Price Dynamics and Volatility Transmission in Cross-Listed Equity Index Futures Markets

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THESIS

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This thesis is dedicated to my father Rongxing Gu, and to my mother Yufen Qian, without whom it would never have been accomplished.

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LIST OF ABBREVIATION

ACE	Alternating Conditional Expectations Algorithm
ADF	Augmented Dickey-Fuller process
CFFEX	China Financial Futures Exchange
CFTC	Commodity Futures Trading Commission
CME	Chicago Mercantile Exchange
ECM	Error-Correction Model
FIA	Futures Industry Association
NSE	National Stock Exchange of India
OSE	Osaka Stock Exchange
SGX	Singapore Exchange
SIMEX	Singapore Monetary Exchange
TSE	Tokyo Stock Exchange

SUMMARY

This dissertation investigates the price dynamics and volatility transmission between the economically equivalent but competing equity index futures traded on the onshore and the offshore markets. 10 most actively cross-traded equity index futures and the 4 underlying indices on China, Indian, Japan, Singapore and the US markets are paired and studied with multiple methods. I find consistent results that are robust across approaches and complement each other.

The evidences show that the futures contracts with same patterns (contract month and currency) are traded more actively than other contracts design. The onshore and offshore futures which are based on different underlying indices are less significant in maintaining and adjusting to the price equilibrium. There also seem to be more long-run holding strategies on the offshore market. The equilibrium between the onshore and offshore futures is more significant and much closer to a one to one fair relationship than the equilibrium between the futures and the underlying index. The two more actively traded futures tend to have more significant equilibrium and meander more narrowly around the equilibrium prices.

The error correction representations between the pair of products are stable over time. The trading activities effectively drive the short-run dynamics revert to the long-run price equilibrium. The actively traded futures (CIF, NIF, CMY, SIN, JNM and SSI) tend to lead the underlying index, while the less actively traded futures (SFC, JNI, NIY and NK) tend to be leaded by the underlying index in the price discovery between futures and the underlying index. In the price discovery between onshore and offshore futures, the actively traded onshore futures (NIF, CMY and JNM) tend to lead the less actively traded offshore futures (SIN, SSI, NIY and NK), while the lower volume onshore futures (JNI) tend to be leaded by the higher volume offshore futures (SSI at the SGX) and the primary offshore futures (NIY at the CME). But it (JNI) still leads the lowest volume offshore futures (NK). However, the error correction adjustment between CIF and SFC which are based on different underlying indices is insignificant. Meanwhile, higher volume futures always lead the lower volume futures in the prices discovery.

The ECM-GARCH-X models jointly estimate the conditional mean and the conditional volatility equations. The squared deviations from equilibrium have significant impacts on the uncertainty in the system. It tends to increase the uncertainty in the system of two futures, while decrease the uncertainty in the system of futures and the underlying index. There is significant information transmission through volatility spillover between the pair of equity index products. The previous unpredictable price shocks positively impact on current conditional volatility, but decay very fast.

Impulse response analysis reveals fast response of 2-3 minutes between the equity index futures and the underlying index, and even faster response of 1-2 minutes between the two futures. Geweke frequency decomposition reveals very large instantaneous feedback between the pair of products – larger between the two futures than between futures and the underlying index. Impulse response analysis, forecast error variance decomposition and Geweke frequency decomposition all disclose the consistent leading product in the price dynamics.

Overall, this study provides strong empirical evidence that the trading volume is a critical factor in determining which of two related equity index products will lead in the price dynamics. This study extends past studies of unilateral lead/lag relationship in the price dynamics, offers consistent explanations to summarize non-uniform prior findings, and supplements the literature by analyzing the pairs of recently developed equity index futures.

1. INTRODUCTION

1.1 Introduction

The onshore and offshore trading of equity index futures has been growing as the global financial markets become more and more integrated. Investors want easy and low cost access to different markets. By getting exposure to a foreign equity index from an offshore market, investors can greatly reduce the cost of accessing foreign market. Meanwhile, exchanges and index providers are keen to attract investors by developing new products. In some cases, the offshore exchange might be more developed and may launch equity index futures before any onshore exchange.[1] In other cases, the domestic exchange may introduce new contracts based on some popular world stock market indices which already have active derivative trading, allowing domestic investors to access world equity market.[2] Since the underlying equity indices are the same or highly correlated and the futures prices are based on the prices of underlying index, we would expect the closely related equity index futures to have close relationships in terms of their price dynamics and information transmission (which is linked to price volatility).

There are different advantages regarding onshore vs. offshore listing of the equity index futures. The onshore market might have advantages in terms of local knowledge, proximity to information sources, and no language or culture barriers, among others, while the offshore market might have advantages in reputation as a more experienced exchange, flexible design of contracts and trading schemes, world currency and foreign investors, among others. As long as there are onshore and offshore trading practice,

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[1] For example, the Nikkei 225 index futures was first launched at Singapore Exchange (SGX, then the Singapore International Monetary Exchange, SIMEX) in September 1986, while the domestic Nikkei 225 futures was launched at Osaka Stock Exchange (OSE) in September 1988. Similarly, the FTSE China A50 index futures was first launched at SGX in September 2006, while CSI 300 index futures was domestically launched at China Financial Futures Exchange (CFFEX) in April 2010, among others.

[2] For example, S&P 500 and DJIA index derivatives in rupees are now traded at Indian’s National Stock Exchange (NSE).

the price dynamics and volatility transmission of equity index futures on different markets are of important interest to regulators, academia and practitioners.

This dissertation focuses on the price dynamics and volatility transmission of equity index futures cross-listed on the onshore and offshore markets. Research questions explored include: Where does price discovery happen in markets with competing but economically equivalent instruments? How does information percolate through related markets? Which market characteristic is more likely to attract price discovery? Evidence gathered from this study may provide insights for exchanges to develop more successful contracts and compete better, and provide insights for investors to develop better strategies of hedging or speculating.

For these purpose, the most actively cross-traded equity index futures products on a range of markets - China, India, Japan, Singapore and the US have been studied simultaneously. TABLE I provides a list of the equity index futures and the underlying indices studied in this dissertation. A total of 10 futures products based on the 4 underlying indices at 5 major international and domestic exchanges are studied. Chapter 2 describes the equity index and futures products in this study, including the trading scheme, contract designs and volume statistics, etc. The detailed descriptions of 1-minute prices data series used in the modeling are provided in Chapter 3.

I use various methodologies to discover consistent conclusions and to protect against spurious findings from different markets. Chapter 4 studies price dynamics by using Engle – Granger cointegration test, standard and moving error correction model. Previous studies find it is either the futures lead the underlying index or the underlying index leads the futures, and it is mostly the offshore futures lead the onshore futures since the international exchanges are generally more advanced and experienced. Here I find the price discovery is not necessarily unilateral and the trading volume is an important factor in determining the leader. The more actively traded products will play a more dominant role in maintaining the price equilibrium. My conclusions reconcile the contradictory findings of unilateral lead and lag relationships in previous studies.

In Chapter 5, I explore 1-minute volatility transmission between two related equity index products by using the ECM-GARCH-X model. The conditional mean equations obtain consistent conclusions as in standard (moving) error correction price dynamics. In the volatility equations, the squared deviation from long-run price equilibrium has significant effect on the conditional volatility. The larger squared deviations imply lower volatility between futures and the underlying index, while the larger squared deviations imply higher volatility between the two futures. There is significant volatility spillover between the related markets. Unpredictable price shocks significantly increase current conditional volatility but decay fast in conditioning future volatility.

In Chapter 6, three additional methodologies are used to investigate the price interaction between the pairs of equity index products. These methods are impulse response analysis, forecast error variance decomposition and Geweke frequency decomposition. The findings are from different perspective but are highly consistent and supplement each other.

Finally, Chapter 7 concludes the findings I obtained from the various methodologies. Overall, I design this study in a comprehensive methodology system which includes the first moment price, second moment volatility and other evidence of the dynamics. I work with 1 minute trading data for a three month period. My conclusions are consistent with each other and are comprehensive from different perspective. Most importantly, my conclusions can summarize previous findings in the literature of this topic. In addition, I supplement the literature by providing evidence on recently developed onshore and offshore pairs of equity index futures (including pairs of China and India equity index futures which have not been fully studied yet).

TABLE I EQUITY INDEX FUTURES PRODUCTS IN THIS STUDY

Country	Index	Exchange	Futures*	Date of Introduction	Trading Hours	Contracts Month	Dominated Currency
China	CSI 300	CFFEX	CIF	04/16/2010	9:15 - 11:30; 13:00 - 15:15	Current and next month, next two calendar quarters (four total)	CNY
	FTSE China A50	SGX	SFC	09/05/2006	9:00 - 15:25; 16:10 - 2:00	2 nearest serial months and Mar, Jun, Sep and Dec months on a 1 year cycle	USD
India	S&P CNX Nifty	NSE	NIF	06/12/2000	9:15 - 16:15	the near, the next and the far month (3 month trading cycle)	IDR
	S&P CNX Nifty	NSE	CMY**	01/01/2008	9:15 - 16:15	the month, the next and the far month (3 month trading cycle)	IDR
	S&P CNX Nifty	SGX	SIN	09/2000	9:00 - 18:10; 19:15 - 2:00	2 nearest serial months and Mar, Jun, Sep and Dec months on a 1 year cycle	USD
Japan	Nikkei 225	OSE	JNI	09/1988	9:00 - 15:15; 16:30 - 3:00	5 month in the March quarterly cycle: Mar, Jun, Sep, Dec	JPY
	Nikkei 225	OSE	JNM**	07/2006	9:00 - 15:15; 16:30 - 3:00	the nearest 2 months from the March quarterly cycle plus the nearest 3 months which do not overlap the March cycle	JPY
	Nikkei 225	SGX	SSI	09/1986	7:45 - 14:25; 15:15 - 2:00	3 nearest serial months and 12 nearest quarterly month on the Mar, Jun, Sep and Dec cycle	JPY
	Nikkei 225	CME	NIY	02/23/2004	17:00 - 16:15; Trading halted 15:15 – 15:30	12 quarterlies and 3 serials months	JPY
	Nikkei 225	CME	NK	09/25/1990	Open Outcry: 8:00 – 15:15 Globex: 17:00 –16:15; Trading halted 15:15 – 15:30	Open Outcry: four quarterly months; Globex: two quarterly months	USD

* The equity index futures contracts are denoted according to the RIC root applied by Thomson Reuters.

** Mini contract.

Due to the low volume of average daily trading, CME E-mini and E-micro S&P CNX NIFTY futures, SGX Mini Nikkei 225 futures (JPY), SGX USD Nikkei 225 futures, CME E-mini Nikkei 225 (JPY) futures are not included in this study.

1.2 Literature Review

There is a large body of literature about the dynamics between derivatives and the underlying asset. The price dynamics and volatility transmission between equity index futures (sometimes include options) and the underlying index have been well studied for the majority of major markets and indices. Most empirical research has studied the intra-day trading data and found significant lead and lag relationships between futures and the underlying index. However, there is no studies have yet offered unifying conclusions. Most studies, including Kawaller, Koch and Koch (1987), Stoll and Whaley (1990), Chan (1992), Tse (1999), Tse, Bandyopadhyay and Shen (2006), find that equity index futures tend to lead the underlying index over periods from few minutes to several hours. Thus the futures market dominates in the price discovery process. Typically, this is explained by noting that transaction costs are lower and liquidity are higher on the futures market, while it is costly to trade a basket of stocks. Some index stocks might even be inactive in trading. Other studies find the index market tends to lead in the price discovery process, such as Wahab and Lashgari (1993) use the daily data, and Yang, Yang and Zhou (2012) use the initial stage of futures trading.

However, the dynamics between onshore and offshore trading of equity index futures have not yet been fully explored perhaps due to less offshore listing of foreign equity index futures in the past. In recent years, many exchanges have begun listing futures or options based on foreign equity indices. This has yielded many more pairs of onshore and offshore equity index futures on the same or highly correlated underlying indices.

Earlier studies of price dynamics between onshore and offshore index futures generally employed daily price data, while recent studies tend to use 1 minute or 5 minute intraday trading data. Bacha and Vila (1994) studied the Nikkei 225 stock index and its futures contracts traded on the Singapore Monetary Exchange (SIMEX, later Singapore Exchange (SGX)), the Osaka Stock Exchange (OSE) and the Chicago

Mercantile Exchange (CME). They concluded that the futures trading did not increase the volatility of the underlying index market, and the opening of new futures market would reduce the volatility on existing market. Booth, Lee and Tse (1996) studied the Nikkei 225 stock index futures traded on OSE, SIMEX and CME. They found that none of the markets Granger-caused the other two markets on a daily basis, but within one day, causality ran from the last trading market(s) in the 24-hour trading sequence.

Ito and Lin (2001) studied the Nikkei 225 futures traded on OSE and SIMEX and found that an increase in margin requirement on one exchange reduced its trading volume and shifted trade to the competing exchange. Frino and West (2003) studied the Nikkei 225 futures traded on OSE and SGX. According to their study, transaction cost hypothesis was supported. With lower trading costs, returns on Singapore Nikkei futures led the returns on Osaka Nikkei futures. Both futures led the underlying index. Covrig, Ding and Low (2004) studied the Nikkei 225 index on Tokyo Stock Exchange and the Nikkei 225 futures on OSE and SGX. They found that the satellite market (SGX) contributed disproportionately higher to price discovery in terms of its share of market trading volume.

Beside these studies on Japanese equity index products, Roope and Zurbruegg (2002) studied the TAIFEX futures on Taiwan Futures Exchange and the TiMSCI futures on SGX. They also found offshore index futures led the price discovery process and the futures contracts had a larger information share than the underlying index. The more detailed descriptions of these studies are provided in TABLE II.

However, the current empirical research about onshore and offshore equity index futures is limited to futures only on Japanese and Taiwanese equity indices. Furthermore, these studies just looked at one pair of index futures at a time. Although their conclusions are generally consistent, but the limited subject of study means their findings might be due to particular samples rather than some unifying dynamics. In addition, some past studies used daily data, which cannot fully reflect the interaction between products in the trading day. The volatility transmission is rarely studied and there is no intraday evidence. Therefore, the intraday price dynamics and volatility transmission between markets need to be explored. Moreover, there are more pairs of onshore and offshore traded equity index futures have been developed in recent years, including the pairs of China and India equity index futures, which yield more onshore and offshore pairs to be studied.

So in my dissertation, I study a wider range of markets and products to obtain more unifying conclusions, as well as use high frequency 1 minute data to investigate the intra-day price dynamics and volatility transmission between the products. This study also allows me to offer new evidence on dynamics of recently developed equity index futures.

TABLE II

RELEVANT RESEARCH ON PRICE DISCOVERY BETWEEN ONSHORE AND OFFSHORE EQUITY INDEX FUTURES

	Research	Products	Data	Methodologies	Findings
1.	Bacha, O. and Vila, A. F., (1994)	Nikkei 225 index and its futures contracts traded on SIMEX, OSE and CME	Daily data from 11/1985 to 08/1991.	Comparison of interday volatility ln[Ct/C(t-1)] and intraday volatility ln(Ht/Lt) across markets; Wilcoxon tests and F-tests	Trading of stock index futures does not increase the volatility of the underlying stock market; the opening of new futures market will reduce the volatility on existing markets.
2.	Booth, G.G., Lee, T.H. and Tse, Y. (1996)	Nikkei 225 index futures traded on OSE, SIMEX and CME	Daily open and close futures prices of nearest contracts until the maturity month from 12/03/1990 to 05/18/1994. (900 observations)	Volatility during trading and non-trading hours; Unit root and cointegration test; Variance decomposition and impulse response analysis; Granger causality	Relevant information is revealed during the Japanese business hours; each trading market is informational efficient by incorporating all relevant information; none of the markets Granger-cause the other two markets on a daily basis, but within one day, causality runs from the last trading market(s) in the 24-hour trading sequence.
3.	Ito, T. and Lin, W. L. (2001)	Nikkei 225 futures traded on OSE and SIMEX	Daily data of Nikkei 225 index and the settlement prices of futures contracts on OSE and SIMEX from 09/03/1988 to 01/28/1994	Regression of trading volume, returns and price volatility on event dummy variables for margin changes and spillover effects from the related markets; two-stage GARCH estimation of volatility	An increase in margin requirement on one exchange reduces its trading volume and shifts trade to the competing exchange. Both conditional price volatility and returns are not systematically affected by changes in margin requirements.

TABLE II

RELEVANT RESEARCH ON PRICE DISCOVERY BETWEEN ONSHORE AND OFFSHORE EQUITY INDEX FUTURES

	Research	Products	Data	Methodologies	Findings
4.	Roope, M. and Zurbruegg, R. (2002)	TAIFEX futures on Taiwan Futures Exchange; TiMSCI futures on Singapore Exchange Derivatives Trading market	Average of two closest prices either side of the 5-min marker from 9:05 to 11:55; 01/11/1999 to 06/30/1999	Error-correction model; Gonzalo and Granger (1995) Information shares; Hasbrouck (1995) Information shares	Offshore index futures dominate the price discovery process, and the futures contract has a larger information share than the underlying index.
5.	Frino, A. and West, A (2003)	Nikkei 225 futures on OSE and SGX	Return innovations derived from ARMA model are used to proxy for true 1-minute returns of last trading price during the period when both exchanges are open; from 08/10/1998 to 09/18/1998	Engle-Granger (1987) and Johansen (1991) cointegration tests; Error-correction model	Transaction cost hypothesis is supported; with lower trading costs, returns on Singapore Nikkei futures lead the returns on Osaka Nikkei futures; both futures lead the underlying index.
6.	Covrig, V., Ding, D.K. and Low,B.S. (2004)	Nikkei 225 index on Tokyo Stock Exchange; Nikkei 225 futures on OSE and SGX	Average of the bid and ask quotes; 1-minute interval from 9:00 to 11:00 and 12:30 to 15:00; from 03/13/2000 to 06/13/2000	Gonzalo and Granger (1995) common factors components method; Hasbrouck (1995) information share; Multivariate Granger causality test	Futures markets contribute 77% to price discovery; Singapore market contributes 42% of the futures and 33% of the all; satellite market (SGX) contributes disproportionately higher to price discovery in terms of its share of market trading volume.

TABLE III

RELEVANT RESEARCH ON PRICE DISCOVERY BETWEEN EQUITY INDEX FUTURES AND THE UNDERLYING INDEX

	Research	Products	Data	Methodologies	Findings
1.	Kawaller, Koch and Koch (1987)	S&P 500 index and index futures	Minute-to-minute data on the prices of nearby S&P 500 futures contracts and the S&P 500 index for all trading days during 1984 and 1985.	Three-stage least squares regression of simultaneous equations	Futures and index are simultaneously related on a minute-to-minute basis; futures prices lead cash prices between 20 and 45 minutes, but cash prices lead futures prices rarely beyond 1 minute; the lead/lag relationships are remarkably stable across different days.
2.	Kawaller, Koch and Koch (1990)	S&P 500 index and index futures	Minute data on all values of nearby S&P 500 futures contracts and S&P 500 index, for every business day in the fourth quarters of 1984-1986.	Sample variance of observations at daily or 30-minute intervals; Granger tests of the volatility measures for futures and index at daily and 30-minute intervals.	Futures volatility is greater than index volatility; both futures and index volatility increase directly with futures trading volume; there is no systematic pattern of futures volatility leading index volatility, or index volatility leading futures volatility.
3.	Stoll and Whaley (1990)	S&P 500 index and index futures; Major Market Index (MMI) and MMI futures	Five minute price data - S&P 500 and index futures from 04/21/1892 to 03/31/1987; MMI index and futures from 07/23/1984 to 03/31/1987.	Serial correlation examination; ARMA model control for the effects of infrequent trading and bid/ask spread; use IBM to proxy for the true index returns to mitigate the effect of infrequent trading.	S&P 500 and MM index futures returns tend to lead stock market returns by about 5 minutes, occasionally as long as 10 minutes or more; lagged stock index returns have a mild positive predictive impact on futures returns.
4.	Chan (1992)	Major Market Index and both MMI and S&P 500 futures	Two sample periods – 08/1984 through 06/1985 and 01/1987 through 09/1987; last price observation in five-minute intervals.	Autocorrelation and cross-correlation; regression model to examine lead-lag relation between index and futures, between futures and component stocks, under bad news and good news, under different intensities of trading activity, and under market-wide movement.	Strong evidence that futures leads cash index and weak evidence that cash index leads futures; The asymmetric lead-lag relation holds between the futures and all component stocks; futures market is the main source of market-wide information.

TABLE III

RELEVANT RESEARCH ON PRICE DISCOVERY BETWEEN EQUITY INDEX FUTURES AND THE UNDERLYING INDEX

	Research	Products	Data	Methodologies	Findings
5.	Wahab and Lashgari (1993)	S&P 500 index and futures; Financial Times index and futures	Daily closing index and futures prices for the period between 01/04/1988 and 05/30/1992	Cointegration and causality test; error correction model; Farely-Hinich test for parameter stability.	Index and futures markets are cointegrated and consistent with market efficiency; Index and futures prices mostly simultaneously related and lagged interactions are rather weak; the spot-to-futures lead appears to be more pronounced than the reversed lead; futures price responses to disequilibrium in spot price stronger than do spot price to last period's futures disequilibrium.
6.	Fleming, J., Ostdiek, B., and Whaley, R.E. (1996)	S&P500 index and index futures, S&P100 index and call and put options	5-min interval returns dropping the first 10 minutes at the opening of trade, from 01/1988 to 03/1991.	ARMA (2,3) to purge infrequent trading and bid/ask price effects; multiple regression model include an error correction term to estimate the lead/lag relationship.	Both futures and options returns lead index returns, futures tend to lead the options; the market with the lowest overall trading costs will react most quickly to new information.
7.	Choudhry, T. (1997)	Australian All Ordinary Index and its futures, Nikkei 500 index and Nikkei stock average futures; Hongkong Hang Seng index and its futures.	Daily returns of the index and futures markets from 01/1990 to 12/1994. Two sets of futures prices based on different expiration dates of the contracts are used.	Johansen cointegration test and Bivariate GARCH-X model.	The deviations from equilibrium have significant positive effect on the index market in Japan, and have significant positive effect on the futures market in Australia.

TABLE III

RELEVANT RESEARCH ON PRICE DISCOVERY BETWEEN EQUITY INDEX FUTURES AND THE UNDERLYING INDEX

	Research	Products	Data	Methodologies	Findings
8.	Abhyankar, A. (1998)	FTSE 100 index and index futures	5-min interval price for the nearest FTSE 100 index futures, four contracts maturing in MAR92, JUNE92, SEPT92, and DEC92 are examined separately without splicing together, and the FTSE 100 index.	Traditional linear Granger causality tests; modified Baek and Brock nonparametric test for detecting any remaining nonlinear causality after the linear effect.	Linear causality is unidirectional from the futures to the index, FTSE index futures tend to lead the index by about 5-15 minutes; nonlinear causality is bidirectional between the two.
9.	Tse (1999)	Dow Jones Industrial Average (DJIA) index and the index futures	Minute-by-minute data for the six months period of 11/1997 to 04/1998	Error-correction model; Hasbrouck (1995) cointegrating model; bivariate EGARCH model.	Most price discovery takes place at the futures market; there is significant bidirectional information flow, futures volatility spillovers to stock market more than vice versa; both market exhibit asymmetric volatility effects, bad news having a greater impact on volatility than good news.
10.	Chu, Q.C., Hsieh, W.G., and Tse, Y. (1999)	S&P 500 index, index futures and S&P 500 SPDRs	Intraday price series for the year 1993 with Harris et al. (1995) matching technique to identify the trading tuples with the closest trading time.	Johansen cointegration analysis; vector error correction model (VECM); Gonzalo and Granger's (1995) common factor model.	The three index markets are a cointegrated system driven by the same common trend; futures market is the leading market and serves the most significant price discovery function, SPDRs contribute the second place, while spot index contributes the least.

