Y70	Settlement Fee	NT$8
	Trading Fee (Customer)	Y110	Futures Transaction Tax	0.0002%
Time Zone Difference	1 hour ahead		Same	
Trading Hours	Day Session		Regular Trading Days	
	Pre-Opening	08:00-09:00	Trading Hours	08:45-13:45
	Opening Auction	09:00		
	Regular Session	09:00-15:10		
	Pre-Closing	15:10-15:15		
	Closing Auction	15:15		
Exchange	National Stock Exchange of India		China Financial Futures Exchange	
Underlying Stock Index	CNX Nifty Index		CSI 300 Index	
Multiplier	Re.1		CNY 300	
Minimum Price Fluctuation	0.5 index points		0.2 index point	
Settlement Procedure	Cash Settlement		Cash Settlement	
Contract Months	3 nearest serial months		2 nearest serial months	
			2 nearest quartely months	
Trading Costs	Transactions Tax(SELL only)	0.01%	Trading Fee	CNY 30
	Transaction Charges	0.00185%		
	SEBI Turnover Charges	0.0001%		
	Stamp Duty	0.002%		
Time Zone Difference	2:30 hour later		Same	
Trading Hours	Regular Trading Days		Regular Trading Days	
	Normal Market	09:15-15:30	First Session	09:15-11:30
	Setup Cutoff Time	16:15	Second Session	13:00-15:15
	Trade Modification	16:15		

Appendix 3: This table reports the relative percentage of transacted index futures by the size of the lot in each exchange. (i.e. 27.92 % means that 27.92% of the CNX Nifty Index futures traded on the Singapore Exchange are less than or equal to 2 lots.) All lot sizes for the foreign index futures are scaled such that they are comparable if they are traded at SGX instead. The last column, Ratios, shows the difference between 1 lot sold on SGX against 1 lot sold on the foreign exchange. (i.e. NSE Ratio of 0.21 implies that a lot sold on the NSE is 0.21 times the size of a lot sold on SGX.) SGX: Singapore Stock Exchange, NSE: National Stock Exchange of India, CFFE: China Financial Futures Exchange, OSE: Osaka Stock Exchange, TFE: Taiwan Futures Exchange.

	Lot Sizes					Lot
CNX Nifty Index	≤2	3 to 5	6 to 10	11 to 20	>20	Ratios
SGX	27.92%	18.55%	15.47%	14.28%	23.79%	1.00
NSE	59.11%	20.87%	9.94%	5.79%	4.28%	0.21
A50 / CSI300	≤2	3 to 5	6 to 10	11 to 20	>20	Ratios
SGX	41.73%	23.45%	17.52%	10.62%	6.69%	1.00
CFFE	0.00%	0.00%	0.00%	3.30%	96.70%	15.68
Nikkei 225 Index	≤2	3 to 5	6 to 10	11 to 20	>20	Ratios
SGX	73.31%	17.28%	6.51%	1.99%	0.92%	1.00
OSE	42.28%	18.63%	17.27%	9.60%	12.21%	2.00
Taiex / MSCI Taiwan Index	≤2	3 to 5	6 to 10	11 to 20	>20	Ratios
SGX	76.97%	16.77%	4.75%	0.98%	0.53%	1.00
TFE	58.06%	16.57%	15.86%	6.14%	3.38%	1.76

Appendix 4: This table reports the summary statistics of our sample for each of the exchanges. Panel A summarizes the Nifty Index futures traded on SGX and NSE, panel B summarizes the China's Index futures traded on SGX and CFFEC, panel C summarizes Nikkei 225 index futures traded on SGX and OSE, and panel D summarizes the Taiwan index futures trading on SGX and TAIFEX. Spread is measures as the time-weighted bid-ask spread as a ratio of the futures price. All lot sizes are converted to a relative lot size if they were to trade on SGX, using the lot ratio computed in appendix 3.

A)	CNX Nifty(SGX)			CNX Nifty(NSE)		
Spread (%)	0.0144			0.0081		
	Traded	Bid	Ask	Traded	Bid	Ask
Mean	43,537	100,312	100,336	68,799	72,658	74,784
Median	34,915	101,824	98,596	58,788	66,823	70,161
Std. Dev.	29,934	28,291	30,798	37,429	22,833	24,507
Std.Error	2,744	2,593	2,823	3,431	2,093	2,247
B)	FTSE China A50 Index Futures (SGX)			CSI 300 Index Futures (CFFEX)		
Spread (%)	0.0622			0.0101		
	Traded	Bid	Ask	Traded	Bid	Ask
Mean	179,800	3,093,629	3,038,831	15,254,105	12,462,827	21,304,061
Media	160,213	3,101,777	3,178,359	13,292,795	13,357,524	13,526,378
Std. Dev	104,721	1,548,610	1,460,299	7,715,988	4,812,029	96,066,204
Std. Error	9,442	139,633	131,671	695,727	433,886	8,661,998
C)	Nikkei 225 (SGX)			Nikkei 225 (OSE)		
Spread (%)	0.0316			0.0607		
	Traded	Bid	Ask	Traded	Bid	Ask
Mean	73,598	553,738	535,572	134,954	8,417,672	16,552,275
Median	68,785	518,868	502,762	127,920	7,869,585	15,024,771
Std. Dev.	38,521	203,378	198,292	70,669	3,256,482	5,955,347
Std. Error	4,419	23,329	22,746	8,106	373,544	683,125
D)	MSCI Taiwan Index Futures (SGX)			TAIEX Index Futures (TAIFEX)		
Spread (%)	0.031			0.0117		
	Traded	Bid	Ask	Traded	Bid	Ask
Mean	62,040	749,873	749,935	177,865	4,613,973	4,597,943
Median	38,448	557,481	561,590	174,615	4,446,020	4,281,071
Std. Dev.	200,114	1,874,906	1,741,393	50,593	1,326,955	1,503,804
Std. Error	18,344	171,872	159,633	4,638	121,642	137,853