TABLE III

RELEVANT RESEARCH ON PRICE DISCOVERY BETWEEN EQUITY INDEX FUTURES AND THE UNDERLYING INDEX

	Research	Products	Data	Methodologies	Findings
11.	Bhar, R. (2001)	The futures contract (SPI) and the All Ordinary Index (AOI) in Australia	Daily settlement prices of the near quarter month futures contract covering 10-year period from 01/1989 to 12/1998.	Unit root and cointegration test with structure break; Bivariate EGARCH-X model; and intervention analysis.	The futures and the underlying index are cointegrated even the futures contract specification has changed. The cointegrating residual is significant in the equations of mean return and conditional volatility.
12.	Tse, Bandyopadhyay and Shen (2006)	DJIA index and its three derivatives: the DIAMOND ETF, the floor-traded regular futures, and the electronically traded mini futures	Intraday trades and quotes for the products for May through July, 2004	Hasbrouck (1995) information share model; analysis for derivatives of the S&P 500 index as a robustness check.	The E-mini futures contribute the most to price discovery, followed by the ArcaEx DIAMOND. The DJIA index and regular futures contribute least to price discovery; multi-market trading ensures greater pricing efficiency; Informed traders favor electronic trading because of immediate and anonymous trade execution.
13.	Yang, J., Yang, Z. and Zhou, Y (2012)	CSI 300 index futures and the underlying index	5-min prices data from 04/16/2010 to 07/30/2010 for the nearby futures contract and switch to the next nearby contract on the first day of delivery month.	Recursive Cointegration Tests and asymmetric ECM-GARCH model.	The cash market plays a more dominant role in the price discovery process; There is strong bidirectional intraday volatility dependence between two markets.

2. EQUITY INDEX FUTURES MARKETS AND PRODUCTS

2.1 The Market of Equity Index Futures

Since the advent of world's first equity index futures in February 1982 at Kansas City Board of Trade, the equity index futures has experienced 30 years of development. According to Bank for International Settlements statistics on exchange traded derivatives, the turnover of equity index futures for all markets in 2012 amounted to 104,022.20 billion of US dollars, and amounted to 138,361.70 billion of US dollars in 2013 with 36.31% in north America, 22.00% in Europe, 40.66% in Asia and Pacific, and 1.04% in other markets.[3]

2.2 Equity Index Futures Products in Study

2.2.1 The Pair of Chinese A-share Index Futures

The pair of Chinese A-share[4] index futures have different underlying index. CSI 300 index futures have been traded at China Financial Futures Exchange (CFFEX) since April 16, 2010 and FTSE China A50 index futures have been traded at Singapore Exchange (SGX) since September 5, 2006. The underlying indices are CSI 300 index and China A50 index respectively. The daily price correlation of the two indices was 0.9822 for the period from July 21, 2003 to July 31, 2012.

1. CSI 300 Index

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[3] Table 23A: Derivative financial instruments traded on organized exchanges, http://www.bis.org/statistics/extderiv.htm.

[4] 'A' shares are securities of companies incorporated in Mainland China. They are traded on the Shanghai or Shenzhen stock exchanges, quoted in Chinese Yuan (CNY). These shares are traded by Chinese or international investors (under the China Qualified Foreign Institutional Investors – QFII regulations).

CSI 300 index is the first equity index jointly launched by the Shanghai Stock Exchange and the Shenzhen Stock Exchange. CSI 300 index sets the base point as 1000 on the base day of December 31, 2004. It comprises 300 A-share stocks with the largest market capitalization and liquidity. With 300 constituent stocks, CSI 300 index covers around 60% of the overall market capitalization and is a good representative for investors to track the overall market performance.

Figure 1 is the performance of CSI 300 index over the 10 years' period from Jan 4, 2002 (which is computed retroactively from the base day back) to Jul 31, 2012. Visually, the volatility of index price was high during the period of 2006 to 2009. This was a volatile period for the Chinese stock market, during which the CSI 300 index price increased from 941.43 on January 4, 2006 to the maximum of 5,877.2 on October 16, 2007, then decreased to the minimum of 1627.76 on November 4, 2008, and ended at 3,575.68 on December 31, 2009. This period also experienced the financial crisis and the downturn of world economy.

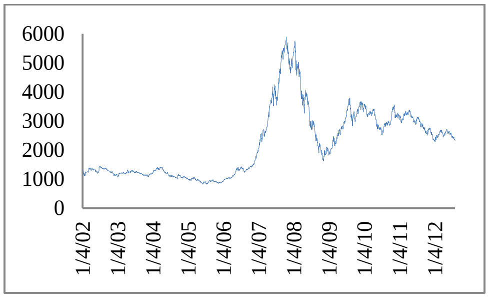

Figure 1. **Daily Price Levels of CSI300 Index**

Source: RESSET database, www.resset.cn.

2. CFFEX CSI 300 Index Futures

To organize and arrange the trading of financial derivatives, China Financial Futures Exchange (CFFEX) was founded on September 8, 2006 - three days after the launch of FTSE China A50 futures at

Singapore Exchange (SGX). Although the mock trading was started in November 2006, the real trading of CSI 300 futures hadn't begun until April 16, 2010. The introduction of CSI 300 futures brought an institutional change to Chinese stock market, which made the short selling and margin trading possible in the market. Before that, investors can only trade on "long" position to make a profit, which made the stock market a unilateral market.

There are four CSI 300 futures contracts in trading, namely the current month, the next month and the next two calendar quarters. The last trading day is the third Friday of the contract month and it postpones to the next business day if it is a public holiday. The value of one contact is 300 Chinese Yuan (CNY) multiplying the index. The margin requirement lists on the general contract specification is 12%, but in actual settlement, the exchange charged 15% for the recent two contracts and 18% for the latter two contracts. The exchange has begun to use the 12% margin since July 2012. Cite the quote of contract IF1205 which expired in May, 2012, the value of one contract was 786,780 CNY (300 * benchmark price 2622.6), and the margin deposit amounted to 118,017 CNY with the 15% requirement. The capital outlay of trading CSI 300 index futures is very high which would restrict the entrance of small individual investors. With this capital requirement, market participants tend to be institutional investors, private equities and rich individuals, who have relative abundant funds.

TABLE IV TRADING STATISTICS FOR CSI300 INDEX FUTURES

	Trading Volume (Contracts)	Year-End Open Interest (Contracts)	Trading Value (CNY)
2010	45,873,295	29,805	41,069,876,729,580
2011	50,411,860	48,443	43,765,855,216,500
2012	105,061,825	110,386	75,840,677,877,960
2013	193,220,516	119,534	140,700,232,320,180

Source: www.cffex.com.cn.

The trading of CSI 300 index futures has grown very fast since its introduction. TABLE IV shows some yearly statistics. According to the annual statistics published by the Futures Industry Association (FIA), CFFEX ranked 29th among top Derivatives Exchanges worldwide by number of futures traded and/or cleared in 2010, and ranked 19th in 2013.

Figure 2 exhibits the average daily trading volume and the month-end open interest for each month since April 2010 to July 2012. The average daily volume increased very fast in the first few months, then declined for a while since August 2010, and began to increase again since April 2011. The month-end open interest kept on growing. The monthly average ratio of open interest to trading volume was 0.1648 for this period. This ratio could indicate the level of long-term versus short-term trading strategies. It suggests that there is much more short-term speculative trading than long-term holding in CSI 300 index futures market. The low open-interest to volume ratio has also been a concern of the administration authority. One possible reason could be the high capital tie up which might induce traders to close out the position daily and avoid the holding risk.

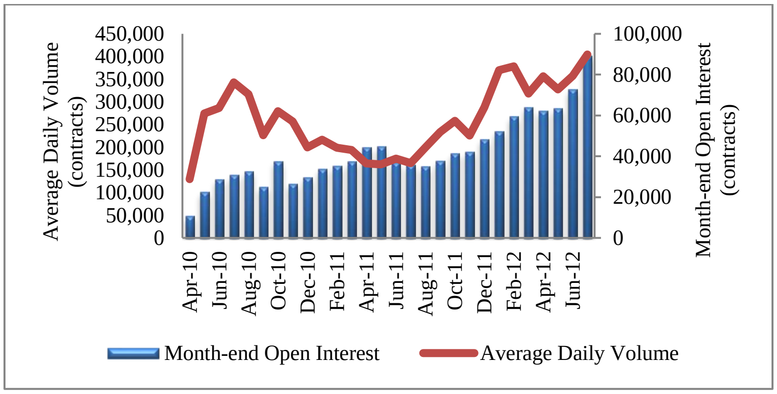

Figure 2. Average Daily Volume and Month-End Open Interest for CSI300 Index Futures

Source: www.cffex.com.cn.

3. FTSE China A50 Index

The FTSE China A50 index is a real-time tradable index consisting of the largest 50 A share companies by full market capitalization on both Shanghai and Shenzhen stock exchanges. The stocks are free-float weighted (exclude government ownership) and liquidity screened to ensure the index is tradable. The index was launched on Dec. 13, 2003 and the base date was July 21, 2003 with a base value of 5000. Its performance from July 21, 2003 to July 31, 2012 is exhibited in Figure 3. After the quarterly turnover review in June 2012, the index had a net market capitalization of 2,385,035 million in CNY.[5] These largest 50 A shares accounts to 46.39% of the FTSE China A all share index as reported in the monthly report of July, 2012.

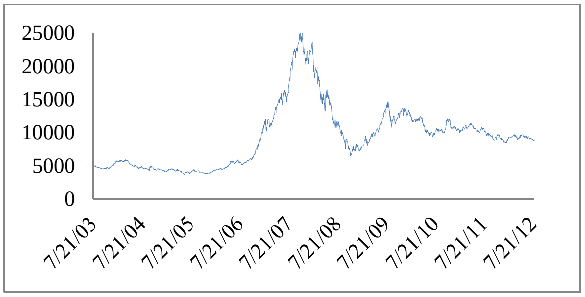

Figure 3. Daily Total Return Price Levels of FTSE A50 Index in CNY

Source: FTSE Group, total return data in CNY, as at July, 31, 2012

4. SGX FTSE China A50 Index Futures

The Singapore Exchange listed FTSE China A50 futures is the only offshore futures contracts on Chinese A-share market. It was launched on Sept. 5, 2006. FTSE China A50 futures' trading provides international investors an easy access to Chinese stock market. But soon after the futures introduction, Shanghai Stock Exchange filed a lawsuit against FTSE XINHUA Co., claiming that the use of its A share data to compile A50 index for futures trading was unauthorized.

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[5] FTSE China A50 index monthly report, July, 2012. www.ftse.com

The trading of A50 futures was tiny after its start, with only 1,974 and 1,879 trades in the first two months. To attract investors and increase its competitiveness, Singapore Exchange made several contract modifications in both November 2007 and August 2010, such as reduced the contract sizes, margin requirements and entry barriers, as well as extended the trading hours. The trading volume of A50 futures was fairly low from 2006 to 2010. However, it started increasing after the substantial revision of contract specifications, the settlement of preceding lawsuit in March 2010, and especially the development of CSI300 index futures. On Jan. 27, 2012, the Commodity Futures Trading Commission (CFTC) certified the FTSE China A50 index futures to be tradable by individuals in the U.S., which further increased its market accessibility to international investors. According to the Annual Volume Survey (2013) of Futures Industry Association, the trading volume of FTSE China A50 futures has increased from 34,232 contracts in 2008 to 21,906,479 contracts in 2013. Its percentage change ranks No.1 among worldwide equity index futures and options over the five years period.

FTSE China A50 index futures have a contract size of US $1 times the index value. The contracts are traded at 2 nearest serial months and Mar, Jun, Sep and Dec quarterly months on a 1-year cycle. The last trading day is the 2nd last business day in the contract month. The trading of contract is electronic only, no open outcry. The T session and T+1 session trading provide a total trading hours of nearly 17 hours. As on Mar 1st 2012, the margin requirements are US$500 for initial and US$400 for maintenance.

Figure 4 plots the average daily volume and the month-end open interest of the A50 futures for each month from January 2011 to July 2012. In this plot, the mean ratio of open interest to volume is around 4.08, which is significantly different with the onshore CSI 300 futures trading. This ratio indicates there might be more long-run holding strategies for China A50 index futures at the offshore exchange.

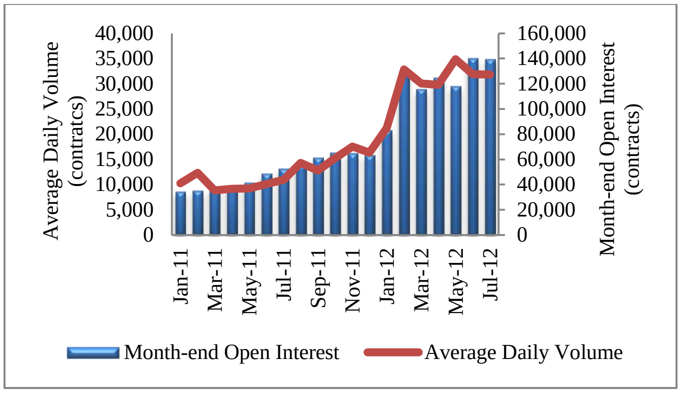

Figure 4. **Average Daily Volume and Month-End Open Interest for FTSE China A50 Index Futures**

Source: Monthly Statistical Report, Singapore Exchange.

2.2.2 The Pair of India Index Futures

The onshore and offshore India equity index futures have the same underlying index of S&P CNX Nifty Index. The domestic futures on S&P CNX Nifty index began trading on June 12, 2000 at the National Stock Exchange of India (NSE), while the offshore S&P CNX Nifty index futures began trading in September 2000 at Singapore Exchange (SGX). The trading of S&P CNX Nifty derivatives is very prosperous. According to the statistics of Futures Industry Association (FIA) in 2011, the S&P CNX Nifty index futures traded on NSE had a turnover of 123,144,880 contracts and ranked 12th among world's leading equity index futures and options contracts.[6]

1. S&P CNX Nifty Index

S&P CNX Nifty Index is a free float adjusted and market capitalization weighted index of 50 blue chip stocks listed on the National Stock Exchange (NSE) of India. These stocks are well diversified and cover 23 sectors of the economy. The index tracks the behavior of the largest and most liquid Indian

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[6] Annual Volume Survey, Futures Industry Association, FIA, http://www.futuresindustry.org

securities and is used for a variety of purposes such as benchmarking fund portfolios, index based derivatives, structured products, ETFs and index funds. The index is reviewed twice a year. To be included in the index, the security should have been traded at an average impact cost of 0.50% or less during the last six months for 90% of observations, for the basket size of Rs. 20 million, and also the security should have free float of at least 10%. S&P CNX Nifty index set the base day on November 3, 1995 with an index value of 1000 and a base capital of Rs. 2.06 trillion. As on June 29, 2012, the index has a free float market capitalization of 1,648,700 Rs. Cr., accounting for about 66.96% of the total free float market capitalization of the universe of the stocks traded on NSE.[7]

Figure 5 shows the performance of S&P CNX Nifty index for the period from November 3, 1995 to August 31, 2012. From 2004, the Indian stock market began to take off, but dropped deeply in 2007 and 2008, while reverted since 2009 and stagnated in 2011 and 2012.

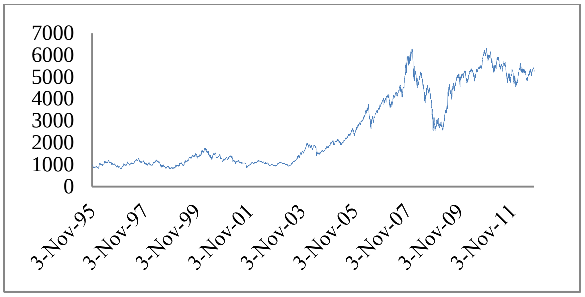

Figure 5. **Daily Close Price Levels of S&P CNX Nifty Index**

Source: http://www.nse-india.com

2. NSE S&P CNX Nifty Index Futures

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[7] Factsheet of the index, http://www.nseindia.com/content/indices/ind_cnx_nifty.pdf

NSE started the trading of futures based on S&P CNX Nifty index on June 12, 2000. On January 1, 2008, the Mini Nifty futures were brought to trade. The minimum contract value of the standard-sized S&P CNX Nifty futures is no less than Rs 2 lac and the permitted lot size is 50, while the Mini S&P CNX Nifty futures has a contract value of no less than Rs 1 lac and the permitted lot size of 20. Currently, there are seven domestic index futures and three global index futures traded on NSE. The other five domestic index futures are based on sectional indices. The three global index futures are based on S&P 500 index, DJIA index and FTSE 100 index.

NSE S&P CNX Nifty index futures run a 3 month trading cycle, the near month, the next month and the far month. New contract is introduced on the next trading day following the expiry of near month contract. The expiry day is the last Thursday of the expiry month, or the previous trading day if the last Thursday is a holiday. The price step is Rs. 0.05. There are no applicable price bands, but an operating range of 10% of the base price will be a buffer. The trading of derivatives at NSE is fully automated screen based and the E market normally runs from 09:15 am to 16:15pm.

3. SGX S&P CNX Nifty Index Futures

Singapore Exchange (SGX) began offering futures on S&P CNX Nifty index in September 2000 - three months later than the domestic listing. The SGX Nifty futures contract is dominated in USD and is approved by Commodity Futures Trading Commission (CFTC) allowing the market entrance of investors in the US. The size per contract is 2 USD multiples the index. The contracts are traded at 2 nearest serial months and Mar, Jun, Sep and Dec months on 1-year cycle. The last trading day is the same as on NSE, which is the last Thursday of the expiring contract month and shall be the preceding business day in case the last Thursday is an India holiday. SGX prescribes an initial margin of 563 USD and a maintenance margin of 450 USD according to the factsheet on June 1st 2012. SGX has a much extended trading hours with a T session from 9:00am to 18:10pm and a T+1 session from 19:15pm to 2:00am the next day.

Figure 6 exhibits the average daily trading volume and the month-end open interest for each month from January 2011 to July 2012. The trading of SGX Nifty index futures is relative stable. The average daily volume has slightly decreased and month-end open interest has kept a similar level except for few jumps. The total trading volume in 2011 was 14,678,520 contracts and the trading volume from January to July in 2012 amounts to 8,474,036 contracts. According to the data, the average open interest to volume ratio for this period is 4.27, which indicates that the investors tend to hold the contracts rather than fast buy and sell. Investors tend to employ long-term strategies at the offshore Singapore market.

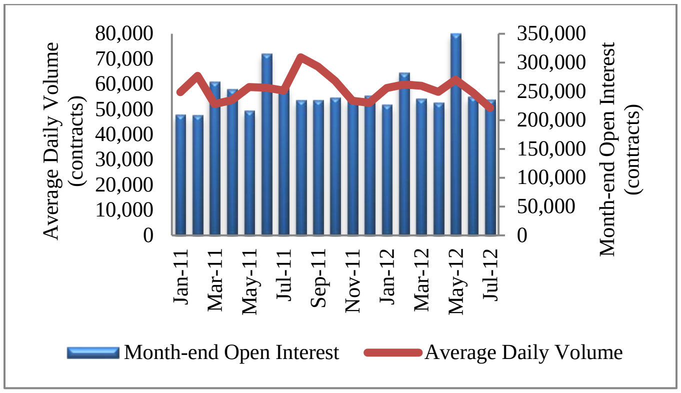

Figure 6. Average Daily Volume and Month-end Open Interest for SGX S&P CNX Nifty Index Futures

Source: Monthly statistical report, Singapore Exchange.

5. CME S&P CNX Nifty Index Futures

There are also two offshore S&P CNX Nifty index futures traded on Chicago Mercantile Exchange (CME). E-mini S&P CNX Nifty futures were launched on July 19, 2010 with a contract size of $10 times the index. E-micro S&P CNX Nifty futures were also launched on July 19, 2010. The contract size is $2 times the index. Both E-mini and E-micro S&P CNX Nifty futures have contract months of two nearest serial months and four quarters of Mar, Jun, Sep and Dec. The last trading day is the same as NSE and SGX. TABLE V shows the transaction data of these two products during my study period of 05/01/2012 to 07/31/2012.

The trading volume and average daily open interest are very tiny, except for the E-micro S&P CNX Nifty contract in May. Due to the inactive trading of the Indian equity index futures on CME, these offshore listing are excluded from my pair study of price dynamics and volatility transmission.

TABLE V TRADING VOLUME AND OPEN INTEREST FOR INDIAN EQUITY INDEX FUTURES AT CME

Equity Index Futures Product	CME E-mini S&P CNX Nifty index futures			
Contract in study	FECK2	FECM2	FECN2	FECQ2
Trading Period in study	5/1 - 5/31	6/1 - 6/28	6/29 -7/26	7/27 -7/31
Last Trading Day	31-May	28-Jun	26-Jul	30-Aug
Total Trading Volume (contract)	9	7	1	Null
Average Daily Open Interest (contract)	3	1	1	Null
Equity Index Futures Product	CME E-micro S&P CNX Nifty index futures			
Contract in study	FNMK2	FNMM2	FNMN2	FNMQ2
Trading Period in study	5/1 - 5/31	6/1 - 6/28	6/29 -7/26	7/27 -7/31
Last Trading Day	31-May	28-Jun	26-Jul	30-Aug
Total Trading Volume (contract)	1,022	95	65	Null
Average Daily Open Interest (contract)	102	17	6	2

2.2.3 The Pair of Japanese Index Futures

The Japanese Index futures are also based on the same underlying index of Nikkei 225. The trading of Nikkei 225 index futures was first on the offshore market at SGX (at that time, was named Singapore International Monetary Exchange) in September 1986, followed by the domestic listing at OSE in September 1988. Currently, there are a variety of Nikkei 225 index futures contracts traded at onshore and offshore exchanges, namely standard-sized Nikkei 225 futures and mini Nikkei 225 futures at OSE; Nikkei 225 futures, Mini Nikkei 225 futures and USD Nikkei 225 futures at SGX; as well as USD Nikkei 225 futures, Yen Nikkei 225 futures and E-mini Nikkei 225 (Yen) futures at CME.

1. Nikkei 225 Index

The Nikkei Stock Average (Nikkei 225) is the most popular benchmark of Japanese stock market. It is a price weighted average of 225 largest and highly liquid Japanese common stocks listed on the First Section of Tokyo Stock Exchange (TSE). The index is calculated and published by the Japanese newspaper publisher Nikkei, Inc. Price of the index stocks are first adjusted to 50 yen par value base, then the adjusted price are summed and divided by the divisor to eliminated the effect of non-market price change and maintain the continuity of the index (so called “Dow adjustment”). Most financial products around the world trading for Japanese stock market are based on the Nikkei 225 index.

The index started on September 7, 1950 and was calculated back to May 16, 1949 when the Tokyo Stock Exchange reopened after the Second World War. It was initially maintained by the Tokyo Stock Exchange and later by Nikkei since 1970. The Nikkei 225 is currently calculated at 15 seconds interval when the Tokyo Stock Exchange opens. To maintain the market representativeness, the constituents of the index are reviewed annually at the beginning of October by taking into account of the market liquidity (measured by “trading value” and “magnitude of price fluctuation by volume”) and the balance of six industry sectors.

Figure 7 shows the daily closing price of Nikkei 225 index from Jan 4, 2000 to Aug 31, 2012. The Nikkei 225 index slide down from mid-2000 and reverted from mid-2003. Along with the world economic recession, the index fall down to half of the price in 2007, and currently is still trapped at a low level which is around 2/5 of the highest level in 2000.

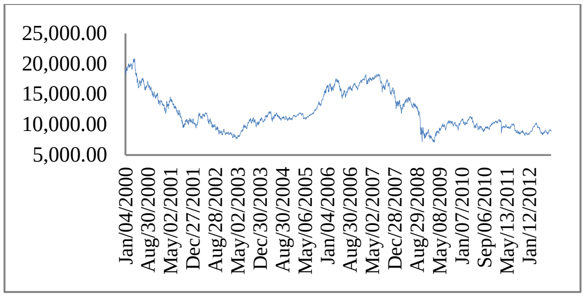

Figure 7. Daily Closing Price Levels of Nikkei 225 Index

Source: http://indexes.nikkei.co.jp/en/nkave/archives/data

2. OSE Nikkei 225 Index Futures

Nikkei 225 index futures contracts (standard-sized) began trading at Osaka Exchange in September 1988, which was two years later than the offshore listing at Singapore Exchange. The mini Nikkei 225 futures contracts are one tenth of the standard-sized contracts and were launched in July 2006 to attract individual investors. According to the statistics of Futures Industry Association (FIA) in 2011, mini Nikkei 225 futures traded at OSE had a turnover of 117,905,210 contracts and ranked 13th globally.

Currently, the standard-sized Nikkei 225 futures are traded at 5 months in the quarterly cycle of March, June, September and December, so the maximum trading period is 1 year and 3 months. The contract is traded at a size of ￥1,000 times the index and the minimum fluctuation is ￥10. The business day preceding the second Friday of each contract month is the last trading day. On expiration, all open contracts will be cash settled at a special quotation which is based on the total opening prices of each component stock of Nikkei 225 on the business day following the last trading day.

The trading hours at Osaka Exchange are extended from 9:00am – 15:15pm and from 16:30pm – 3:00am. The trading can be executed either in the action trading system which is a fully automated computer system or in the J-NET derivatives trading system where the cash and derivatives contracts can be traded simultaneously. The J-Net system has features of non-auction need, longer trading hours (from 8:20am to 16:00pm in the T session), smaller price unit of ￥1, differently calculated price limit and different trading strategies, among others. The margin requirements for futures and options trading at OSE are calculated as the SPAN requirement minus total amount of net option value. The calculation is more complicated and the amount is higher than the margin requirements at SGX. But OSE introduced the give-up system and the position transfer system to reduce the margin requirements and reduce the settlement-related expense.

Mini Nikkei 225 futures contracts have a multiple of ￥100, and its minimum price fluctuation is ￥5. Mini Nikkei 225 futures trade at 5 months which are the nearest 2 months from the March quarterly cycle plus the nearest 3 months which do not overlap the quarterly cycle. The expiration day for mini Nikkei 225 contracts is the same as standard-sized Nikkei 225 contracts. Both futures are available for traders in the U.S..

Figure 8 and 9 plot the average daily trading volume and the month-end open interest for standard-sized and mini Nikkei 225 futures from Jan 2010 to Aug 2012. The mini futures have a much higher volume than the standard-sized futures in the number of contracts traded.

In the figure of standard-sized Nikkei 225 futures, the month-end open interest was relative stable (from a minimum of 304,054 contracts to a maximum of 465,646 contracts), while the daily trading volume was more volatile (from a minimum of 48,579 contracts to a maximum of 160,083 contracts). The average ratio of open interest to volume for the year 2010, 2011 and the 8 months in 2012 are 4.22, 5.38 and 5.04, which indicates the investors tend to apply a relative long-term holding strategy.

In the figure of mini Nikkei 225 futures, the open interest fluctuated more (from a minimum of 302,219 contracts to a maximum of 920,028 contracts), while average daily trading volume fluctuated less (from a minimum of 343,111 contracts to a maximum of 821,805 contracts). The open interest and the daily volume were around the same scale, so the average ratios of open interest to volume for the year 2010, 2011 and the 8 months in 2012 are 0.88, 1.45 and 1.38, separately, which indicates the traders tend to apply a relative short-term strategy.

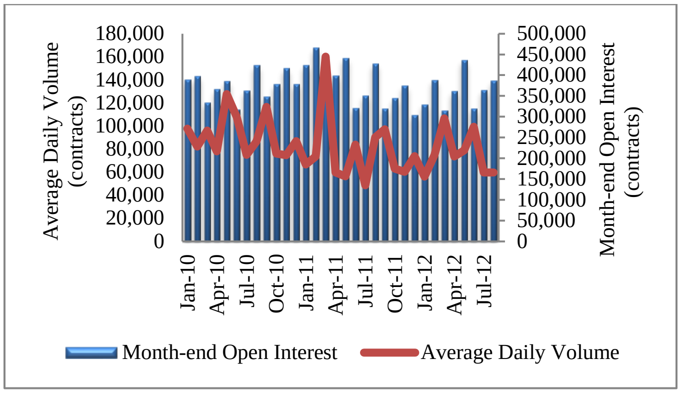

Figure 8. Average Daily Volume and Month-end Open Interest for OSE Standard-sized Nikkei 225 Futures

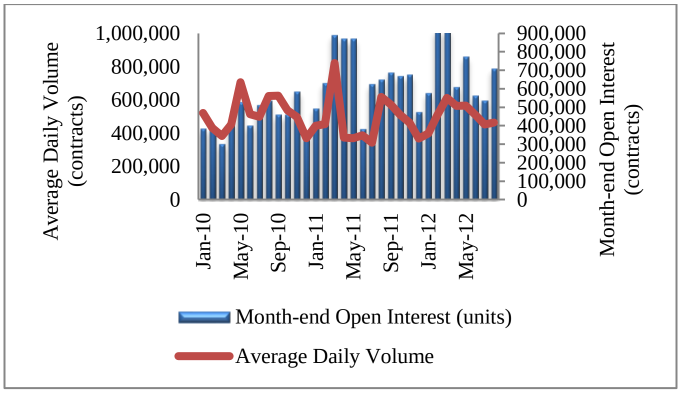

Figure 9. Average Daily Volume and Month-end Open Interest for OSE mini Nikkei 225 Futures

Source: http://www.ose.or.jp/e/market/statistics/trading_volume

3. SGX Nikkei 225 Index Futures

The first offshore Nikkei 225 futures were listed in September 1986 at Singapore Exchange, which are denominated in Yen and have a multiplier of ￥500. The Yen Nikkei 225 futures are traded at 3 nearest serial months and 12 nearest quarterly month. SGX has extended trading hours of 7:45am – 14:25pm for the T session and 15:15pm – 2:00am for the T+1 session. The last trading day is the day before the second Friday of the expiration month, on which day the open position will be cash settled with a special quotation based on the opening prices of each component stock on the following business day. SGX has much straightforward margin requirements with the initial margin of ￥187,500 and the maintenance margin of ￥150,000 as on Mar 1, 2012.[8]

In November 2006, the USD denominated Nikkei 225 futures were offered to investors with a size of 5 USD times the index. The contracts are traded at 4 nearest quarterly months. On November 19 2007, the Mini Nikkei 225 futures which are one-fifth the size of original Yen-dominated Nikkei 225 futures were launched. A smaller size contract makes the capital attachment and trading cost more affordable and also allows the hedging and trading activity more precisely for the market participants. Mini Nikkei 225 futures have a size of ￥100 times the index price and have 4 nearest quarterly contract months.

Figure 10, 11 and 12 show the average daily trading volume and the month-end open interest for the SGX Yen denominated Nikkei 225 futures, the USD denominated Nikkei 225 futures and the Mini Nikkei 225 futures for the period from January 2011 to July 2012. In Figure 10 Yen Nikkei 225 futures, investors tend to hold the contracts at higher volume than trade them, and the month-end open interest tends to be less volatile than the average daily trading volume. The average ratio of open interest to

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[8] Fact sheet of the Nikkei 225 index futures and options, Singapore Exchange.

trading volume was around 2.17 for this period, which indicates that investors tend to enter and hold the futures positions for relative long-run strategies.

In Figure 11 USD Nikkei 225 futures, the month-end open interest is significantly higher than the average daily trading volume. During the period, the average daily trading volume had a maximum of 44 contracts, a minimum of 1 contract and an average of 8 contracts, while the month-end open interest had a maximum of 21,500 contracts, a minimum of 11,488 contracts and an average of 2,293 contracts. It's obvious that investors tend to hold the USD Nikkei futures for long-run strategies and the daily trading is not active.

In Figure 12 Mini Nikkei 255 futures, the average daily trading volume was also very low, except for one month jump in March 2011. Before June 2011, the month-end open interest was maintained at a relative higher level which was more than 1000 contracts. Since June 2011, the month-end open interest plummeted significantly. The reason for this dramatic change needs further exploration. For the whole period, the average ratio of open-interest to trading volume is 8.70.

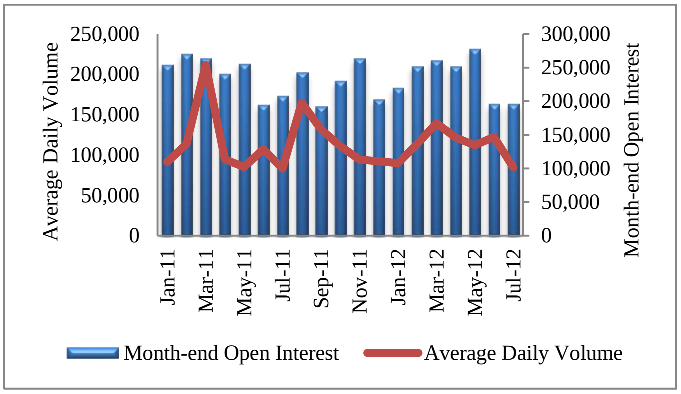


Figure 10. **Average Daily Volume and Month-end Open Interest for SGX Yen Nikkei 225 Futures**

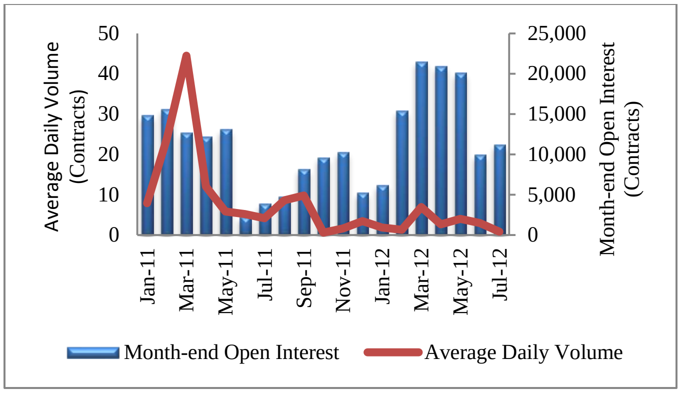


Figure 11. Average Daily Volume and Month-end Open Interest for SGX USD Nikkei 225 Futures

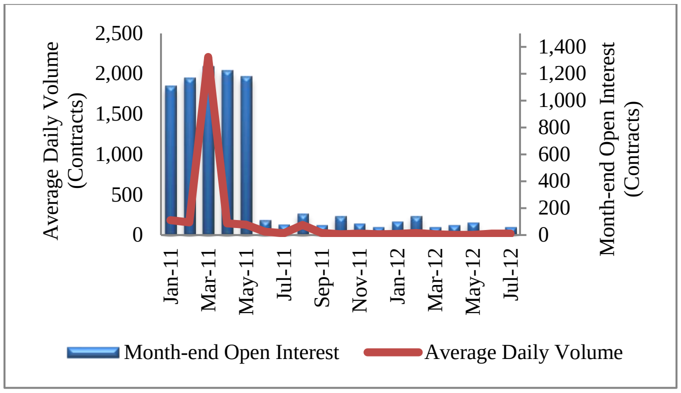


Figure 12. Average Daily Volume and Month-end Open Interest for SGX Mini Nikkei 225 Futures

Source: Monthly Statistical Report, Singapore Exchange.

4. CME Nikkei 225 Index Futures

On the Chicago Mercantile Exchange (CME) offshore market, there are also three Japanese equity index futures in trading. They are the USD denominated Nikkei 225 futures launched on Sep 25, 1990, the Yen denominated Nikkei 225 futures launched on Feb 23, 2004 and the E-mini Nikkei 225 futures launched on June 18, 2012 which does not have the period I want to study. USD Nikkei 225 futures have the size of $5 times Nikkei stock average. The contracts are traded at four months in the

March quarterly cycle on open outcry market and at two months in the March Quarterly cycle on the CME Globex market. Yen Nikkei 225 futures have the size of ￥500 times Nikkei stock average. The contracts are traded only on the Globex market at 12 quarterly and 3 serial months. E-mini Nikkei 225 futures have the size of ￥100 times Nikkei stock average. The contracts are traded on the Globex market at four quarterly months. The last trading day is the same for all these contracts, which is the Thursday (business day) prior to the second Friday of the contract month.

Among all Japanese futures, two offshore futures at SGX (USD Nikkei 225 futures and mini Yen Nikkei 225 futures) and one offshore futures at CME (E-mini Yen Nikkei225 futures) are traded at a very low volume. TABLE VI lists the average daily trading volume and average daily open interest during the period I study (May 1, 2012 to July 31, 2012) for the three products. Due to their tiny volume, these three products are not included in my study.

TABLE VI TRADING VOLUME AND OPEN INTEREST FOR JAPANESE EQUITY INDEX FUTURES AT SGX AND CME

Equity Index Futures Product	SGX Nikkei 225 (USD Denominated)		SGX Mini Nikkei 225 (Yen Denominated)		CME E-mini Nikkei 225 (Yen Denominated)
Contract in study	SNUM2	SNUU2	SNSM2	SNSU2	ENYU2
Trading Period in study	5/1 - 6/7	6/8 - 7/31	5/1 - 6/7	6/8 - 7/31	6/18 - 7/31
Last Trading Day	7-Jun	13-Sep	7-Jun	13-Sep	13-Sep
Average Daily Trading Volume (contract)	88	76	262	477	9
Average Daily Open Interest (contract)	19,449	10,675	80	38	1

3. DATA DESCRIPTIONS

3.1 Equity Index Futures Contracts and Their Trading Period in Study

The data series for any futures is fractured into contracts with different maturity. When a contract with a distant maturity is first traded, volume tends to start small and maybe discontinuous. When the contract becomes closer to expiry, the trading volume tends to rise greatly. Carchano and Pardo (2009) discussed the different ways to construct continuous data series in futures study, namely how to choose a proper date to switch between the contracts and connect the trading data from different contracts. According to the previous research, I construct the continuous prices series by using the data of the nearest ("near") contract and switching to the second-nearest ("next") contract when the trading volume of the next contract exceeds that of the near contract in the expiration week. In this way, I link the trading data for the most liquid and actively traded futures contracts. The three months period from 05/01/2012 to 07/31/2012 is studied.

Since financial markets are increasingly integrated, we expect that when the economic equivalent but competing products are traded at the same time on different markets, the prices dynamics and volatility transmission would react instantaneously to each other. The markets and products in this study either have close time zone or have extended T+1 trading hours, which makes the majority of trading time overlapped. I obtain the trading price at each minute marker from the Thomson Reuters Tick History. To study the instantaneous dynamics between onshore and offshore equity index futures as well as between futures and the underlying index, I truncate the common trading hours and set up the 1-minute trading data series.

TABLE VII exhibits the trading period and trading statistics for the specific contracts used in this study. Panel A shows the Chinese equity index futures studied: onshore CSI300 index futures are denoted as CIF and offshore FTSE China A50 index futures are denoted as SFC. Generally two days before the last trading day, the trading volume of CIF near contract falls below the trading volume of the next one and I switch the contract of interest. The switch of SFC contracts generally happens on the day before the last trading day. Comparing the trading statistics, the average daily trading volume for the onshore market is much higher than that for the offshore market, around 15 times more in number of contracts, however, the average close-of-day open interest for the onshore market is only around 42% of that for the offshore market (in number of contracts).

Panel B shows the Indian equity index futures studied: standard sized S&P CNX Nifty futures traded onshore are denoted as NIF and Mini S&P CNX Nifty futures traded onshore are denoted as CMY; offshore Nifty futures at SGX are denoted as SIN. In most cases, the trading volume of the near contract is still higher than that of the next contract on the last trading day. However, I roll over to the next contract generally on the day before the last trading day to avoid any expiration effect. The NIF and CMY are both traded at very high volume. However, the average daily volume of NIF contracts is around 20 times of the volume of CMY contracts and the close-of-day open interest of NIF is around 24 times of that of CMY. Both the average daily trading volume and the close-of-day open interest on the onshore market are much higher than these statistics on the offshore market.

Panel C shows the Japanese equity index futures studied: standard sized and mini Nikkei futures at the OSE are denoted as JNI and JNM; the Yen-denominated Nikkei futures at the SGX are denoted as SSI; and the Yen-denominated and the USD-denominated Nikkei futures at the CME are denoted as NIY and NK. In terms of contracts number, the average daily trading volume is ranked as JNM > SSI > JNI > NIY > NK. The onshore Mini Nikkei 225 futures are traded most actively followed by the offshore Yen-denominated Nikkei 225 futures at the SGX which are traded more actively than the onshore standard sized futures. The Nikkei 225 futures at the CME (NIY and NK) are traded at a much lower volume than the futures traded on the Asian markets.

The first onshore Nikkei 225 futures are standard sized and are only traded on quarter-end months with high volume and open interest. Correspondingly, the trading volume and open interest of other contracts (including onshore OSE Mini Nikkei 225 futures, offshore SGX Yen Nikkei 225 futures and offshore CME Yen Nikkei 225 futures) are significantly higher for quarter-end months (e.g. June and September) than for serial months. The trading statistics for all onshore and offshore Japanese equity index futures are provided in TABLE VIII. Although Japanese equity index futures have various contract months, different products demonstrate the same significantly active trading in quarterly months, while the contracts in serial months are relatively thinly traded. In addition, the offshore futures denominated in Yen are traded more actively than the offshore futures denominated in USD. It seems that investors tend to prefer trading the futures contracts with same design (contract month and currency) to facilitate the arbitrage among the products on different markets.

TABLE VII EQUITY INDEX FUTURES CONTRACTS AND TRADING PERIOD USED IN THIS STUDY

Panel A: Specific Contract Months Used for Studying Chinese Equity Index Futures

Equity Index Futures Product	CFFE CSI 300 Index Futures				SGX FTSE China A50 Index Futures			
Contract** in Study	CIFK2	CIFM2	CIFN2	CIFQ2	SFCK2	SFCM2	SFCN2	SFCQ2
Trading Period Used in Study	5/2 - 5/15	5/16 - 6/12	6/13 - 7/17	7/18 - 7/31	5/2 - 5/29	5/30 - 6/27	6/28 - 7/27	7/28 - 7/31
Last Trading Day	5/18	6/15	7/20	8/17	5/30	6/28	7/30	8/30
Average Daily Trading Volume (contract)	274,301	323,017	354,286	352,106	24,327	18,401	19,169	24,300
Average Daily Open Interest (contract)	42,529	42,889	53,124	59,822	95,299	108,371	128,549	138,541

Panel B: Specific Contract Months Used for Studying India Equity Index Futures

Equity Index Futures Product	NSE S&P CNX Nifty Index Futures				NSE Mini S&P CNX Nifty Index Futures			
Contract in Study	NIFK2	NIFM2	NIFN2	NIFQ2	CMYK2	CMYM2	CMYN2	CMYQ2
Trading Period Used in Study	5/2 - 5/30	5/31 - 6/27	6/28 - 7/25	7/26 - 7/31	5/2 - 5/30	5/31-6/27	6/28 - 7/25	7/26 - 7/31
Last Trading Day	5/31*	6/28*	7/26*	8/30	5/31	6/28*	7/26*	8/30
Average Daily Trading Volume (contract)	15,897,752	15,629,115	11,917,838	14,741,425	798,147	797,524	554,338	748,975
Average Daily Open Interest (contract)	20,481,576	17,206,905	23,445,220	22,244,525	1,199,038	809,665	903,966	722,390

Equity Index Futures Product	SGX S&P CNX Nifty Index Futures			
Contract in Study	SINK2	SINM2	SINN2	SINQ2
Trading Period Used in Study	5/1 - 5/29	5/30 - 6/27	6/28 - 7/25	7/26 - 7/31
Last Trading Day	5/31	6/28	7/26	8/30
Average Daily Trading Volume (contract)	37,977	37,190	34,494	36,721
Average Daily Open Interest (contract)	270,127	255,177	231,088	227,199

* On the last trading day, the trading volume of near contract is slightly higher than the trading volume of next contract. However, I switch to next contract on the day before the last trading day to avoid any expiration effect.

** The equity index futures contracts are denoted according to the data vendor Thomson Reuters. The first three letters of CIF, SFC, NIF, CMY and SIN (and JNI, JNM, SSI, NIY and NK in the continued table) are the RIC root applied by Thomson Reuters, K, M, N, Q and U (in the continued table) denote the contract month of May, June, July, August and September. The number 2 denotes the contract year 2012.

TABLE VII EQUITY INDEX FUTURES CONTRACTS AND TRADING PERIOD USED IN THIS STUDY

Panel C: Specific Contract Months Used for Studying Japanese Equity Index Futures

Equity Index Futures Product	OSE Nikkei 225 (Yen)		OSE Mini Nikkei 225	
Contract in Study	JNIM2	JNIU2	JNMM2	JNMU2
Trading Period Used in Study	5/1 - 6/6	6/7 - 7/31	5/1 - 6/6	6/7 - 7/31
Last Trading Day	6/7*	9/13	6/7*	9/13
Average Daily Trading Volume (contract)	63,171	48,230	533,841	405,056
Average Daily Open Interest (contract)	346,852	285,077	590,754	382,222

Equity Index Futures Product	SGX Nikkei 225 Index Futures	
Contract in Study	SSIM2	SSIU2
Trading Period Used in Study	5/1 - 6/6	6/7 - 7/31
Last Trading Day	6/7*	9/13
Average Daily Trading Volume (contract)	110,385	85,960
Average Daily Open Interest (contract)	245,137	176,522

Equity Index Futures Product	CME Nikkei 225 (Yen Denominated)		CME Nikkei 225 (USD Denominated)	
Contract in Study	NIYM2	NIYU2	NKM2	NKU2
Trading Period Used in Study	5/1 - 6/6	6/7 - 7/31	5/1 -6/6	6/7 - 7/31
Last Trading Day	6/7	9/13	6/7	9/13
Average Daily Trading Volume (contract)	25,656	19,684	6,710	4,528
Average Daily Open Interest (contract)	61,580	41,565	35,572	28,880

* On the last trading day, the trading volume of the near contract is slightly higher than that of the next contract. However, I switch to the next contract on the day before the last trading day to avoid any expiration effect.

TABLE VIII JAPANESE EQUITY INDEX FUTURES LISTED AT THE ONSHORE AND OFFSHORE MARKETS

Panel A: Nikkei 225 index futures listed on OSE (Osaka Securities Exchange)

Equity Index Futures Product	OSE Nikkei 225 (Yen)		OSE Mini Nikkei 225 (Yen)				
Contract in Study	**JNIM2**	**JNIU2**	JNMK2	**JNMM2**	JNMN2	JNMQ2	**JNMU2**
Trading Period in Study	**5/1 - 6/7**	**6/8 - 7/31**	5/1 - 5/10	**5/1 - 6/7**	6/8 - 7/12	7/13 - 7/31	**6/8 - 7/31**
Last Trading Day	**6/7**	**9/13**	5/10	**6/7**	7/12	8/9	**9/13**
Average Daily Trading Volume (contract)	**62,330**	**48,420**	36,916	**526,259**	33,173	26,633	**410,046**
Average Daily Open Interest (contract)	**343,826**	**286,099**	66,912	**590,302**	130,598	50,171	**385,590**

Panel B: Nikkei 225 index futures listed on SGX (Singapore Exchange)

Equity Index Futures Product	SGX Nikkei 225 (Yen Denominated)					SGX Nikkei 225 (USD Denominated)		SGX Mini Nikkei 225 (Yen Denominated)	
Contract in Study	SSIK2	**SSIM2**	SSIN2	SSIQ2	**SSIU2**	SNUM2	SNUU2	SNSM2	SNSU2
Trading Period in Study	5/1 - 5/10	**5/1 - 6/7**	6/8 - 7/12	7/13-7/31	**6/8 - 7/31**	5/1 - 6/7	6/8 - 7/31	5/1 - 6/7	6/8 - 7/31
Last Trading Day	5/10	**6/7**	7/12	8/9	**9/13**	6/7	9/13	6/7	9/13
Average Daily Trading Volume (contract)	1,868	**111,316**	635	224	**84,871**	88	76	262	477
Average Daily Open Interest (contract)	4,626	**243,072**	8,292	1,422	**176,939**	19,449	10,675	80	38

Panel C: Nikkei 225 index futures listed on CME

Equity Index Futures Product	CME Nikkei 225 (Yen Denominated)					CME Nikkei 225 (USD Denominated)		CME E-mini Nikkei 225 (Yen Denominated)
Contract in Study	NIYK2	**NIYM2**	NIYN2	NIYQ2	**NIYU2**	**NKM2**	**NKU2**	ENYU2
Trading Period in Study	5/1 - 5/10	**5/1 - 6/7**	6/8 - 7/12	7/13-7/31	**6/8 - 7/31**	**5/1 -6/7**	**6/8 - 7/31**	6/18 - 7/31
Last Trading Day	5/10	**6/7**	7/12	8/9	**9/13**	**6/7**	**9/13**	9/13
Average Daily Trading Volume (contract)	Null	**25,422**	Null	Null	**19,268**	**6,663**	**4,463**	9
Average Daily Open Interest (contract)	2	**61,075**	73	Null	**41,759**	**34,785**	**28,916**	1

Contracts in common quarterly months are traded at higher volume than contracts in serial months. Contracts in domestic currency (Yen) are traded at higher volume than contracts in foreign currency (USD).

The ratio of open-interest to trading volume (OIV) could indicate the prevalence of long-term versus short-term strategies. A higher OIV suggests there might be more long-run (and less short-term or intermediation) holding strategies for that contract, while a lower ratio suggests there might be more short-run or intermediation speculative trading. The average daily OIV ratios are provided in TABLE IX for each futures product according to the statistics in TABLE VII.

The OIV ratios tend to be higher on the offshore markets than on the onshore markets. Both offshore SFC and SIN have a much higher OIV ratio than the onshore futures. CIF has an especially low OIV ratio indicating the highly speculative trading on Chinese domestic market. One reason could be the high contract multiplier and margin requirements tend to tie up a huge amount of capital, which induce traders to close out positions daily and avoid overnight risk. For Japanese futures products, JNI has a fairly high OIV ratio indicating a lot of long-term positions being held in the onshore standard sized contract. The OIV ratios of all three offshore futures are higher than the OIV ratio of onshore mini contract JNM. Excluding the high OIV ratio of NK (which might reflect the low trading volume), the OIV ratios of SSI and NIY do not exceed the OIV ratio of JNM as much as in the cases of China and Indian.

TABLE IX AVERAGE DAILY OPEN-INTEREST TO TRADING VOLUME (OIV) RATIOS

Equity Index Futures	CIF	**SFC**	NIF	CMY	**SIN**
OIV Ratio*	0.1507	**5.3362**	1.4008	1.2118	**6.6979**
Equity Index Futures	JNI	JNM	SSI	NIY	NK
OIV Ratio*	5.6915	1.0186	2.134	2.2467	5.79.4

* The OIV ratios are calculated from the trading statistics in Table 3.1 for the period studied.

3.2 Statistical Summary of the Prices Series

After linking the futures contracts, the simultaneous trading periods are truncated to obtain the overlapping time for my pair study of the prices series. Generally, the trading hours on the futures markets are longer than the trading hours on the index markets and the trading hours on the offshore exchanges (SGX and CME) are longer than the trading hours on the onshore exchanges (CFFEX, NSI and OSE). However, for the purpose of pair study, I truncate the common trading hours for onshore and offshore futures and the underlying index according to their GMT/UTC trading time in a day. The first observation of the prices series is set to be 1000 and the rescaled series are transformed into the natural log prices. When there is no transaction in some specific minute, which results in a missing value in the 1-min price series, the last minute trading price is carried forward to fill the vacant observation. The GMT/UTC trading hours and the descriptive statistics for the 1-min prices series are provided in the TABLE X.

Among the two futures and two indices prices series in Panel A for Chinese equity index products, we can see that onshore futures have the highest mean prices (6.854241) and the smallest skewness, and its underlying index has the highest standard deviation (0.041312), while the offshore futures and its underlying index have relatively lower mean prices and standard deviations. In Panel B of one underlying index and three futures for Indian, the underlying index has the highest mean price (6.871591) and the lowest standard deviation (0.028432). The offshore futures have relatively higher mean price (6.869015) and higher standard deviation (0.03075) than the onshore futures. In Panel C of Japanese equity index and futures (one index and five futures), except for lnPr_NK which is the least actively traded offshore futures, the underlying index has relatively higher mean price and lower standard deviation than the futures. The three offshore futures have higher mean prices than the onshore futures.

For all prices series, the skewness and excess kurtosis indicate a leptokurtotic (fat-tail) distribution. The significant Jarque-Bera statistics support the non-normal distribution.

TABLE XI exhibits the covariance (lower triangle) and correlation (upper triangle) matrix for 1 minute prices series of all products. In the matrix of Chinese products, the onshore futures and its underlying index have the highest correlation, followed by the correlation between onshore futures and the other index underlying the offshore futures. The correlation between onshore and offshore futures based on different indices is the lowest. In the matrix of Indian products, the correlation between the two most actively traded onshore futures is the highest (NIF & CMY). The correlations between onshore and offshore futures are higher than the correlations between futures and the underlying index. In the matrix of Japanese products, the same trend can be found. The correlation between the two most actively traded futures is the highest (JNM & SSI). The correlations between two futures are generally higher than the correlations between futures and the underlying index, except for the lowest volume offshore futures NK, which has higher correlation with the underlying index than with other futures. The correlations between two futures also follows the same order of trading volume (JNM > SSI > JNI > NIY > NK).

Figure 13 plots the rescaled prices series for all products in research. Visually, they are non-stationary and share the common trend for each country.

TABLE X DESCRIPTIVE STATISTICS OF 1-MIN TRADING PRICES SERIES IN THIS STUDY

Panel A: Chinese Equity Index Products

Trading Hours (GMT/UTC) 1:30:00 - 3:30:00; 5:00:00 - 6:59:00*

	LnPr_CSI300	***LnPr_A50***	***LnPr_CIF***	***LnPr_SFC***
Count (241*64)**	15424	15424	15424	15424
Mean	6.853922	6.848193	6.854241	6.842376
Std. dev.	0.041312	0.035113	0.038478	0.035592
Max	6.927311	6.920527	6.929	6.922131
Min	6.773956	6.783249	6.786119	6.778778
Skewness	-0.15748	0.038213	0.00329	0.295648
Kurtosis (Excess)	-1.17252	-0.8493	-1.07119	-0.60852
Jarque-Bera	947.2899	467.3205	737.4584	462.6716
Signif Level (JB=0)	0	0	0	0

Panel B: Indian Equity Index Products

Trading Hours (GMT/UTC) 3:45:00 -10:00:00

	lnPr_Nifty	***lnPr_NIF***	***lnPr_CMY***	***lnPr_SIN***
Count (376*65)**	24440	24440	24440	24440
Mean	6.871591	6.868205	6.868443	6.869015
Std. dev.	0.028432	0.030428	0.030435	0.03075
Max	6.921767	6.920866	6.921219	6.922403
Min	6.8079	6.802051	6.802415	6.801891
Skewness	-0.23315	-0.25124	-0.25073	-0.25557
Kurtosis (Excess)	-1.0159	-1.04079	-1.04094	-1.04583
Jarque-Bera	1272.401	1360.207	1359.484	1379.856
Signif Level (JB=0)	0	0	0	0

Panel C: Japanese Equity Index Products

Trading Hours (GMT/UTC) 0:00:00 -2:30:00; 3:00:00 -6:00:00

	lnPr_Nik225	***lnPr_JNI***	***lnPr_JNM***	***lnPr_SSI***	***lnPr_NIY***	***lnPr_NK***
Count (302*63)**	19026	19026	19026	19026	19026	19026
Mean	6.827906	6.827438	6.827485	6.827819	6.827582	6.831291
Std. dev.	0.027301	0.027512	0.027496	0.027493	0.027502	0.027591
Max	6.907755	6.907755	6.907755	6.907755	6.907755	6.908813
Min	6.768839	6.76875	6.768456	6.768894	6.768819	6.772483
Skewness	0.499122	0.528929	0.529782	0.529217	0.527607	0.508966
Kurtosis (Excess)	-0.00982	0.007074	0.00656	0.004671	0.011486	0.004785
Jarque-Bera	790.0432	887.1781	890.0345	888.1199	882.8117	821.4537
Signif Level (JB=0)	0	0	0	0	0	0

*The last minute trading data are unavailable for the FTSE ChinaA50 index. So I truncate the trading hours for both indices according to the shorter period.

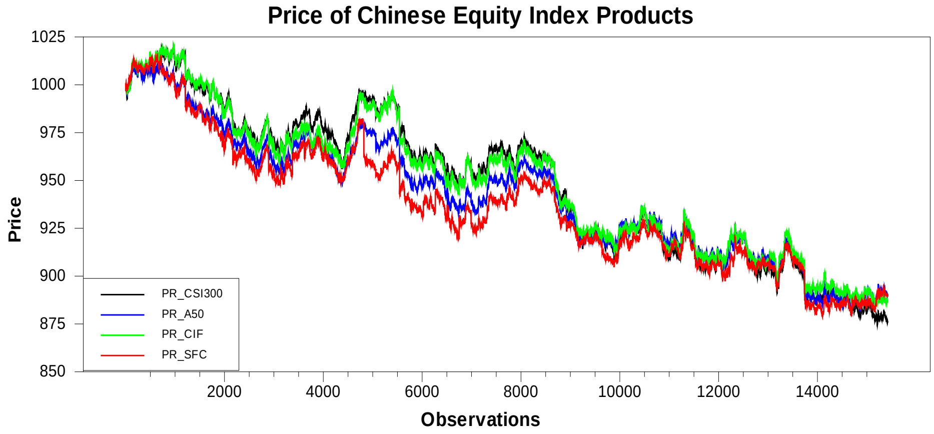
**Number of obs. per-day times trading days in the period studied.

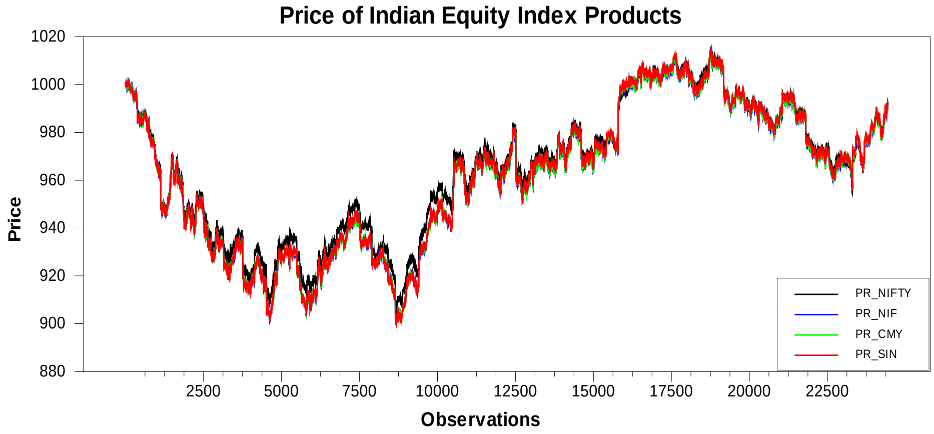
TABLE XI COVARIANCE\CORRELATION MATRIX OF 1-MIN TRADING PRICES SERIES

	LNPR_CSI300	**LNPR_A50**	**LNPR_CIF**	**LNPR_SFC**
LNPR_CSI300	*0.001707*	0.98844	0.99646	0.96882
LNPR_A50	*0.001434*	*0.001233*	0.99246	0.99196
LNPR_CIF	*0.001584*	*0.001341*	*0.00148*	0.97811
LNPR_SFC	*0.001424*	*0.00124*	*0.001339*	*0.001267*

	LNPR_NIFTY	**LNPR_NIF**	**LNPR_CMY**	**LNPR_SIN**
LNPR_NIFTY	*0.000808*	0.9984	0.99839	0.99847
LNPR_NIF	*0.000864*	*0.000926*	0.99999	0.99988
LNPR_CMY	*0.000864*	*0.000926*	*0.000926*	0.99987
LNPR_SIN	*0.000873*	*0.000936*	*0.000936*	*0.000946*

	LNPR_Nik225	**LNPR_JNI**	**LNPR_JNM**	**LNPR_SSI**	**LNPR_NIY**	**LNPR_NK**
LNPR_Nik225	*0.000745*	0.99958	0.99967	0.99966	0.99951	0.9993
LNPR_JNI	*0.000751*	*0.000757*	0.99989	0.99988	0.99973	0.99909
LNPR_JNM	*0.00075*	*0.000756*	*0.000756*	0.99998	0.99982	0.99915
LNPR_SSI	*0.00075*	*0.000756*	*0.000756*	*0.000756*	0.99981	0.99915
LNPR_NIY	*0.00075*	*0.000756*	*0.000756*	*0.000756*	*0.000756*	0.99919
LNPR_NK	*0.000753*	*0.000758*	*0.000758*	*0.000758*	*0.000758*	*0.000761*





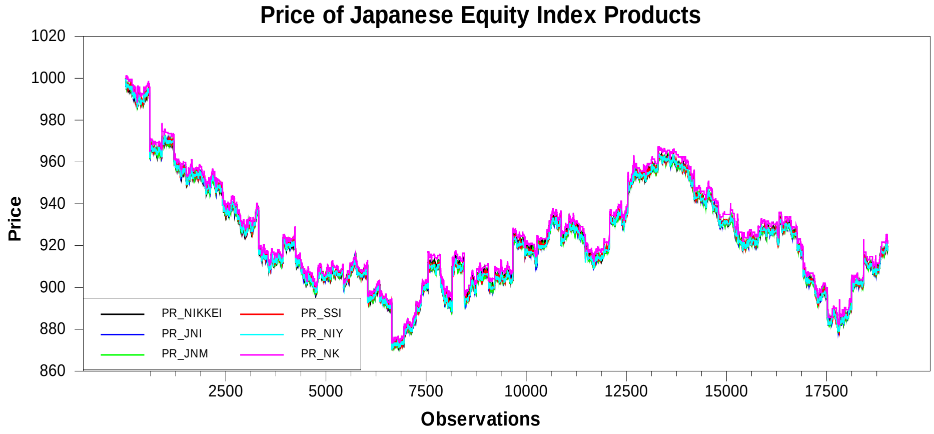


Figure 13. **Plot of Rescaled Prices Series for Equity Index Products**

4. PRICE DISCOVERY WITH ERROR-CORRECTION MODEL

4.1 Unit Root Test

4.1.1 Model and Methodology

Three augmented forms of Dickey – Fuller (1979) tests have been performed to check the unit root of the prices series.[9] They are the random walk form (γ) (4.1), the form with an intercept (a_0 & γ) (4.2) and the form with both the intercept and the linear time trend (a_0 & γ & $a_2 t$) (4.3).

$$\Delta y_t = \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t \qquad (4.1)$$

$$\Delta y_t = a_0 + \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t \qquad (4.2)$$

$$\Delta y_t = a_0 + \gamma y_{t-1} + a_2 t + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t \qquad (4.3)$$

The null hypothesis is $\gamma = 0$, which is equivalent to $\{y_t\}$ sequence contains a unit root. The critical values of t-statistics are determined by the different regression forms and the specific sample size, but not determined by the autoregressive process. In addition to t test, Dickey and Fuller (1981) proposed three F-statistics to test joint hypothesis on the coefficients, which are $a_0 = \gamma = 0$, $a_0 = \gamma = a_2 = 0$, and $\gamma = a_2 = 0$. The joint hypothesis can be tested by constructing the statistics from restricted and unrestricted models as normal F-tests.

In augmented Dickey-Fuller process, I select the appropriate number of autoregressive lags according to the white noise properties of the residuals, the information criterion (AIC & BIC) and the significance of that lag. Among different diagnostic checking, I give more weight to obtain the white

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[9] Augmented Dickey-Fuller process is needed if the time series cannot be well represented by the first-order autoregressive process.

noise residuals. At the appropriate lag, the plotting of residuals shouldn't exhibit observable structural change or serial correlation. The Ljung-Box Q-statistics of residuals should be insignificant which indicate the null hypothesis of the absence of serial correlation cannot be rejected. [10]

4.1.2 Empirical Evidence

TABLE XII provides the lag length selected for the log prices series with AIC and BIC criteria in three regression forms.[11] At the same time, the white noise properties of the residuals and the significance of that lag are also checked. Combining the results, I select the lag length for Dickey-Fuller test as indicated in the bolded row of "tested lag" in TABLE XII. TABLE XIII exhibits the results of Dickey-Fuller unit root test for the log prices series and its one level differenced series in three regression equations, eq. 4.1 is denoted as ADF_None, eq. 4.2 is denoted as ADF_C and eq. 4.3 is denoted as ADF_C+T.

In the result, Dickey-Fuller unit root tests demonstrate that: (1) Prices series cannot reject a unit root at 1% significance level,[12] and F tests suggested that the prices series contain a unit root with zero drift[13]; (2) One level differenced price series highly reject a unit root at 1% significance level, and F tests suggested that the differenced price series have no unit root. (3) Prices series are non-stationary at original level, but are stationary at first differenced level, so they satisfy the conditions of I(1) series.

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[10] In augmented Dickey-Fuller process, appropriate number of lags is important. Including too many lags will increase the number of estimated parameters, decrease the degree of freedom and reduce the power of unit root test to reject the null. While estimating too less lags will not capture the proper error process and cause the γ and its standard error not well established. As stated by Enders "In fact, the augmented Dickey-Fuller test may indicate a unit root for some lag length but not for others". (Enders, 2010)

[11] The RATS procedure @adfautoselect is used to select the optimal lag length for ADF test based on the criteria of AIC, BIC, HQ and MAIC.

[12] In panel A, equation ADF_C+T, the test statistics are significant at 5% level. However, the estimated coefficients with the trend term are as small as at 10*(E-9) level, and there is always an inherent risk of incorrectly rejecting the true null hypothesis at a wider significant level, which is called the type 1 error. If we are more cautious to hold the 1% significance level, we cannot reject the null of a unit root for all the tests on four prices series (two indices and two futures).

[13] The tests are performed in RATS at 1% significance level.

TABLE XII LAG LENGTH SELECTION FOR ADF UNIT ROOT TEST

	lnPr_CSI300			**lnPr_A50**			**lnPr_CIF**			**lnPr_SFC**								
Equation*	**4.1**	**4.2**	**4.3**	**4.1**	**4.2**	**4.3**	**4.1**	**4.2**	**4.3**	**4.1**	**4.2**	**4.3**						
AIC	5	5	5	1	1	1	3	3	3	5	5	5						
BIC	2	2	2	1	1	1	2	1	1	1	1	1						
Tested Lags	**5**			**1**			**3**			**5**								
	lnPr_NIFTY			**lnPr_NIF**			**lnPr_CMY**			**lnPr_SIN**								
Equation	**4.1**	**4.2**	**4.3**	**4.1**	**4.2**	**4.3**	**4.1**	**4.2**	**4.3**	**4.1**	**4.2**	**4.3**						
AIC	3	3	3	19	19	19	2	2	2	19	19	19						
BIC	2	2	2	2	2	2	2	2	2	2	2	2						
Tested Lags	**2**			**2**			**2**			**2**								
	lnPr_Nik225			**lnPr_JNI**			**lnPr_JNM**			**lnPr_SSI**			**lnPr_NIY**			**lnPr_NK**		
Equation	**4.1**	**4.2**	**4.3**	**4.1**	**4.2**	**4.3**	**4.1**	**4.2**	**4.3**	**4.1**	**4.2**	**4.3**	**4.1**	**4.2**	**4.3**	**4.1**	**4.2**	**4.3**
AIC	14	14	14	3	3	3	2	2	2	0	0	0	1	1	1	1	1	1
BIC	3	3	3	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1
Tested Lags	**5**			**3**			**2**			**1**			**1**			**1**		

*The three columns under each product list the lag length selected for eq. 4.1, eq. 4.2 and eq. 4.3.

TABLE XIII DICKEY-FULLER UNIT ROOT TEST FOR LOG PRICES SERIES

Panel A: Chinese Equity Products

	LnPr_CSI300	**LnPr_A50**	**LnPr_CIF**	**LnPr_SFC**	**DLnPr_CSI300**	**DLnPr_A50**	**DLnPr_CIF**	**DLnPr_SFC**
Tested lags	**5**	**1**	**3**	**5**	**4**	**0**	**2**	**4**
ADF_None	-1.60562	-1.54901	-1.58176	-1.47456	-51.5725**	-84.2441**	-68.7869**	-56.7439**
Critical Value			*1%(**)--(-2.566)5% (*)--(-1.939) 10%--(-1.616)*					
ADF_C	-0.43149	-1.13767	-0.68713	-1.33933	-51.6001**	-84.2620**	-68.8083**	-56.7650**
Critical Value			*1%(**)--(-3.434) 5%(*)--(-2.862) 10%--(-2.567)*					
ADF_C+T	-3.58243*	-3.80239*	-3.55391*	-3.61606*	-51.6025**	-84.2593**	-68.8071**	-56.7638**
Critical Value			*1%(**)--(-3.964) 5%(*)--(-3.413) 10%--(-3.128)*					

F test for joint hypotheses on the coefficients----1% significance level

Prices Series contains a unit root with zero drift ***Differenced Price Series has no unit root***

Panel B: Indian Equity Products

	lnPr_Nifty	**lnPr_NIF**	**lnPr_CMY**	**lnPr_SIN**	**DlnPr_Nifty**	**DlnPr_NIF**	**DlnPr_CMY**	**DlnPr_SIN**
Tested lags	**2**	**2**	**2**	**2**	**1**	**1**	**1**	**1**
ADF_None	-0.11636	-0.12033	-0.11661	-0.10573	-107.516**	-107.257**	-107.958**	-108.570**
Critical Value			*1%(**)--(-2.566) 5%(*)--(-1.939) 10%--(-1.616)*					
ADF_C	-1.61081	-1.56944	-1.54139	-1.57361	-107.513**	-107.255**	-107.956**	-108.568**
Critical Value			*1%(**)--(-3.434) 5%(*)--(-2.862) 10%--(-2.567)*					
ADF_C+T	-3.21277	-3.19138	-3.17992	-3.20377	-107.523**	-107.265**	-107.966**	-108.578**
Critical Value			*1%(**)--(-3.964) 5%(*)--(-3.413) 10%--(-3.128)*					

F test for joint hypotheses on the coefficients----1% significance level

Prices Series contains a unit root with zero drift ***Differenced Price Series has no unit root***

TABLE XIII DICKEY-FULLER UNIT ROOT TEST FOR LOG PRICES SERIES

Panel C: Japanese Equity Products

	lnPr_Nik225	**lnPr_JNI**	**lnPr_JNM**	**lnPr_SSI**	**lnPr_NIY**	**lnPr_NK**
Tested lags	**5**	**3**	**2**	**1**	**1**	**1**
ADF_None	-0.89315	-0.91095	-0.92504	-0.91955	-0.93468	-0.86829
Critical Value			*1%(**)--(-2.566) 5%(*)--(-1.939) 10%--(-1.616)*			
ADF_C	-2.92564*	-2.92255*	-2.92126*	-2.93490*	-2.94308*	-2.83907
Critical Value			*1%(**)--(-3.434) 5%(*)--(-2.862) 10%--(-2.567)*			
ADF_C+T	-2.67788	-2.66034	-2.65536	-2.67163	-2.67622	-2.60488
Critical Value			*1%(**)--(-3.964) 5%(*)--(-3.413) 10%--(-3.128)*			

F test for joint hypotheses on the coefficients----1% significance level

Prices Series contains a unit root with zero drift

	DlnPr_Nik225	**DlnPr_JNI**	**DlnPr_JNM**	**DlnPr_SSI**	**DlnPr_NIY**	**DlnPr_NK**
Tested lags	**4**	**2**	**1**	**0**	**0**	**0**
ADF_None	-57.7053**	-84.7149**	-96.9382**	-136.584**	-135.420**	-133.536**
Critical Value			*1%(**)--(-2.566) 5%(*)--(-1.939) 10%--(-1.616)*			
ADF_C	-57.7117**	-84.7193**	-96.9421**	-136.586**	-135.423**	-133.538**
Critical Value			*1%(**)--(-3.434) 5%(*)--(-2.862) 10%--(-2.567)*			
ADF_C+T	-57.7280**	-84.7321**	-96.9541**	-136.596**	-135.433**	-133.546**
Critical Value			*1%(**)--(-3.964) 5%(*)--(-3.413) 10%--(-3.128)*			

F test for joint hypotheses on the coefficients----1% significance level

Differenced Price Series has no unit root

4.2 Cointegration Test

In multivariate context, a specific combination (linear or non-linear) of the non-stationary series might yield the stationary residuals. This is defined as cointegration (including both linear and non-linear cointegration). The cointegrated variables have long-run equilibrium relationship and share the common stochastic trend, which would be insufficiently modeled with only the differenced terms.[14] To specify the full dynamics, we need to include both the deviation from long-run equilibrium and the short-run dynamics in the modeling. An excellent and consistent estimation is the two-step procedure which contains the cointegration regression and the error correction model.

4.2.1 Engle - Granger Linear Cointegration Test

According to Engle and Granger (1987), the component of the vector$x_t = (x_{1t}, x_{2t}, \cdots, x_{nt})'$ are said to be cointegrated of order d, b, denoted by $x_t \sim CI(d, b)$ if

1. All components of x_t are integrated of order d.[15]
2. There exists a vector$\beta = (\beta_1, \beta_2, \cdots, \beta_n)$ such that the linear combination $\beta x_t = \beta_1 x_{1t} + \beta_2 x_{2t} + \cdots + \beta_n x_{nt}$ is integrated of order (d-b) where b>0.

The vector β is called the cointegration vector[16]. The number of cointegration vectors is called the cointegration rank of x_t. Cointegrated variables have stationary long-run equilibrium relationship with regression residuals $\{e_t\}$ meandering around the mean. If the variables are not cointegrated, then the regression residuals could drift widely from the mean, which suggests there is no sustainable equilibrium.

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[14] In univariate context, non-stationary series is usually differenced and the Box-Jenkins technique can then be applied on the differenced stationary series to estimate the model.

[15] In Engle and Granger definition, cointegration is among variables that are integrated in the same order. However, Lee and Granger (1990) proposed the term of multicointegration to describe the equilibrium relationships among variables that are integrated at different orders.

[16] The cointegration vector is not unique. It can be multiplied by any nonzero value.

In previous unit root test, the index and futures price series are tested to be I(1) series. The series individually is non-stationary. To test whether there exist any long run equilibrium relationship between the products, pairwise cointegration tests are performed between futures and the underlying index, between onshore and offshore futures, as well as between different futures (higher volume vs. lower volume) and between different index (underlying onshore futures vs. underlying offshore futures).

The fair price between futures and the underlying asset follows the holding cost model: $F_t = S_t e^{(r-d)(T-t)}$.[17] If the fair price theory holds, the relationship between futures prices and spot prices should be stationary and maintain an equilibrium state. Meanwhile, the onshore and offshore equity index futures are based on the same underlying index or two highly correlated indices.[18] If each equity index futures share the common stochastic trend with the underlying index, then two futures on the different markets or on the same market should also share the common stochastic trend. The two economically equivalent index futures are expected to cointegrate which is also indicated by the one price law. Furthermore, if natural logarithm is taken on both sides of the fair price model, we will get: $logF_t = logS_t + (r-d)(T-t)$. So the fair price relationship in log term theoretically equals to 1 to 1.

Applying the Engle-Granger method, the linear long-run equilibrium relationship is estimated as:[19]

$$y_t = \beta_0 + \beta_1 x_t + e_t \qquad (4.4)$$

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[17] However, the complete arbitrage is prevented by various market imperfections, such as transaction costs, restrictions on short selling, and different borrowing and lending rate, etc. In practice, the futures price varies around the theoretical price within the boundary of arbitrage.

[18] In India and Japan cases, all futures are based on the same underlying index which is the S&P CNX Nifty index and the Nikkei 225 index. In China case, onshore futures are based on the CSI 300 index and offshore futures are based on the FTSE China A50 index.

[19] Series y_t are normalized to be unit in the cointegration vector. If the variables are cointegrated, the OLS regression would yield a “super-consistent” estimator of the cointegration parameters.

The full dynamics haven't been specified at this stage yet since y_t and x_t are I (1) series. There might be serial correlation or omitted variable problems due to the misspecified dynamics.[20] So the distribution of t-statistics is unknown and cannot be interpreted as usual. However, the issue mattering here is the stationary or non-stationary of the residuals. The residuals series $\{\hat{e}_t\}$ provide the estimated deviations from the long-run equilibrium. The stationarity of the $\{\hat{e}_t\}$ series are tested in equations (4.5) or (4.6) to validate the cointegration of y_t and x_t. MacKinnon (1991) critical values are adopted considering the bias in OLS procedure of generating a stationary error process.[21]

$$\Delta\hat{e}_t = a_1\hat{e}_{t-1} + \varepsilon_t \qquad (4.5)$$

$$\text{Or } \Delta\hat{e}_t = a_1\hat{e}_{t-1} + \sum_{i=1}^{n} a_{i+1}\Delta\hat{e}_{t-i} + \varepsilon_t \qquad (4.6)$$

There is no need to include the intercept in the auto regression, because the residuals series $\{\hat{e}_t\}$ are already from a regression equation. If the null hypothesis $a_1 = 0$ can be rejected, then we can conclude that the $\{\varepsilon_t\}$ series is stationary and the variables y_t and x_t are cointegrated.

In the two variables cointegration test, y_t and x_t are paired in four situations: futures versus the underlying index, onshore futures versus offshore futures, higher volume futures versus lower volume futures, and the index underlying onshore futures versus the index underlying offshore futures. A total of 25 pairs of equity index products are tested.

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[20] By allowing for more dynamics in the equilibrium equation (including lagged terms of the variables), the bias caused by serial correlation in residuals can be reduced. Only in case that the cointegrated variables are actually independent and the error terms are serial uncorrelated, the coefficients would have asymptotic t-distribution.

[21] Since the residuals series $\{\hat{e}_t\}$ is generated from a regression equation, we can only get the estimated error $\hat{e}_t$, but not the actual error $\hat{e}_t$. More importantly, the OLS regression tries to minimize the sum of squared residuals, which tends to make the residual variance as small as possible. So the procedure would be biased to find a stationary error process. The RATS procedure I used adopts the adjusted MacKinnon (1991) critical values. Only when the true $\{\hat{e}_t\}$ series is constructed from the known β_0 and β_1, we can apply the Dickey-Fuller critical value to test the stationarity.

The results of Engle-Granger cointegration test are provided in TABLE XIV.[22] The test statistics reported are for the autoregression form of $\{\hat{e}_t\}$ with zero AR polynomial on the differenced term. Longer lags of the AR polynomial on the differences are also tested and the results are consistent. Although I have specified the pairs of variables as regressing y_t on x_t, the equilibrium regression can also be performed in the reverse way. When regress x_t on y_t, the coefficient of y_t are very close to the inverse of the x_t coefficient reported. The test statistics and the standard error of estimated coefficients are very similar.

4.2.2 Empirical Evidence on Each Market

1. Evidence from Chinese Equity Index Products

Panel A exhibits Engle-Granger test for Chinese equity index products. (1) Regress lnPr_CIF (onshore futures) on lnPr_CSI300 (underlying index), we get coefficient of 0.928111. When index prices change 1 unit, the futures prices change 0.928111 units - less than but close to 1 unit. The positive constant (0.493043) helps to increase the futures price. Both effects drive the relationship between futures and the underlying index to be 1 to 1 as fair price model indicate. The statistics of cointegration test is significant at 1% level (-8.13478), which suggests the rejection of null hypothesis of non-cointegration. So the onshore futures and the underlying index are cointegrated.

(2) Regress lnPr_SFC (offshore futures) on lnPr_A50 (underlying index), we get the coefficient of 1.005483, which is slightly greater than 1. However, the negative constant (-0.043367) acts to bring down the overall futures price, which again helps to support the 1 to 1 fair relationship. The test statistics (-6.61187) significantly rejects the non-cointegration null.

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[22] I applied the RATS procedure @egtestresids to test the cointegration on the residuals from the equilibrium regression. The procedure @egtest can also be applied and it automatically conducts the first stage regression.

(3) Regress the offshore futures prices (lnPr_SFC) on the onshore futures prices (lnPr_CIF), we get the coefficient of 0.904748. This number suggests that the offshore futures prices respond to onshore futures prices at a scale smaller than 1 unit. However, the positive constant 0.641017 acts to increase the response. The test statistics of cointegration is marginal significant at 1% level, which is -4.08460. When I increase the lag terms of the AR polynomial on differenced residuals, the test statistics becomes less significant.

(4) In the cointegration test of two underlying indices, the test statistics is -2.29520. This insignificant value indicates that the non-cointegration null cannot be rejected. Although the two equity indices are highly correlated and the index A50 is a subset of the index CSI300, their prices do not show evidence of cointegration.

It's interesting that there is long-run equilibrium between onshore and offshore futures prices, but their different underlying indices do not show long-run equilibrium. It seems that the onshore and offshore futures share some common trend even the two underlying indices do not. However, in such case, the cointegration between onshore and offshore futures is not always significant. When adding more dynamics to the tested error term, the significance may decrease. We might infer that designing onshore and offshore futures on two different equity indices might not work best for prices equilibrium between the two futures.

2. Evidence from Indian Equity Index Products

Panel B exhibits 6 Engle-Granger tests for Indian equity index products, among which three are between futures and the underlying index (in panel B-1), two are between onshore and offshore futures, and one is between two onshore futures (in panel B-2).

(1) In panel B-1, the cointegration test statistics are -10.55858, -10.36671 and -12.33996. All are highly significant to reject the non-cointegration null, which demonstrates the futures and the underlying index have equilibrium. In the equilibrium regressions, the coefficients of underlying index are greater than 1 when the cointegration vector of futures is normalized to be 1. They are 1.068506, 1.068750 and 1.079895 in three pairs. It suggests the futures prices respond to the underlying index prices at a scale larger than 1 unit. However, the negative constants bring down the futures prices. The two factors help to maintain the 1 to 1 fair price relationship. The trading volume and the open interest of the three futures descend in the order of NIF, CMY and SIN[23]. Coincidently, the coefficients of underlying index ascend in the same order and the absolute values of negative constants ascend in the same order. It seems that the more liquid trading of the product, the narrower deviation of the futures prices from its theoretical fair price. Their price interaction tends to meander more closely around the arbitrage-free equilibrium.

(2) In panel B-2, the test statistics between onshore and offshore futures are -35.00577, -35.76138 and the test statistics between two onshore futures is -87.04795. The magnitude of test statistics implies that the equilibrium between two futures is more significant than the equilibrium between futures and the underlying index. It also seems that the equilibrium between two more actively traded onshore futures is more significant than the equilibrium between onshore and offshore futures.

The regression coefficients (1.010471, 1.010217 and 1.000230) are higher than 1. It suggests that the offshore futures prices (lower volume) respond at a larger scale to the onshore futures prices (higher volume), and the lower volume onshore futures prices respond at a larger scale to the high volume onshore futures prices. The facts are corresponding to the liquidity order of the three futures. The negative constant again consistently acts to maintain the fair price equilibrium between the two futures. In addition, the smaller regression coefficients in Panel B-2 indicate that the equilibrium between two futures is much

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[23] The measure is in the number of contracts. The trading volume and open interest of NIF are much higher than that of the other two futures (refer to Chapter 3).

closer to 1 to 1 than the equilibrium between the futures and the underlying index. Among all, the equilibrium between two most liquid onshore futures is most close to 1 to 1.

3. Evidence from Japanese Equity Index Products

Panel C exhibits the cointegration tests for Japanese equity index products. The average daily trading volume and the open interest hold the order of JNM, SSI, JNI, NIY and NK in terms of contract numbers.

Panel C-1 lists the cointegration tests between 5 futures and the underlying index. All test statistics are significant at 1% level (range from -29.94677 to -47.85880), which support the stationary equilibrium between the futures prices and the index prices. The regression coefficients are higher than 1 (range from 1.006670 to 1.009907), which indicate the futures prices respond to index prices at a higher scale. The negative constants bring the relationship back to 1 to 1 and maintain the prevailing fair price equilibrium. In the regressions of more actively traded futures, the coefficients tend to be smaller. JNM, SSI and NIY are the most actively traded futures on three markets. The coefficients in their regressions are smaller than the other two. It implies that the more liquid trading of the products, the narrower their prices meandering around the fair price equilibrium.

Panel C-2 lists the cointegration tests between onshore and offshroe futures. The test statistics (range from -32.26813 to -111.97821) are highly significant indicating the existence of stationary equilibrium. The equilibrium between two futures seems to be more significant than the equilibrium between futures and the underlying index as shown by the more significant test statistics. The equilibrium between Japanese and Singapore market seems to be more significant than the equilibrium between Japanese and the US market. Comparing with Panel C-1, the regressions in Panel C-2 yield the coefficients closer to 1 and the constants closer to 0. It suggests the equilibrium between onshore and offshore futures is much closer to 1 to 1 than the equilibrium between futures and the underlying index. Among all, the equilibrium between higher volume futures such as JNM, SSI and NIY are much closer to 1 to 1 than the equilibrium between lower volume futures such as NK and JNI.

Panel C-3 lists the cointegration tests between two onshore futures and between two offshore futures. Again, all statistics are highly significant (range from -32.85953 to -103.86738), suggesting the stationary equilibrium. In panel C-3, lower volume futures are regressed on higher volume futures and have coefficients greater than 1, indicating lower volume futures prices respond to higher volume futures prices at a larger scale. Again, the equilibrium between two more actively traded futures is much closer to 1 to 1 fair relationship than the equilibrium between two less actively traded futures, which is evident by the smaller coefficients and constants.

4.2.3 Insights from Cointegration Test

Following conclusions can be summarized from the Engle-Granger cointegration tests:

(1) All test statistics (except for CSI300 and A50) are significant at 1% level. There is stationary equilibrium between futures and the underlying index, between onshore and offshore futures, and between other combinations of two futures. The equilibrium follows the fair price model. When one price respond to the other price at a scale larger than (less than) 1 unit, a negative (positive) constant would bring the equilibrium back to 1 to 1 fair relationship;

(2) The two highly correlated stock indices (A50 and CSI300) do not show evidence of cointegration, but the two futures (CIF and SFC) based on them show marginal evidence of cointegration. However, the cointegration is not always significant as adding more dynamics to the tested error term. We might infer that having onshore and offshore futures designed on two different stock indices might not encourage arbitrageurs to keep the products prices in line with each other;

(3) The equilibrium between two futures is more significant and much closer to 1 to 1 fair relationship than the equilibrium between futures and the underlying index. The equilibrium between two more actively traded futures is more significant than the equilibrium between two less actively traded futures. The more actively traded the futures pair are, the narrower difference between their trading prices and the fair price. Their equilibrium tends to be more proximate to the arbitrage-free equilibrium, as indicated by the coefficient closer to 1 and the constant closer to 0.

The empirical evidence is consistent with the theory and is consistent among the pairs. However, the more detailed dynamics between the pairs are further explored in the later chapters.

TABLE XIV ENGLE-GRANGER COINTEGRATION TEST OF LOG PRICE SERIES

Panel A: Chinese Equity Index Products	**Equity Index Futures vs.Equity Index**				**Offshore vs. Onshore Equity Index Futures**		**Domestic Index**	
Dependent Variable{y_t}	LNPR_CIF		LNPR_SFC		LNPR_SFC		LNPR_A50	
Variable{x_t}	LNPR_CSI300	Constant	LNPR_A50	Constant	LNPR_CIF	Constant	LNPR_CSI300	Constant
Coefficient	**0.928111**	0.493043	**1.005483**	-0.043367	**0.904748**	0.641017	0.840133	1.089984
Std Error	0.000630	0.004321	0.001033	0.007076	0.001550	0.010624	0.001038	0.007112
			Engle-Granger Cointegration Test					
Test Statistic	-8.13478**		-6.61187**		-4.08460**		-2.29520	
Critical Values			1%(**)----(-3.90)	5%(*)----(-3.34)	10%----(-3.05)			

Panel B-1: Indian Equity Index Products	**Equity Index Futures vs. Equity Index**					
Dependent Variable{y_t}	LNPR_ NIF		LNPR_ CMY		LNPR_ SIN	
Variable{x_t}	LNPR_NIFTY	Constant	LNPR_NIFTY	Constant	LNPR_NIFTY	Constant
Coefficient	**1.068506**	-0.474128	**1.068750**	-0.475567	**1.079895**	-0.551583
Std Error	0.000387	0.002658	0.000388	0.002670	0.000382	0.002626
			Engle-Granger Cointegration Test			
Test Statistic	-10.55858**		-10.36671**		-12.33996**	

Panel B-2: Indian Equity Index Products	**Offshore vs. Onshore Equity Index Futures**				**Between Domestic Futures**	
Dependent Variable{y_t}	LNPR_ SIN		LNPR_ SIN		LNPR_CMY	
Variable{x_t}	LNPR_NIF	Constant	LNPR_CMY	Constant	LNPR_NIF	Constant
Coefficient	**1.010471**	-0.071107	**1.010217**	-0.069599	**1.000230**	-0.001341
Std Error	0.000098	0.000676	0.000103	0.000706	0.000031	0.000210
			Engle-Granger Cointegration Test			
Test Statistic	-35.00577**		-35.76138**		-87.04795**	
Critical Values		1%(**)----(-3.90)	5%(*)----(-3.34)	10%----(-3.05)		

TABLE XIV ENGLE-GRANGER COINTEGRATION TEST OF LOG PRICE SERIES

Panel C-1: Japanese Equity Index Products	**Equity Index Futures vs. Equity Index**									
Dependent Variable{y_t}	LNPR_JNI		LNPR_JNM		LNPR_SSI		LNPR_NIY		LNPR_NK	
Variable{x_t}	LNPR _NIK225	Constant	LNPR _NIK225	Constant	LNPR _NIK225	Constant	LNPR _NIK225	Constant	LNPR _NIK225	Constant
Coefficient	**1.007280**	-0.050174	**1.006784**	-0.046742	**1.006670**	-0.045625	**1.006848**	-0.047082	**1.009907**	-0.064261
Std Error	0.000212	0.001450	0.000187	0.001277	0.000191	0.001301	0.000229	0.001566	0.000273	0.001865
	Engle-Granger Cointegration Test									
Test Statistic	-47.85880**		-29.94677**		-33.29655**		-34.12517**		-35.51700**	
Critical Values	1%(**)----(-3.90) 5%(*)----(-3.34) 10%----(-3.05)									

Panel C-2: Japanese Equity Index Products	**Offshore vs. Onshore Equity Index Futures**					
Dependent Variable{y_t}	LNPR_SSI		LNPR_NIY		LNPR_NK	
Variable{x_t}	LNPR_JNI	Constant	LNPR_JNI	Constant	LNPR_JNI	Constant
Coefficient	**0.999195**	0.005881	**0.999376**	0.004401	**1.001969**	-0.009588
Std Error	0.000111	0.000759	0.000167	0.001140	0.000310	0.002118
	Engle-Granger Cointegration Test					
Test Statistic	-103.43376**		-68.92650**		-40.89774**	
Dependent Variable{y_t}	LNPR_SSI		LNPR_NIY		LNPR_NK	
Variable{x_t}	LNPR_JNM	Constant	LNPR_JNM	Constant	LNPR_JNM	Constant
Coefficient	**0.999874**	0.001196	**1.000046**	-0.000219	**1.002621**	-0.014090
Std Error	0.000051	0.000349	0.000138	0.000944	0.000299	0.002043
	Engle-Granger Cointegration Test					
Test Statistic	-111.97821**		-53.00177**		-32.26813**	
Critical Values	1%(**)----(-3.90) 5%(*)----(-3.34) 10%----(-3.05)					

TABLE XIV ENGLE-GRANGER COINTEGRATION TEST OF LOG PRICE SERIES

Panel C-3: Japanese Equity Index Products	**Onshore Equity Index Futures**		**Offshore Equity Index Futures**					
Dependent Variable$\{y_t\}$	LNPR_JNI		LNPR_NIY		LNPR_NK		LNPR_NK	
Variable$\{x_t\}$	LNPR_JNM	Constant	LNPR_SSI	Constant	LNPR_SSI	Constant	LNPR_NIY	Constant
Coefficient	**1.000478**	-0.003317	**1.000142**	-0.001204	**1.002719**	-0.015094	**1.002431**	-0.012889
Std Error	0.000106	0.000727	0.000141	0.000961	0.000300	0.002048	0.000292	0.001995
	Engle-Granger Cointegration Test							
Test Statistic	-103.86738**		-56.12841**		-33.18149**		-32.85953**	
Critical Values	1%(**)----(-3.90) 5%(*)----(-3.34) 10%----(-3.05)							

4.2.4 ACE Fit Non-Linear Cointegration Test

The linear cointegration can be extended to nonlinear context. Two “long memory” variables x_t and y_t are nonlinear cointegrated if there exist a particular function f, such that $z_t = f(x_t, y_t)$ is “short memory”. A sufficient condition for z_t to be short memory is that some other form of function $w_t = g(x_t) - h(y_t)$ is “short memory”. As one of the various nonparametric estimation procedures, Granger and Hallman (1991) suggested the Alternating Conditional Expectations (ACE) algorithm to estimate g and h. The objective of the ACE algorithm is to maximize the correlation between the transformed variables of $g(x)$ and $h(x)$. If w_t is short memory, it will appear to be I(0) in test. While if w_t has a unit root, x_t and y_t are not cointegrated. As indicated by a Monte Carlo experiment, Granger and Hallman (1991) suggested that the Augmented Dickey – Fuller test can serve a useful approximation.

Therefore, the ACE algorithm is used to transform the same pairs of raw data in the Engle-Granger test. The two transformed series and the residuals from ACE fit are tested with an ADF test (4 lags) to check for a unit root. The plots of ACE transformed series (TYBEST and XBEST) for the 25 pairs of products are approximately linear, especially in the cases of Indian pairs and the Japanese pairs (except for the pairs involve NK futures). The numerical test results are provided in TABLE XV. We can see that: (1) All transformed series cannot reject the unit root at 1% significance level, but the residuals can significantly reject the unit root, which demonstrating that there exist non-linear cointegration; (2) The test statistics for the residuals imply that the significance of cointegration follows the order of product’s trading volume; (3) The regression coefficients between the pairs of transformed series are very close to 1. It’s much more closer to the fair relationship than the case of raw series in linear cointegration; (4) Two different underlying indices CSI300 and A50 are not linear cointegrated but are nonlinear cointegrated. The graphs of ACE transformed CSI300 and A50 series demonstrate the most non-linearity pattern.

TABLE XV NONLINEAR COINTEGRATION TESTS WITH ACE FIT

Panel A: Chinese Equity Index Products						
TYBEST	**CIF**	**SFC**	**SFC**	**A50**		
XBEST	**CSI300**	**A50**	**CIF**	**CSI300**		
Coefficient	1.0006661	1.001729	1.001226	1.003018		
Std Error	3.68E-04	5.66E-04	8.25E-04	5.87E-04		
ADF test of tybest (4 lag)	-0.6272	-1.313	-1.186	-1.006		
ADF test of xybest (4 lag)	-0.6453	-1.220	-1.023	-0.8649		
ADF test of resduals (4 lag)	-11.28**	-8.425**	-7.306**	-7.682**		
Panel B: Indian Equity Index Products						
TYBEST	**NIF**	**CMY**	**SIN**	**SIN**	**SIN**	**CMY**
XBEST	**NIFTY**	**NIFTY**	**NIFTY**	**NIF**	**CMY**	**NIF**
Coefficient	1.0001557	1.000093	1.000724	0.99963	0.999637	0.999963
Std Error	3.06E-04	3.07E-04	2.98E-04	9.10E-05	9.55E-05	3.03E-05
ADF test of tybest (4 lag)	-1.576	-1.546	-1.571	-1.570	-1.570	-1.549
ADF test of xybest (4 lag)	-1.592	-1.591	-1.593	-1.575	-1.548	-1.576
ADF test of resduals (4 lag)	-8.411**	-8.480**	-9.314**	-16.22**	-16.42**	-42.93**
Panel C: Japanese Equity Index Products						
TYBEST	**JNI**	**JNM**	**SSI**	**NIY**	**NK**	
XBEST	**Nik225**	**Nik225**	**Nik225**	**Nik225**	**Nik225**	
Coefficient	1.0003515	1.000306	1.000255	1.000281	1.000299	
Std Error	1.95E-04	1.68E-04	1.71E-04	2.11E-04	2.57E-04	
ADF test of tybest (4 lag)	-2.923	-2.918	-2.917	-2.924	-2.841	
ADF test of xybest (4 lag)	-2.932	-2.928	-2.929	-2.932	-2.921	
ADF test of resduals (4 lag)	-21.09**	-15.95**	-16.88**	-23.79**	-27.32**	
TYBEST	**SSI**	**NIY**	**NK**	**SSI**	**NIY**	**NK**
XBEST	**JNI**	**JNI**	**JNI**	**JNM**	**JNM**	**JNM**
Coefficient	0.9997064	1.000047	0.999948	1.000011	1.000059	1.000031
Std Error	1.11E-04	1.67E-04	2.92E-04	5.11E-05	1.38E-04	2.79E-04
ADF test of tybest (4 lag)	-2.913	-2.921	-2.844	-2.913	-2.918	-2.844
ADF test of xybest (4 lag)	-2.918	-2.920	-2.915	-2.915	-2.916	-2.914
ADF test of resduals (4 lag)	-46.02**	-39.37**	-25.03**	-52.08**	-38.46**	-24.27**
TYBEST	**JNI**	**NIY**	**NK**	**NK**		
XBEST	**JNM**	**SSI**	**SSI**	**NIY**		
Coefficient	1.0002038	1.000038	1.000033	1.000147		
Std Error	1.06E-04	1.40E-04	2.80E-04	2.74E-04		
ADF test of tybest (4 lag)	-2.918	-2.918	-2.843	-2.844		
ADF test of xybest (4 lag)	-2.915	-2.914	-2.911	-2.915		
ADF test of resduals (4 lag)	-45.85**	-38.87**	-24.35**	-23.31**		
		99% critical value	-3.434			

** Significant at 1% level.

4.3 Price Discovery with Standard Error Correction Model

4.3.1 Model and Methodology

The cointegrated variables cannot continuously drift away from each other. Any deviation from long-run equilibrium will affect their short-run dynamics. As stated by Enders, "A principal feature of cointegrated variables is that their time paths are influenced by the extent of any deviation from long-run equilibrium. ……, the movements of at least some of the variables must respond to the magnitude of the disequilibrium." (Enders, 2010, p.365) Granger representation theorem states that "If a set of variables are cointegrated, then there exists a valid error correction representation of the data, and vice versa." (Enders, 2010, p.370)

In this case, estimating a VAR system using a first difference is inappropriate since it filters out the low frequency information. As a result it cannot specify how short-run dynamics respond to the deviation from long-run equilibrium. Instead, the error correction model needs to be used. The error-correction model can be viewed as a restricted VAR system in first difference augmented by the error-correction terms.

Using the residuals $\{\hat{e}_{t-1}\}$ from long-run equilibrium regression as the error correction term,[24] the error correction model (ECM) can be written as:

$$\Delta y_t = \alpha_1 + \alpha_y \hat{e}_{t-1} + \sum_{i=1}^{p} \alpha_{11}(i) \Delta y_{t-i} + \sum_{i=1}^{q} \alpha_{12}(i) \Delta x_{t-i} + \varepsilon_{yt} \qquad (4.7)$$

$$\Delta x_t = \alpha_2 + \alpha_x \hat{e}_{t-1} + \sum_{i=1}^{p} \alpha_{21}(i) \Delta y_{t-i} + \sum_{i=1}^{q} \alpha_{22}(i) \Delta x_{t-i} + \varepsilon_{xt} \qquad (4.8)$$

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[24] There are three ways to set up the cointegration vector for the error correction terms: (1) set from the desired theoretical combination; (2) employ the residuals from long-run equilibrium regression; and (3) estimate from a procedure which does not select a dependent variable, e.g. the Johnson method estimates according to the largest eigenvalue.

Here, $\varepsilon_{\mathrm{yt}}$ and $\varepsilon_{\mathrm{xt}}$ are white-noise disturbances which might be correlated with each other, α_1 and α_2 are the constants, $\alpha_{11}(i)$, $\alpha_{12}(i)$, $\alpha_{21}(i)$ and $\alpha_{22}(i)$ measure how does the change of level respond to the short-run dynamics, p and q are the lag length of the differenced variables.

α_y and α_x are the important coefficients of interest measuring how does the change of level responds to previous deviation from long-run equilibrium and revealing the price discovery (or lead-lag relationship). The magnitude and sign of α_y and α_x tell the speed and direction of the short-run adjustment responds to previous period's disequilibrium. The larger the coefficient is, the faster the adjustment. The one which adjusts more significantly and at a larger magnitude tends to follow and be leaded by the other one. The sign indicates whether the short-run dynamics move back to equilibrium or move away from equilibrium. A stable error correction system needs short-run dynamics move back to the long-run equilibrium. α_y and α_x cannot be both zero if the variables are cointegrated.

According to the fair price model of futures and spots and the one price law of economically equivalent products on different market, $\{y_t\}$ and $\{x_t\}$ theoretically hold the 1 to 1 equilibrium relationship. When the realization of $\{y_t\}$ is higher than the equilibrium value, the arbitrage activities would bring down the prices of $\{y_t\}$ and push up the prices of $\{x_t\}$. So the sign of α_y is expected to be negative and the sign of α_x is expected to be positive when we specify the error correction term as: $\hat{e}_{t-1} = y_{t-1} - \hat{\beta}_0 - \hat{\beta}_1 x_{t-1}$.

The error-correction models with one lag of differenced variables have been estimated for 24 pairs of equity index products (no error correction model estimated for the pair of CSI300 and A50 since they are not linear cointegrated). After the preliminary estimation, diagnostic checks are performed to determine the adequacy of the models. The autocorrelations and cross correlation of the residuals are checked with no significant spikes. Therefore, the error correction model with one lag differenced variables can filter the residuals approximate the white noise. However, models with more lags of differenced variables are also estimated, in which the autocorrelations and cross-correlations of residuals are even smaller, but the value and statistical properties of the error correction coefficients have no significant difference. Overall, I unify to report the error correction models with one lag of differenced variables. The simple model can both describe the price dynamics and have white noise residuals.

4.3.2 Empirical Evidence on Each Market

The estimated ECM models are reported in TABLE XVI to TABLE XVIII. The standard error and t-statistics are reported below the estimated coefficient value. The equilibrium regressions to generate the error correction term are also reported for each model.[25] The constants in all models are very small and insignificant, since they have been included in the equilibrium regressions where they are significant. Here we might also exclude the constants in the error correction model estimation.

1. Evidence from the Chinese Equity Index Products

TABLE XVI reports the error correction models for the Chinese equity index products. The first two models are between the futures and the underlying index. The third model is between the onshore and offshore futures. In all models, the error correction terms are correctly signed indicating the reversion of short-run dynamics back to the equilibrium. For example, in the model of lnPr_CIF and lnPr_CSI300, a positive error correction term suggests the realized futures prices (lnPr_CIF) is smaller than the equilibrium price or the realized index prices (lnPr_CSI300) is larger than the equilibrium prices. The positive error correction term in the first equation will increase the futures prices, while the negative error correction term in the second equation will decrease the index prices. Both movements make the short-run dynamics revert to the equilibrium.

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[25] In the RATS programming, the dependent variable in the cointegration regression is normalized to have a -1 coefficient.

In the first model, the futures (D_lnPr_CIF) respond to the error correction term insignificantly and smaller, while the index (D_lnPr_CSI300) respond to the error correction term significantly and larger (|3.2975E-04| < |-5.8712E-03|). It suggests that when there is disequilibrium between the onshore futures and the underlying index, the index prices will adjust significantly and faster, thus be leaded by the futures prices. In the short-run dynamics of prices changes, D_lnPr_CIF responds to D_lnPr_CIF(1) at 0.1474 and responds to D_lnPr_CSI300(1) at -0.0769. D_lnPr_CSI300 responds to D_lnPr_CIF(1) at 0.2322 and responds to D_lnPr_CSI300(1) at 0.1678. D_lnPr_CSI300 responds to both lagged prices changes at a larger scale, which suggests the current index prices changes are impacted more by the lagged short-run prices changes. On the other hand, lagged futures prices changes D_lnPr_CIF(1) have a larger coefficient in the two equations than lagged index prices changes D_lnPr_CSI300(1), which suggests the lagged short-run futures prices changes have larger impact on the system. Overall, the futures tend to lead the underlying index and play a dominant role in the price discovery.

In the second model, when there is disequilibrium in the system, the futures prices adjust faster (|2.8472E-03| > |-1.7482E-03|) and thus be leaded by the index prices. In the short-run dynamics, both current prices changes (D_lnPr_SFC and D_lnPr_A50) respond to short-run lagged prices change significantly. The lagged index prices changes (D_lnPr_A50(1)) impact the system more than the lagged futures prices changes (D_lnPr_SFC(1)) in two equations, which are 0.2723 > -0.0582 and 0.3199 > 0.0507. The evidences imply that the underlying index prices tend to play a more dominant role and lead the futures prices on the offshore market.

In the third model of onshore and offshore futures, both D_lnPr_CIF and D_lnPr_SFC respond to the error correction term insignificantly. The cointegration between onshore and offshore futures is the least robust in the previous test. Here the evidence suggests the prices dynamics doesn’t respond significantly to the disequilibrium. It seems that when the onshore and offshore futures are constructed on different indices, the price discovery tends to be weak. However, the error correction coefficient is larger in the equation of D_lnPr_SFC (1.2212E-03 > -6.3869E-04), which indicates a faster adjustment of the offshore futures prices. In the short-run dynamics, the current offshore futures prices changes (D_lnPr_SFC) are impacted more by the two lagged short-run variables (|0.3096| > |0.1090| and |-0.1319| > |-3.9880E-03|), and the lagged onshore futures prices changes impact positively more in the system, (0.1090 and 0.3096 respectively, larger than -3.9880E-03 and -0.1319). Overall, the prices dynamics adjust to the disequilibrium weakly in the system of onshore and offshore futures based on different underlying indices. But still the onshore futures seem to play a relatively more leading role.

TABLE XVI

ERROR CORRECTION MODEL FOR CHINESE EQUITY INDEX PRODUCTS

Chinese Equity Index Products				
Equity Index Futures vs. Underlying Index				
	Constant	**EC(1)***	**D_LNPR_CIF(1)***	**D_LNPR_CSI300(1)***
D_LNPR_CIF	-7.2998E-06	3.2975E-04	**0.1474****	**-0.0769****
Std. Error	4.3921E-06	1.3639E-03	0.0105	0.0125
T-Stat	-1.66204	0.24177	14.07584	-6.15419
D_LNPR_CSI300	-5.3165E-06	**-5.8712E-03****	**0.2322****	**0.1678****
Std. Error	3.3670E-06	1.0456E-03	8.0257E-03	9.5753E-03
T-Stat	-1.57899	-5.61523	28.93555	17.52911
	EC = 0.928111*LNPR_CSI300 – LNPR_CIF + 0.493034			
	Constant	**EC(1)**	**D_LNPR_SFC(1)**	**D_LNPR_A50(1)**
D_LNPR_SFC	-6.0225E-06	**2.8472E-03****	**-0.0582****	**0.2723****
Std. Error	4.9553E-06	1.1018E-03	0.0104	0.0156
T-Stat	-1.21536	2.58405	-5.60444	17.42608
D_LNPR_A50	-4.7525E-06	**-1.7482E-03***	**0.0507****	**0.3199****
Std. Error	3.0817E-06	6.8523E-04	6.4531E-03	9.7190E-03
T-Stat	-1.54217	-2.55121	7.85671	32.91910
	EC = 1.005483*LNPR_A50 – LNPR_SFC – 0.043367			
Chinese Equity Index Futures				
Onshore vs. Offshore Equity Index Futures				
	Constant	**EC(1)**	**D_LNPR_CIF(1)**	**D_LNPR_SFC(1)**
D_LNPR_CIF	-6.9670E-06	-6.3869E-04	**0.1090****	-3.9880E-03
Std. Error	4.3970E-06	5.9394E-04	0.0111	9.7593E-03
T-Stat	-1.5845	-1.07535	9.85721	-0.40863
D_LNPR_SFC	-6.2262E-06	1.2212E-03	**0.3096****	**-0.1319****
Std. Error	4.9049E-06	6.6254E-04	0.0123	0.0109
T-Stat	-1.2694	1.84324	25.08921	-12.11173
	EC = 0.904748*LNPR_CIF – LNPR_SFC + 0.641017			

* (1) is 1-minute lag of the terms ---- Error-Correction term and the differenced prices variables.

** indicates significance level of 1%, and * indicates the significance level of 5%.

The product underlined is the leading one in the pair.

2. Evidence from the Indian Equity Index Products

TABLE XVII reports the error correction models for the Indian equity index products. The first three models are between the three futures and the underlying index. The error correction coefficients are significant and larger in the second equation of index prices dynamics (D_lnPr_NIFTY), they are -6.7115E-03, -6.2556E-03 and -7.4227E-03, respectively, while the error correction coefficients are insignificant and smaller in the first equation of futures prices dynamics (D_lnPr_NIF, D_lnPr_CMY, and lnPr_SIN)), they are -9.2549E-04, -3.3998E-04 and 7.9242E-04, respectively. The evidences indicate that when there is disequilibrium in the system, the index prices tend to adjust faster to the equilibrium and be leaded by the futures prices.

In the short-run dynamics, a horizontal comparison between two equations find that the current index prices changes consistently adjust faster to both lagged futures and index prices changes (e.g. |0.5097| > |0.2508| and |-0.3306| > |-0.1492|). A vertical comparison between two lagged differenced variables find that the lagged futures prices changes have larger impact on the domestic market than the lagged index prices changes (e.g. |0.1708| > |-0.0479| and |0.4285| > |-0.2493|). On the domestic market, the lagged futures prices changes play a positive role while the lagged index prices changes play a negative role in current prices dynamics. On the offshore market, the lagged futures prices changes also play a positive larger role on current index prices changes. Overall the evidences suggest the futures prices tend to lead in the price discovery.

The continued TABLE XVII reports the error correction models between the onshore and offshore futures (2 models) and between the two onshore futures (1 model). The error correction coefficients are all significantly and correctly signed driving the short-run dynamics revert to the equilibrium. According to the magnitude of the error correction coefficients, the two offshore futures and the onshore mini sized futures adjust faster to the equilibrium in the systems (|0.0415| > |-0.0206|,

|0.0344| > |-0.0298|, and |0.3097| > |-0.0545|). The faster the adjustment, the larger tendency it is leaded by the other product. The evidences suggest the offshore futures are leaded by the onshore futures, and the onshore lower volume futures are leaded by the onshore higher volume futures.

In the short-run dynamics, the current offshore futures prices dynamics (D_lnPr_SIN) respond faster to both lagged variables than the onshore futures prices dynamics (|0.4599| > |0.0955| and |-0.3144| > |0.0281|), and the lagged onshore futures prices changes have larger impact in the first model (|0.0955| > |0.0281| and |0.4599| > |-0.3144|). The evidences suggest the onshore standard sized futures which have the highest trading volume lead the offshore futures in the price discovery.

In the second model, the current offshore futures prices dynamics respond faster to lagged onshore mini futures prices changes than the current onshore mini futures prices dynamics (|0.3082| > |-0.0425|), and the lagged onshore mini futures prices changes have a larger impact on the offshore futures than the lagged offshore futures prices changes do (|0.3082| > |-0.1735|). The onshore mini futures tend to lead the short-run dynamics of the offshore futures, although it’s not as significant as the onshore standard sized futures do. The difference might due to the onshore mini futures have a middle trading volume.

In the third model of two onshore futures, the prices changes of higher volume standard sized futures consistently play a leading role to the lower volume mini futures in the short-run dynamics. The current mini futures prices changes respond faster to both lagged prices changes in the system (|0.4227| > |0.1979| and |-0.2889| > |-0.0760|), and the lagged standard sized futures prices changes have larger influence to the system (|0.1979| > |-0.0760| and |0.4227| > |-0.2889|). The lagged standard sized futures prices changes have positive impact, while the lagged mini futures prices changes have negative impact on the system. Overall the evidences support that the higher volume standard sized futures tend to lead the lower volume mini futures in both equilibrium reversion and short-run dynamics.

TABLE XVII

ERROR CORRECTION MODEL FOR INDIAN EQUITY INDEX PRODUCTS

Indian Equity Index Products
Equity Index Futures vs. Underlying Index

	Constant	**EC(1)***	**D_LNPR_NIF(1)***	**D_LNPR_NIFTY(1)***
D_LNPR_NIF	-3.9683E-07	-9.2549E-04	**0.2508****	**-0.1492****
Std. Error	3.2562E-06	1.8987E-03	0.0146	0.0153
T-Stat	-0.12187	-0.48743	17.15912	-9.75055
D_LNPR_NIFTY	-3.1252E-07	**-6.7115E-03****	**0.5097****	**-0.3306****
Std. Error	3.0135E-06	1.7572E-03	0.0135	0.0142
T-Stat	-0.10370	-3.81940	37.67203	-23.34425
	EC = 1.068506*LNPR_NIFTY - LNPR_NIF - 0.474128			
	Constant	**EC(1)**	**D_LNPR_CMY(1)**	**D_LNPR_NIFTY(1)**
D_LNPR_CMY	-3.7754E-07	-3.3998E-04	**0.1708****	**-0.0479****
Std. Error	3.2164E-06	1.8670E-03	0.0148	0.0152
T-Stat	-0.11738	-0.18209	11.57911	-3.14484
D_LNPR_NIFTY	-3.2430E-07	**-6.2556E-03****	**0.4285****	**-0.2493****
Std. Error	3.0423E-06	1.7660E-03	0.0140	0.0144
T-Stat	-0.10660	-3.54228	30.71174	-17.29050
	EC = 1.068750*LNPR_NIFTY – LNPR_CMY – 0.475567			
	Constant	**EC(1)**	**D_LNPR_SIN(1)**	**D_LNPR_NIFTY(1)**
D_LNPR_SIN	-3.6276E-07	7.9242E-04	**0.0435****	**0.0556****
Std. Error	3.4520E-06	2.0389E-03	0.0132	0.0146
T-Stat	-0.10509	0.38865	3.28723	3.80582
D_LNPR_NIFTY	-3.4652E-07	**-7.4227E-03****	**0.2932****	**-0.1335****
Std. Error	3.0612E-06	1.8081E-03	0.0117	0.0130
T-Stat	-0.11320	-4.10528	24.97800	-10.30432
	EC = 1.079895*LNPR_NIFTY – LNPR_SIN – 0.551583			

* (1) is 1-minute lag of the terms ---- Error-Correction term and the differenced prices variables.

** indicates significance level of 1%, and * indicates the significance level of 5%.

The product underlined is the leading one in the pair.

TABLE XVII

ERROR CORRECTION MODEL FOR INDIAN EQUITY INDEX PRODUCTS

Indian Equity Index Futures

Onshore vs. Offshore Equity Index Futures

	Constant	**EC(1)**	**D_LNPR_NIF(1)**	**D_LNPR_SIN(1)**
D_LNPR_NIF	-3.9764E-07	**-0.0206****	**0.0955****	0.0281
Std. Error	3.2617E-06	7.1418E-03	0.0173	0.0164
T-Stat	-0.12191	-2.88859	5.52766	1.71413
D_LNPR_SIN	-3.2027E-07	**0.0415****	**0.4599****	**-0.3144****
Std. Error	3.3994E-06	7.4434E-03	0.018	0.0171
T-Stat	-0.09421	5.57650	25.54680	-18.37848

EC = 1.010471*LNPR_NIF – LNPR_SIN – 0.071107

	Constant	**EC(1)**	**D_LNPR_CMY(1)**	**D_LNPR_SIN(1)**
D_LNPR_CMY	-3.8311E-07	**-0.0298****	**-0.0425****	**0.1748****
Std. Error	3.2049E-06	6.73E-03	0.0161	0.0151
T-Stat	-0.11954	-4.43343	-2.64319	11.54825
D_LNPR_SIN	-3.3818E-07	**0.0344****	**0.3082****	**-0.1735****
Std. Error	3.4255E-06	7.1913E-03	0.0172	0.0162
T-Stat	-0.09873	4.78831	17.92179	-10.72515

EC = 1.010217*LNPR_CMY – LNPR_SIN – 0.069599

Indian Equity Index Futures

Between Onshore Equity Index Futures

	Constant	**EC(1)**	**D_LNPR_NIF(1)**	**D_LNPR_CMY(1)**
D_LNPR_NIF	-3.9447E-07	**-0.0545***	**0.1979****	**-0.0760****
Std. Error	3.2620E-06	0.0259	0.0267	0.0266
T-Stat	-0.12093	-2.10341	7.41185	-2.86171
D_LNPR_CMY	-3.6878E-07	**0.3097****	**0.4227****	**-0.2889****
Std. Error	3.1645E-06	0.0252	0.0259	0.0258
T-Stat	-0.11654	12.31054	16.31806	-11.20858

EC = 1.000230*LNPR_NIF – LNPR_CMY – 0.001341

* (1) is 1-minute lag of the terms ---- Error-Correction term and the differenced prices variables.

** indicates significance level of 1%, and * indicates the significance level of 5%.

The product underlined is the leading one in the pair.

3. Evidence from the Japanese Equity Index Products

TABLE XVIII reports the error correction models for the Japanese equity index products. The trading volume of the 5 Japanese futures has the order of JNM (domestic Mini futures) > SSI (SGX futures) > JNI (domestic standard sized futures) > NIY (CME Yen futures) > NK (CME USD futures).

The first section exhibits the 5 models between the futures and the underlying index. The sign of error correction coefficients consistently supports the reversion of the price dynamics to the equilibrium.

In the first two models between higher volume futures (JNM and SSI) and the underlying index (Nikkei 225), the index prices respond to the disequilibrium (error correction term) faster than the futures prices do (|-0.0585| > |4.6108E-03| and |-0.0604| > |0.0151|), indicating the leading role is played by the higher volume futures (JNM and SSI) to maintain the equilibrium. In the short-run dynamics, the current index prices changes (D_lnPr_Nik225) respond to both lagged prices changes of futures and index at a higher speed than the futures do (|0.3246| > |0.0571| and |-0.2544| > |-0.0194|, (|0.2371| > |-0.0492| and |-0.1694| > |0.0796|). The lagged JNM prices changes have a larger impact on the system of JNM and Nikkei 225 than the lagged Nikkei 225 prices changes do (|0.0571| > |-0.0194| and |0.3246| > |-0.2544). The lagged SSI prices changes also have a larger impact on the current index prices changes than the lagged index prices changes do (|0.2371| > |-0.1694|). Overall the evidences support that the two highest volume futures JNM and SSI tend to lead the underlying index in the price discovery.

In the rest three models of the relatively lower volume futures (JNI, NIY, NK) and the underlying index, the futures prices consistently respond to the disequilibrium faster than the index prices do (|0.0994| > |-0.0487|, |0.0724| > |-0.0316| and |0.0984| > |-0.0181|), indicating the leading role is played by the underlying index. In the short-run dynamics, the current futures prices changes respond to both futures and index lagged prices changes faster than the current index prices changes respond, except for the response of D_lnPr_NIY to D_lnPr_NIY(1). At the same time, the lagged index prices changes have a larger impact to the current futures prices changes than the lagged futures prices changes have. So overall, when the futures have a lower trading volume, the underlying index tends to play the leading role in the price discovery process. In the system of the lowest volume futures NK and the underlying index, NK is significantly leaded by the underlying index in the price discovery.

The trading volume plays an important role in the price discovery between futures and the underlying index. Those futures (JNM and SSI) with higher volume tend to lead the underlying index, while those futures with lower volume (JNI, NIY and NK) tend to be leaded by the underlying index.

The second section exhibits the error correction models between the highest volume onshore futures (JNM) and the three offshore futures. The error correction coefficients have correct signs indicating the reversion to equilibrium. When there are deviations from equilibrium, the three offshore futures prices adjust faster than the JNM prices do (|0.4548| > |-0.2925|, |0.2208| > |-0.0263|, and |0.0847| > |-2.9200E-03|), indicating the leading role is played by JNM in maintaining the equilibrium. In the short-run dynamics, the current offshore futures prices changes respond faster to both lagged variables than the current JNM prices changes do in 5 of 6 equations, and the lagged JNM prices changes have a larger impact to current prices changes system than the lagged offshore futures prices changes do in 5 of 6 equations. Overall, the highest volume onshore futures JNM lead all offshore futures in the price discovery.

The third section exhibits the error correction models between the lower volume onshore futures (JNI) and the three offshore futures. The error correction coefficients are correctly signed indicating the reversion to equilibrium. JNI prices respond to disequilibrium faster than SSI and NIY prices respond (|-0.5405| > |0.1035| and |-0.1800| > |0.1620|), indicating the leading role is now played by the offshore futures SSI and NIY. The short-run dynamics also support this leading relationship. However, the JNI prices lead the NK prices in both equilibrium revision and the short-run dynamics. When the onshore futures are traded at a lower volume, its prices tend to be leaded by the higher volume offshore futures (SSI) or the primary offshore futures (NIY, compare to NK),[26] but anyhow it can lead the lowest volume offshore futures (NK).

The last section reports the error correction models between the higher volume futures and the lower volume futures paired either on the onshore market or on the offshore market. Again, the signs of error correction coefficients consistently indicate the reversion of prices dynamics back to the equilibrium. Between JNM and JNI, the lower volume JNI prices respond to disequilibrium faster than JNM prices do (|0.5829| > |-0.0624|), and the current prices changes of JNI respond faster to the both lagged prices changes variables (|0.1290| > |0.0191| and |-0.0827| > |0.0254|). The evidences suggest the JNM lead the JNI in the price discovery between two onshore futures. In the other three pairs, we can see SSI lead NIY and NK, and NIY lead NK in maintaining the price equilibrium. The short-run dynamics also reveal SSI lead NK and NIY lead NK. Overall the higher volume futures lead the lower volume futures in the price discovery.

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[26] SSI and NIY are the most actively traded futures at each offshore market (SGX and CME).

TABLE XVIII

ERROR CORRECTION MODEL FOR JAPANESE EQUITY INDEX PRODUCTS

Japanese Equity Index Products	***Equity Index Futures vs. Underlying Index***			
	Constant	**EC(1)**	**D_LNPR_JNM(1)**	**D_LNPR_NIK225(1)**
D_LNPR_JNM	-4.3310E-06	4.6108E-03	__0.0571**__	**-0.0194**
Std. Error	4.7678E-06	6.9560E-03	0.0164	0.0176
T-Stat	-0.90838	0.66285	3.48467	-1.10188
D_LNPR_NIK225	-4.1227E-06	__-0.0585**__	__0.3246**__	__-0.2544**__
Std. Error	4.2962E-06	6.2679E-03	0.0148	0.0159
T-Stat	-0.95961	-9.32672	21.97943	-16.00668
	EC = 1.006784*LNPR_Nik225 – LNPR_JNM – 0.046742			
	Constant	**EC1(1)**	**D_LNPR_SSI(1)**	**D_LNPR_NIK225(1)**
D_LNPR_SSI	-4.3516E-06	__0.0151*__	__-0.0492**__	__0.0796**__
Std. Error	4.8913E-06	7.0439E-03	0.0150	0.0165
T-Stat	-0.88965	2.14435	-3.27742	4.82086
D_LNPR_NIK225	-4.1421E-06	__-0.0604**__	__0.2371**__	__-0.1694**__
Std. Error	4.3140E-06	6.2125E-03	0.0132	0.0146
T-Stat	-0.96015	-9.7157	17.92000	-11.63073
	EC = 1.006670*LNPR_Nik225 – LNPR_SSI – 0.045625			
	Constant	**EC1(1)**	**D_LNPR_JNI(1)**	**D_LNPR_NIK225(1)**
D_LNPR_JNI	-4.2856E-06	__0.0994**__	__-0.2264**__	__0.2774**__
Std. Error	5.5364E-06	7.3490E-03	0.0112	0.014
T-Stat	-0.77407	13.52578	-20.19502	19.81306
D_LNPR_NIK225	-4.1517E-06	__-0.0487**__	__0.0789**__	-0.0134
Std. Error	4.3479E-06	5.7714E-03	8.8032E-03	0.0110
T-Stat	-0.95487	-8.44297	8.95914	-1.22094
	EC = 1.007280*LNPR_Nik225 – LNPR_JNI – 0.050174			
	Constant	**EC1(1)**	**D_LNPR_NIY(1)**	**D_LNPR_NIK225(1)**
D_LNPR_NIY	-4.2908E-06	__0.0724**__	__-0.0325**__	__0.0848**__
Std. Error	4.7831E-06	5.7064E-03	0.0121	0.0132
T-Stat	-0.89707	12.6866	-2.67860	6.40653
D_LNPR_NIK225	-4.0999E-06	__-0.0316**__	__0.0702**__	6.7242E-03
Std. Error	4.3622E-06	5.2042E-03	0.0110	0.0121
T-Stat	-0.93987	-6.07676	6.35274	0.55687
	EC = 1.006848*LNPR_Nik225 – LNPR_NIY – 0.047082			
	Constant	**EC1(1)**	**D_LNPR_NK(1)**	**D_LNPR_NIK225(1)**
D_LNPR_NK	-3.8401E-06	__0.0984**__	__-0.0513**__	__0.1544**__
Std. Error	4.7965E-06	4.8225E-03	0.0100	0.0113
T-Stat	-0.80061	20.41437	-5.10625	13.69558
D_LNPR_NIK225	-4.1505E-06	__-0.0181**__	-0.0135	__0.0799**__
Std. Error	4.3718E-06	4.3955E-03	9.1548E-03	0.0103
T-Stat	-0.94938	-4.10853	-1.47827	7.77823
	EC = 1.009907*LNPR_Nik225 – LNPR_NK – 0.064261			

TABLE XVIII

ERROR CORRECTION MODEL FOR JAPANESE EQUITY INDEX PRODUCTS

Japanese Equity Index Futures

Onshore JNM Futures vs. Offshore Equity Index Futures

	Constant	**EC1(1)**	**D_LNPR_JNM(1)**	**D_LNPR_SSI(1)**
D-LNPR_JNM	-4.3009E-06	**-0.2925****	0.0407	5.0057E-03
Std. Error	4.7498E-06	0.0316	0.0255	0.0252
T-Stat	-0.90547	-9.25980	1.59619	0.19882
D_LNPR_SSI	-4.2963E-06	**0.4548****	**0.0965****	**-0.0559***
Std. Error	4.8388E-06	0.0322	0.0260	0.0256
T-Stat	-0.88789	14.13359	3.71443	-2.18068
EC = 0.999874*LNPR_JNM – LNPR_SSI + 0.001196				
	Constant	**EC1(1)**	**D_LNPR_JNM(1)**	**D_LNPR_NIY(1)**
D_LNPR_JNM	-4.2799E-06	**-0.0263****	0.0152	**0.0341***
Std. Error	4.7655E-06	9.7674E-03	0.0143	0.0139
T-Stat	-0.89809	-2.69144	1.06487	2.44928
D_LNPR_NIY	-4.3750E-06	**0.2208****	**0.0524****	-0.0200
Std. Error	4.7296E-06	9.6938E-03	0.0142	0.0138
T-Stat	-0.92502	22.77899	3.70353	-1.44737
EC = 1.000046*LNPR_JNM – LNPR_NIY – 0.000219				
	Constant	**EC1(1)**	**D_LNPR_JNM(1)**	**D_LNPR_NK(1)**
D_LNPR_JNM	-4.3220E-06	-2.9200E-03	**0.0450****	-5.3036E-03
Std. Error	4.7679E-06	4.3337E-03	0.0105	0.0101
T-Stat	-0.90648	-0.67378	4.29078	-0.52595
D_LNPR_NK	-3.8522E-06	**0.0847****	**0.2028****	**-0.1051****
Std. Error	4.7709E-06	4.3365E-03	0.0105	0.0101
T-Stat	-0.80743	19.54096	19.31630	-10.41641
EC = 1.002621LNPR_JNM – LNPR_NK – 0.014090				

* (1) is 1-minute lag of the terms ---- Error-Correction term and the differenced prices variables.

** indicates significance level of 1%, and * indicates the significance level of 5%.

The product underlined is the leading one in the pair.

TABLE XVIII

ERROR CORRECTION MODEL FOR JAPANESE EQUITY INDEX PRODUCTS

Japanese Equity Index Futures

Onshore JNI Futures vs. Offshore Equity Index Futures

	Constant	**EC1(1)**	**D_LNPR_JNI(1)**	**D_LNPR_SSI(1)**
D_LNPR_JNI	-4.4034E-06	**-0.5405****	**-0.0701****	**0.0968****
Std. Error	5.3593E-06	0.0159	0.0133	0.0148
T-Stat	-0.82163	-34.03736	-5.26888	6.55682
D_LNPR_SSI	-4.3946E-06	**0.1035****	**0.0344****	-0.0143
Std. Error	4.8790E-06	0.0145	0.0121	0.0134
T-Stat	-0.90073	7.15854	2.84030	-1.06465
EC = 0.999195*LNPR_JNI – LNPR_SSI + 0.005881				
	Constant	**EC1(1)**	**D_LNPR_JNI(1)**	**D_LNPR_NIY(1)**
D_LNPR_JNI	-4.4075E-06	**-0.1800****	**-0.1595****	**0.1823****
Std. Error	5.5190E-06	9.7594E-03	0.0111	0.0125
T-Stat	-0.79861	-18.44702	-14.32574	14.56622
D_LNPR_NIY	-4.42706E-06	**0.1620****	-0.0151	**0.0357****
Std. Error	4.7603E-06	8.4179E-03	9.6026E-03	0.0108
T-Stat	-0.92998	19.23955	-1.56983	3.30966
EC = 0.999376LNPR_JNI – LNPR_NIY + 0.004401				
	Constant	**EC1(1)**	**D_LNPR_JNI(1)**	**D_LNPR_NK(1)**
D_LNPR_JNI	-4.6012E-06	**-0.0396****	**-0.1498****	**0.1373****
Std. Error	5.5992E-06	4.9800E-03	9.2795E-03	0.0104
T-Stat	-0.82176	-7.95927	-16.14251	13.14237
D_LNPR_NK	-4.0188E-06	**0.0828****	**0.0954****	**-0.0312****
Std. Error	4.8045E-06	4.2733E-03	7.9625E-03	8.9637E-03
T-Stat	-0.83645	19.38048	11.98436	-3.47551
EC = 1.001969*LNPR_JNI – LNPR_NK – 0.009588				

* (1) is 1-minute lag of the terms ---- Error-Correction term and the differenced prices variables.

** indicates significance level of 1%, and * indicates the significance level of 5%.

The product underlined is the leading one in the pair.

TABLE XVIII

ERROR CORRECTION MODEL FOR JAPANESE EQUITY INDEX PRODUCTS

Japanese Equity Index Futures
Between Two Onshore Equity Index Futures

	Constant	**EC1(1)**	**D_LNPR_JNM(1)**	**D_LNPR_JNI(1)**
D_LNPR_JNM	-4.3009E-06	**-0.0624****	0.0191	**0.0254***
Std. Error	4.7616E-06	0.0148	0.0139	0.0123
T-Stat	-0.90325	-4.23046	1.38029	2.06605
D_LNPR_JNI	-4.3046E-06	**0.5829****	**0.1290****	**-0.0827****
Std. Error	5.3291E-06	0.0165	0.0155	0.0138
T-Stat	-0.80775	35.28131	8.31552	-6.00606

EC = 1.000478*LNPR_JNM – LNPR_JNI – 0.003317

Japanese Equity Index Futures
Between Two Offshore Equity Index Futures

	Constant	**EC1(1)**	**D_LNPR_SSI(1)**	**D_LNPR_NIY(1)**
D_LNPR_SSI	-4.3407E-06	**-0.0429****	**-0.0493****	**0.0815****
Std. Error	4.8851E-06	9.9245E-03	0.0137	0.0136
T-Stat	-0.88857	-4.32678	-3.60106	5.97669
D_LNPR_NIY	-4.4065E-06	**0.2209****	0.0214	4.8797E-03
Std. Error	4.7333E-06	9.6161E-03	0.0133	0.0132
T-Stat	-0.93095	22.97551	1.61407	0.36915

EC = 1.000142*LNPR_SSI – LNPR_NIY – 0.001204

	Constant	**EC1(1)**	**D_LNPR_SSI(1)**	**D_LNPR_NK(1)**
D_LNPR_SSI	-4.4123E-06	-4.8124E-03	-4.1903E-03	**0.0221***
Std. Error	4.8946E-06	4.4456E-03	0.0104	0.0102
T-Stat	-0.90145	-1.08249	-0.40405	2.16356
D_LNPR_NK	-3.9057E-06	**0.085****	**0.1767****	**-0.0891****
Std. Error	4.7808E-06	4.3423E-03	0.0101	9.97E-03
T-Stat	-0.81696	19.58400	17.44403	-8.93136

EC = 1.002719*LNPR_SSI – LNPR_NK – 0.015094

	Constant	**EC1(1)**	**D_LNPR_NIY(1)**	**D_LNPR_NK(1)**
D_LNPR_NIY	-4.4063E-06	**-0.0139****	4.9512E-03	**0.0231***
Std. Error	4.8119E-06	4.4720E-03	0.0106	0.0103
T-Stat	-0.91570	-3.11765	0.46856	2.25088
D_LNPR_NK	-3.8600E-06	**0.0738****	**0.1995****	**-0.1030****
Std. Error	4.7910E-06	4.4526E-03	0.0105	0.0102
T-Stat	-0.80567	16.57579	18.95905	-10.05486

EC = 1.002431*LNPR_NIY – LNPR_NK – 0.012889

* (1) is 1-minute lag of the terms ---- Error-Correction term and the differenced prices variables.

** indicates significance level of 1%, and * indicates the significance level of 5%.

The product underlined is the leading one in the pair.

4.3.3 Insights from the Error Correction Modeling

The implications from the error-correction modeling are summarized as follows: (1) The signs of error correction coefficients indicate the price dynamics properly revert to the equilibrium in 22 cases. In the models of NIF & NIFTY and CMY & NIFTY, the error correction coefficients in futures equations are insignificant, but the error correction coefficients in index equations are correctly signed and significant, showing the index moving toward to the equilibrium. It's obvious that the arbitrage activities on markets effectively drive prices dynamics revert to long-run equilibrium.

(2) The product having a more significant and larger error correction coefficient adjusts to the disequilibrium more significantly and faster. It implies that this product is leaded by the other one in maintaining the price equilibrium. The coefficients of lagged prices changes also reveal the short-run price dynamics. Overall the leading product in the price discovery can be determined. TABLE XIX summarizes the leading product in the 24 pairwise equity index products.

In the prices discovery between futures and the underlying index, the actively traded futures (CIF, NIF, CMY, SIN, JNM and SSI) tend to lead the underlying index, while the less actively traded futures (SFC, JNI, NIY and NK) tend to be leaded by the underlying index. In the prices discovery between onshore and offshore futures, the actively traded onshore futures (NIF, CMY and JNM) tend to lead the less actively traded offshore futures. However, when the onshore futures are traded at a lower volume as in the case of JNI, it tend to be leaded by the higher volume offshore futures (SSI) at the SGX and the primary offshore futures (NIY) at the CME. But it (JNI) still leads the lowest volume offshore futures (NK) at the CME. When two futures are based on different indices (the case of CIF and SFC), the adjustment of prices dynamics to long-run equilibrium is insignificant, as indicated by the insignificant error correction coefficients. Finally, in the prices discovery between higher volume and lower volume futures, the higher volume futures always lead the lower volume futures.

TABLE XIX LEADING PRODUCT IN THE PAIRWISE PRICE DISCOVERY STUDY

(From Average (Moving) Error-Correction Model)

China Products	CIF & CSI300	SFC & A50	CIF & SFC			
Comparison	Futures vs. Index		Onshore vs. Offshore			
Leading Product	Futures	Index	Insignificant			
India Products	NIF & NIFTY	CMY & NIFTY	SIN & NIFTY	NIF & SIN	CMY & SIN	NIF & CMY
Comparison	Futures vs. Index			Onshore vs. Offshore		Higher vs. Lower volume
Leading Product	Futures	Futures	Futures	Onshore	Onshore	Higher volume
Japan Products	JNM & Nik225	SSI & Nik225	JNI & Nik225	NIY & Nik225	NK & Nik225	
Comparison	Futures vs. Index					
Leading Product	Futures	Futures	Index	Index	Index	
Japan Products	JNM & SSI	JNM & NIY	JNM & NK	JNI & SSI	JNI & NIY	JNI & NK
Comparison	Onshore vs. Offshore					
Leading Product	Onshore	Onshore	Onshore	Offshore	Offshore	Onshore
Japan Products	JNM & JNI	SSI & NIY	SSI & NK	NIY & NK		
Comparison	Higher vs. Lower volume					
Leading Product	Higher volume	Higher volume	Higher volume	Higher volume		

This table summarizes the leading product in the error-correction models for 24 pairs of equity index products, by analyzing the error correction coefficients estimated.

4.4 Price Discovery with Moving Error Correction Model

Estimate the error correction models with all data points reveals the price discovery on average. However, we are interested in the evolvement of prices discovery over time. For this purpose, the moving error correction models are estimated at each data point with a time window of daily observations (e.g. 241 observations for Chinese products as there are 241 useful minutes in a trading day, 376 observations for Indian products and 302 observations for Japanese products). Figure 14 to Figure 16 plot the estimated values and the t-statistics of α_y and α_x over time for all the pairs in three countries. The product having larger magnitude and more significant error correction coefficient tends to adjust faster and stronger to last period's deviation from the long-run equilibrium, implying it is leaded by the other product in the prices discovery.

Observing the figures, although the error correction coefficients are calculated by different data with a fixed window and there are small fluctuations, the overall trend is quite stable over time and there is no structure breaks or unusual jumps. This pattern indicates the parameters consistency in the cointegration and the error correction system. The identified cointegration and error correction relationship are stable over the study period. Analyzing the value and significance of the estimations, the same conclusions about the leading product in the price discovery can be obtained as in the standard error correction models (See TABLE XIX).

Most prior studies obtain the conclusions from the specific samples in their research. They found it is either the futures lead the underlying index, or the underlying index leads the futures, and it is mostly the offshore futures lead the onshore futures since the international exchanges are generally more advanced and experienced. Here I find the price discovery is not necessarily unilateral and the trading volume is an important factor in determining the leader. The more actively traded products will play a more leading role in the price discovery.

Figure 14. **Moving Error Correction Model for Chinese Equity Index Products**

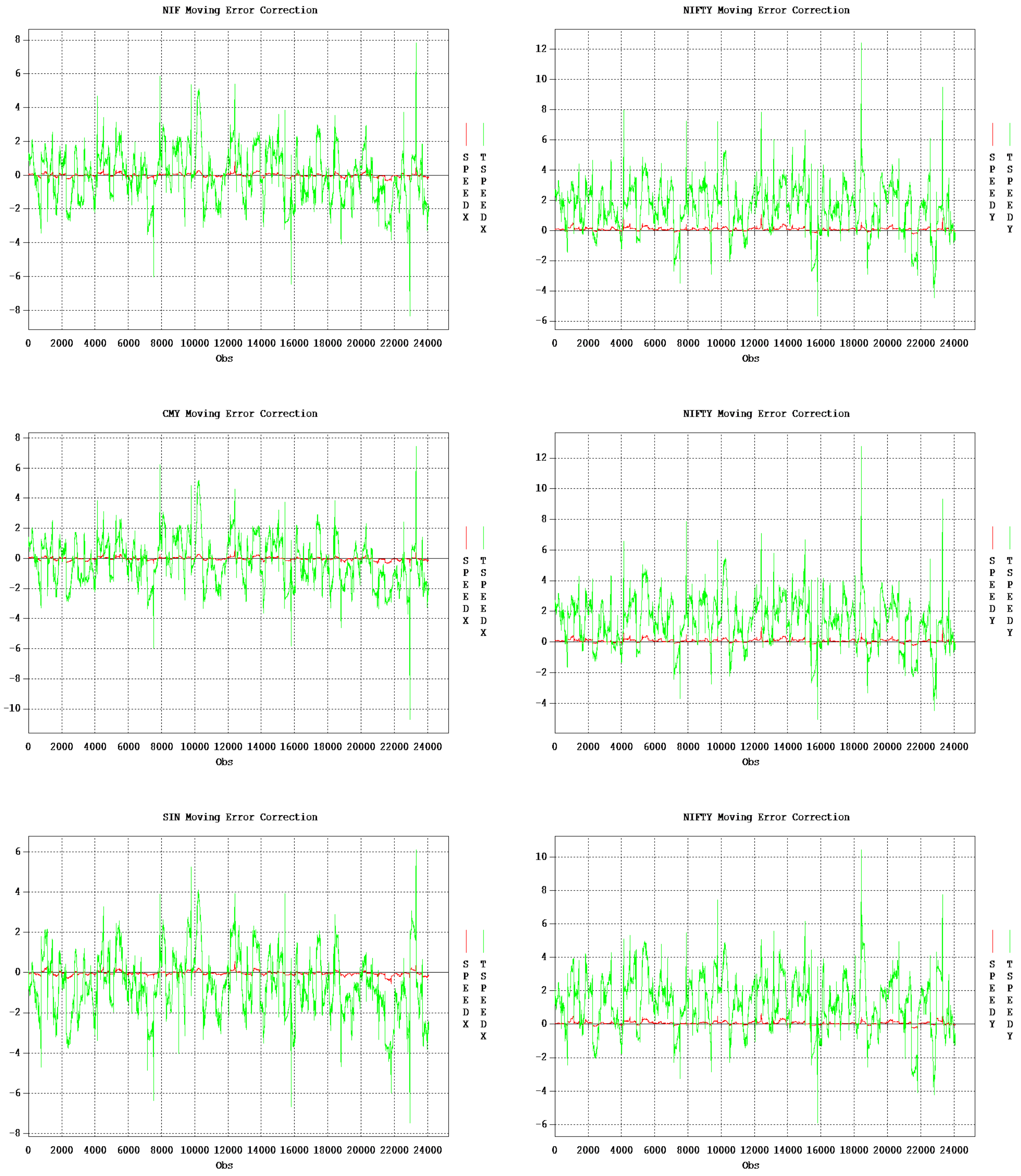

Figure 15. Moving Error Correction Model for Indian Equity Index Products

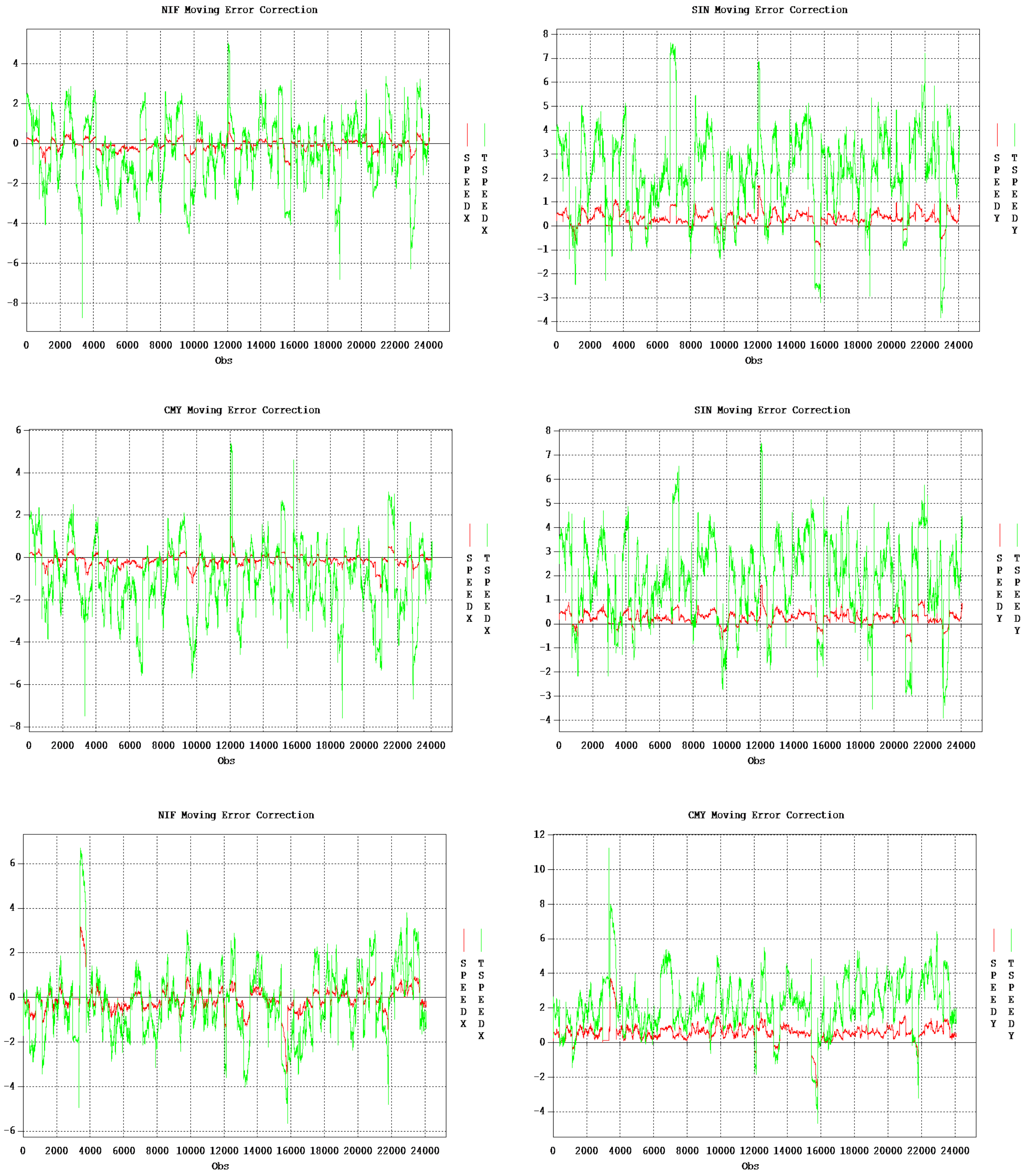

Figure 15. **Moving Error Correction Model for Indian Equity Index Products**

Figure 16. Moving Error Correction Model for Japanese Equity Index Products

Figure 16. **Moving Error Correction Model for Japanese Equity Index Products**

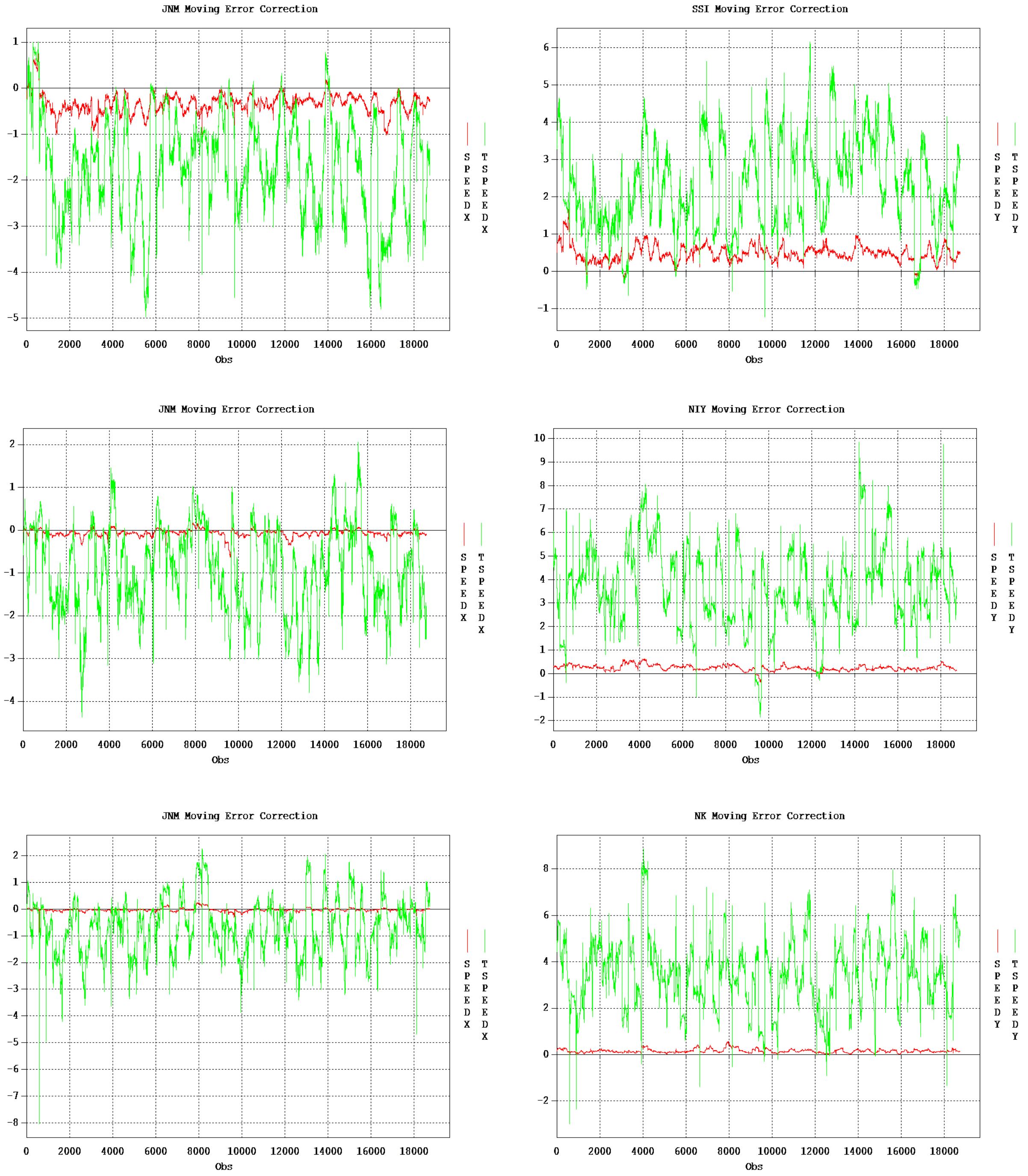

Figure 16. Moving Error Correction Model for Japanese Equity Index Products

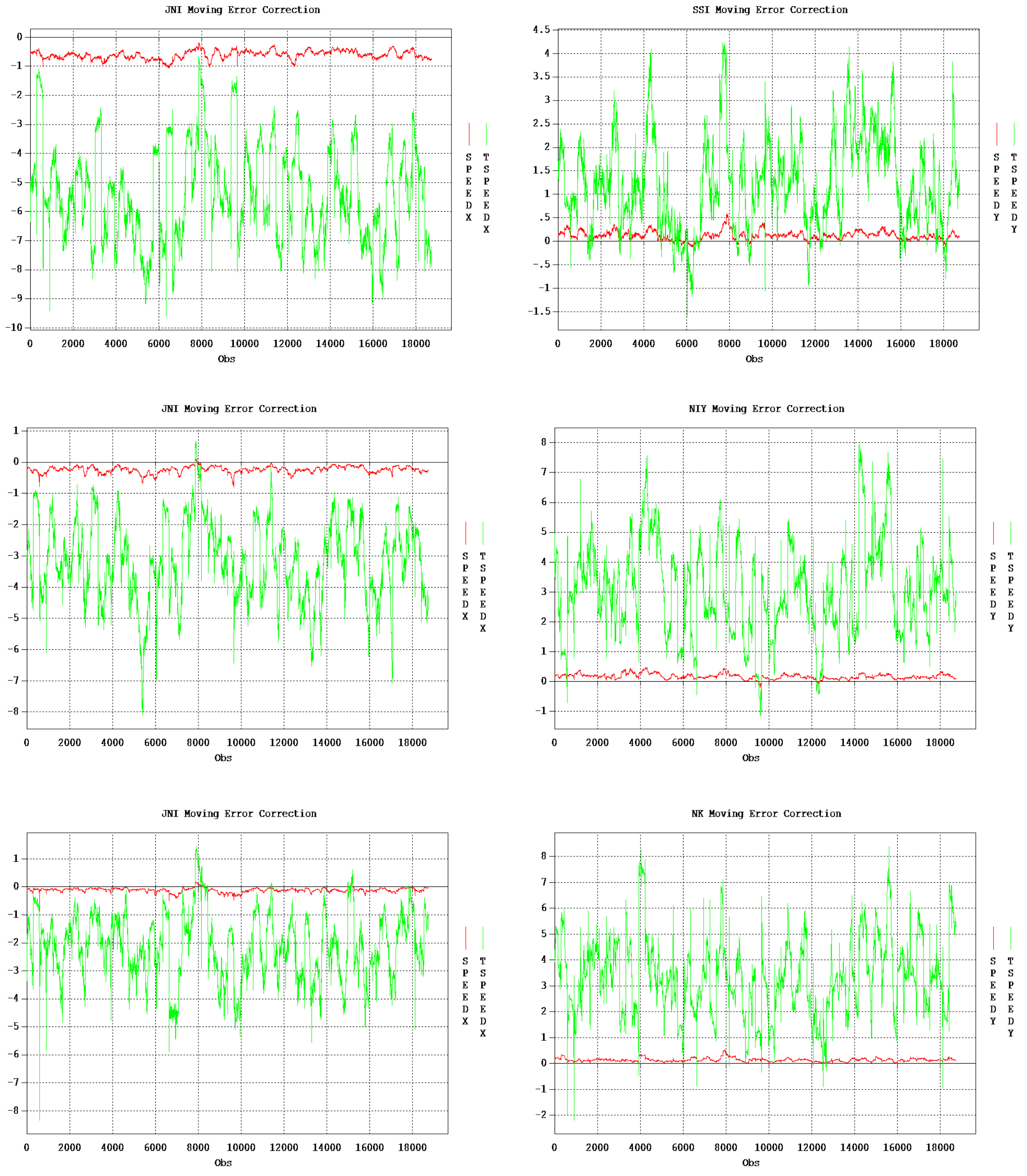

Figure 16. Moving Error Correction Model for Japanese Equity Index Products

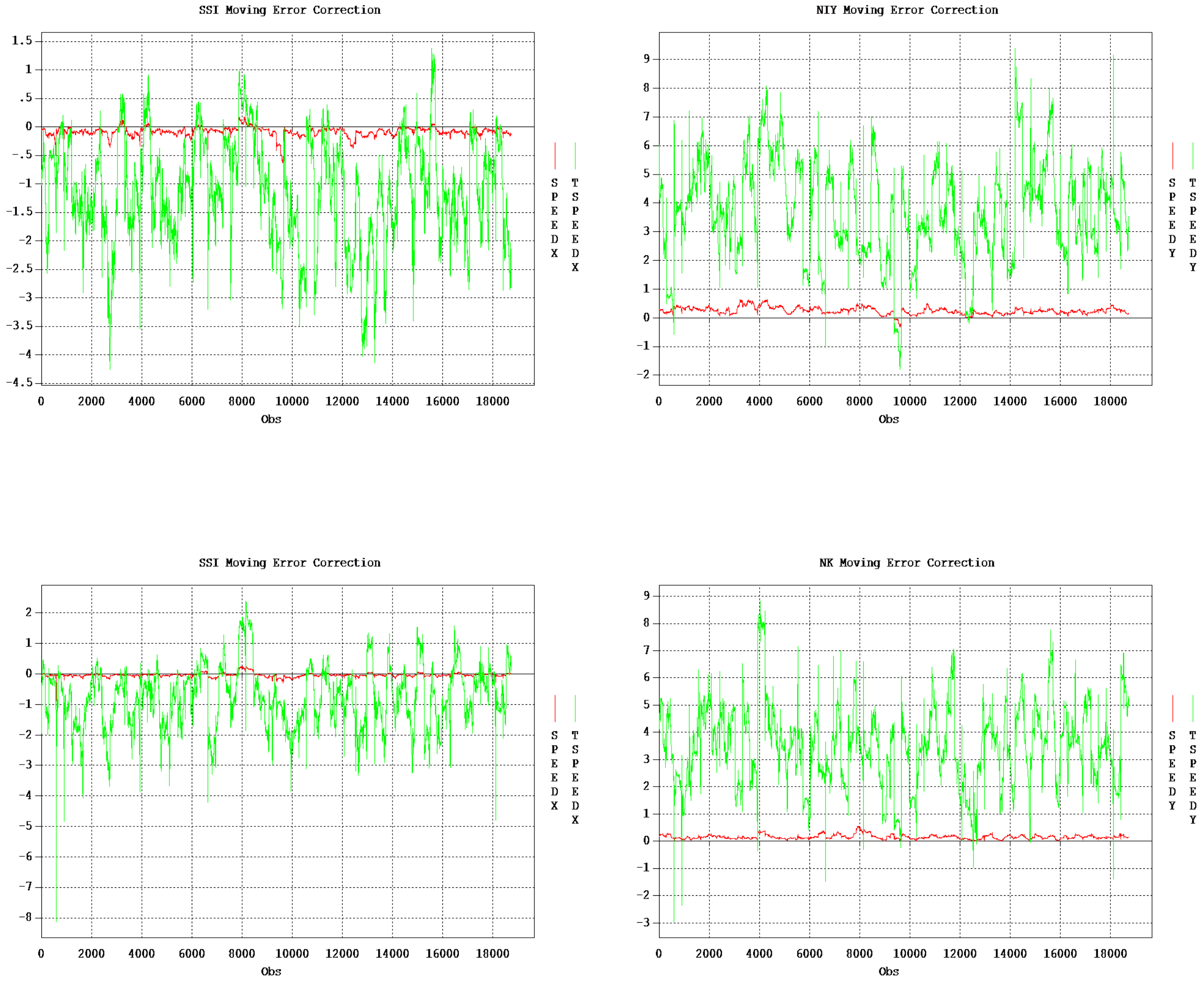

Figure 16. Moving Error Correction Model for Japanese Equity Index Products

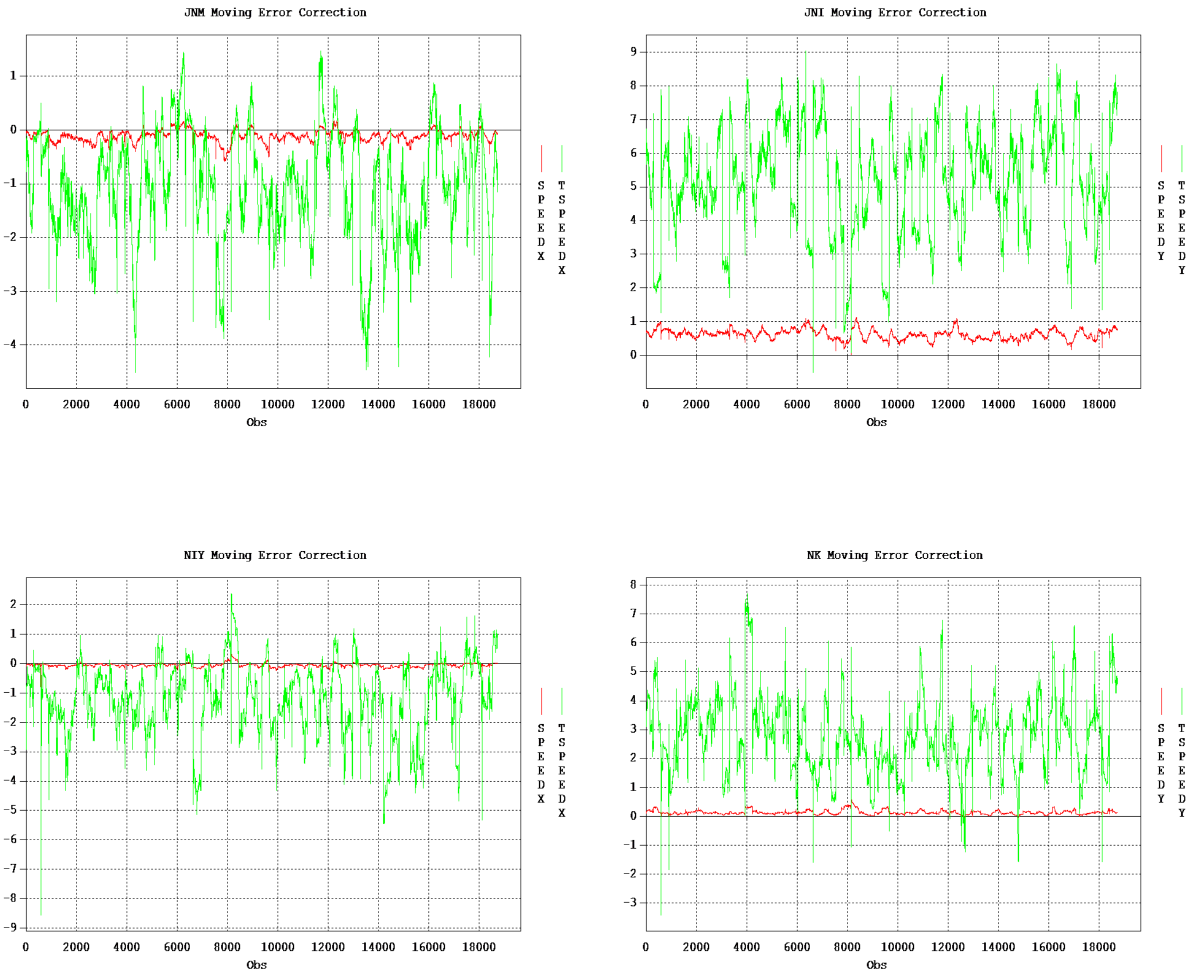

Figure 16. **Moving Error Correction Model for Japanese Equity Index Products**

5. VOLATILITY TRANSMISSION WITH ECM-GARCH-X MODEL

5.1 Model and Methodology

Multivariate GARCH models can be used to examine the volatility transmission between products for a further investigation of the second moment dynamics. Since the log price series are significantly cointegrated, error correction term becomes the most important part in modeling the conditional means, as it measures the adjustment of prices dynamics towards the long-run equilibrium. When the conditional mean and the conditional volatility are jointly estimated in the GARCH model, it is naturally to concern whether the error correction term (deviation from long-run equilibrium) also has an effect on the volatility dynamics. In this respect, the ECM-GARCH-X model can be developed to examine the potential relationship between the disequilibrium and the prices, and the potential relationship between the disequilibrium and the uncertainties (measured by volatility) in the cointegrated system. As suggested by Lee (1994), ECM-GARCH-X model is appropriate to study the causality relationship in variance and mean introduced by the error correction term. The model is specified as:

$$\Delta y_t = \alpha_1 + \alpha_y \hat{e}_{t-1} + \alpha_{11}\Delta y_{t-1} + \alpha_{12}\Delta x_{t-1} + \varepsilon_{yt} \quad (5.1)$$

$$\Delta x_t = \alpha_2 + \alpha_x \hat{e}_{t-1} + \alpha_{21}\Delta y_{t-1} + \alpha_{22}\Delta x_{t-1} + \varepsilon_{xt} \quad (5.2)$$

$$H_{yy,t} = C_{11} + A_{11}\left(\varepsilon_{y,t-1}\right)^2 + B_{11}H_{yy,t-1} + D_{11}\hat{e}_{t-1}^2 \quad (5.3)$$

$$H_{xy,t} = C_{21} + A_{21}\left(\varepsilon_{x,t-1}\varepsilon_{y,t-1}\right) + B_{21}H_{xy,t-1} + D_{21}\hat{e}_{t-1}^2 \quad (5.4)$$

$$H_{xx,t} = C_{22} + A_{22}\left(\varepsilon_{x,t-1}\right)^2 + B_{22}H_{xx,t-1} + D_{22}\hat{e}_{t-1}^2 \quad (5.5)$$

In this model, the error correction term is expressed as the residuals from the equilibrium regression. One lag residuals ($\hat{e}_{t-1}$) is specified in the GARCH conditional mean equations, standing for the deviation from long-run equilibrium in the last period. The parameters in conditional mean equations have the same explanations as in the standard error correction models. The squared error correction term (squared one lag residuals ($\hat{e}_{t-1}^{2}$)) is specified in the GARCH conditional volatility equations as the X term, measuring the effect on the uncertainty caused by deviations from long-run equilibrium in the last period.

In the conditional volatility equations, the diagonal restriction on multivariate GARCH parameters matrix is imposed to obtain a parsimonious representation. The diagonal restriction assumes that each variance and covariance depends only on its own past value and past unpredictable price shocks as noted in Bollerslev, Engle and Wooldridge (1988) and Baillie and Myers (1991). Engle and Kroner (1995) stated that to make the estimation of multivariate GARCH model easier, various restrictions may be imposed on the general form of parameterization.[27] Baillie and Myers (1991) proposed that it is vital to assume the time varying conditional covariance, rather than the constant covariance. Therefore, the diagonal restriction is applied in this study.

The ECM-GARCH-X models are jointly estimated using BFGS method to achieve the unconstrained nonlinear optimization. C_{11}, C_{21} and C_{22} are constants in the second moment. A_{11} and A_{22} present the ARCH process in the mean residuals for each conditional variance equation, B_{11} and B_{22} present the dependence of conditional variance on its previous realization. $H_{xy,t}$ is the conditional covariance equation which describes the volatility spillover between the two products. A_{21} and B_{21} present the transmission of lagged unpredictable price shocks and the lagged conditional covariance between the two products. D_{11}, D_{21} and D_{22} present the impact of deviations from long-run equilibrium on the conditional volatility.

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[27] In some literature, Engle and Kroner (1995) suggested imposing the positive definiteness on the variance matrix (the BEKK formulation). However, the parameters are not globally identified when they are taking the quadratic forms. Changing signs of the parameters will not impact on the function value.

5.2 Empirical Evidence

In the ECM-GARCH-X estimation, 22 pairs out of total 24 pairs of products converged. The pairs of JNI & SSI and JNM & JNI did not converge. The results are provided in TABLE XX to TABLE XXII and the implications are summarized as follows:

(1) Analyzing the parameters in conditional mean equations, the sign of error correction coefficient suggests whether prices changes adjust towards or against the long-run equilibrium. 19 out of 22 estimations obtain the appropriate signs for the error correction coefficient, which demonstrate that the arbitrage activities in the markets will drive short-run price dynamics revert to the long-run equilibrium. 2 of the rest 3 estimations yield an insignificant coefficient for one product, but the other product has a correct and significant sign adjusting back to the equilibrium.

(2) The value of error correction coefficient in the mean equations indicates which product will revert faster and more significantly to the equilibrium when there is disequilibrium in the system. The product moving faster and more significantly tends to follow and be leaded by the prices changes of the other product within certain boundary around the equilibrium. The other product leads in the price discovery process. 17 out of 22 estimations obtain the same leading conclusions on price discovery as in the standard (moving) error correction models. 2 estimations have very minor difference. It shows that when the futures are traded actively, the futures prices will lead the underlying index prices; when the futures are traded less actively, the futures prices will be leaded by the underlying index prices (as in pairs SFC vs. A50; JNI, NIY and NY vs. Nik225). Generally, the actively traded onshore futures prices will lead the less actively traded offshore futures prices. When the trading of onshore futures is less active, it will be leaded by the primary futures on the offshore market. However, in onshore and offshore futures CIF & SFC which are based on different underlying indices, the error-correction adjustment is insignificant. Meanwhile, the higher volume futures prices always lead the lower volume futures prices.

(3) The squared error correction term (D_{11} , D_{21} and D_{22}) significantly explains the conditional variance and covariance in the dynamic system, except for an insignificant D_{21} in the pair of NK & Nik225. However, the impact tends to be smaller than the impact of two GARCH terms (previous unpredictable price shocks and previous conditional variance/covariance) in most cases. It indicates that the squared deviations from long-run price equilibrium significantly impacts on the uncertainty in the dynamic system. In 7 out of 10 pairs between futures and the underlying index, the larger squared deviations, the lower volatility (uncertainty) in the system, as the negative parameters will decrease the conditional variance and covariance. In 10 out of 12 pairs between two futures, the larger squared deviations, the higher volatility (uncertainty) in the system, as the positive parameters will increase the conditional variance and covariance. It seems that the squared deviations from long-run price equilibrium tend to decrease the uncertainty in the dynamic systems of futures and the underlying index (7 out of 10 pairs), while the squared deviations from long-run price equilibrium tend to increase the uncertainty in the dynamic systems of onshore and offshore futures (10 out of 12 pairs).

(4) 22 estimates of parameter A_{21} are significant and positive, 21 estimates of B_{21} are significant and 19 of which are positive. It indicates that there is significant information transmission through volatility spillover between the pair of products. Previous unpredictable price shocks and previous conditional covariance will increase current information transmission.

(5) 22 estimates of parameters A_{11} and A_{22} are significant and positive, which indicates previous unpredictable price shocks tend to increase current conditional variance. 21 estimates of B_{11} are significant and 20 of which are positive. 21 estimates of B_{22} are both significant and positive. It indicates that previous conditional variance tend to increase current conditional variance, which is a sign of momentum. The summations of two GARCH terms ($A_{11} + B_{11}$, $A_{22} + B_{22}$, $A_{21} + B_{21}$) are much smaller than unity. It suggests the unpredictable price shocks decay fast in conditioning future variance and covariance.

Overall, the estimate of mean equations in ECM-GARCH-X model provides consistent conclusions on price discovery as in standard (moving) error correction model. The estimate of conditional variance and covariance demonstrate that squared deviations from long-run price equilibrium have significant effects on the uncertainty in the dynamic system. It tends to increase the uncertainty in the system of two futures, while decrease the uncertainty in the system of futures and the underlying index. There is significant information transmission between the pair of products. Previous unpredicted price shocks and previous conditional volatility positively impact on current volatility. The unpredictable price shocks decay fast in conditioning the dynamics.

TABLE XX ECM-GARCH-X MODEL FOR CHINESE EQUITY INDEX PRODUCTS

	(CIF, CSI300)				**(SFC, A50)**				**(CIF, SFC)**			
	Convergence in 2 Iterations				Convergence in 2 Iterations				Convergence in 2 Iterations			
	Variable	Coeff	Std Error	T-Stat	Variable	Coeff	Std Error	T-Stat	Variable	Coeff	Std Error	T-Stat
1	Constant	-1.3174E-05	2.86E-06	-4.60	Constant	-1.7449E-05	2.74E-06	-6.38	Constant	-1.3182E-05	2.37E-06	-5.57
2	***Alp(CIF)***	***2.9808E-04***	***8.66E-04***	***0.34***	**Alp(SFC)**	**-4.2928E-03**	**4.99E-04**	**-8.60**	***Alp(CIF)***	***-7.5200E-04***	***3.57E-04***	***-2.11***
3	DCIF{1}	0.1575	7.43E-03	21.21	DSFC{1}	-0.0608	5.28E-03	-11.52	DCIF{1}	0.1258	6.50E-03	19.35
4	DCSI300{1}	-0.0304	9.56E-03	-3.18	DA50{1}	0.3561	0.0106	33.61	*DSFC{1}*	*2.4069E-03*	*4.38E-03*	*0.55*
5	Constant	-1.3028E-05	1.48E-06	-8.78	Constant	-1.5581E-05	1.43E-06	-10.87	Constant	-1.6800E-05	1.82E-06	-9.22
6	**Alp(300)**	**3.5394E-03**	**4.51E-04**	**7.85**	***Alp(A50)***	***8.4556E-04***	***3.36E-04***	***2.51***	***Alp(SFC)***	***8.6819E-04***	***3.90E-04***	***2.23***
7	DCIF{1}	0.2490	4.29E-03	58.10	DSFC{1}	0.0949	2.90E-03	32.69	DCIF{1}	0.3604	6.07E-03	59.37
8	DCSI300{1}	0.4445	4.71E-03	94.39	DA50{1}	0.4186	6.89E-03	60.75	DSFC{1}	-0.1742	3.33E-03	-52.35
9	C(1,1)	1.8812E-07	3.40E-09	55.28	C(1,1)	2.4734E-07	2.16E-09	114.65	C(1,1)	1.9482E-07	2.51E-09	77.73
10	C(2,1)	1.3999E-07	3.41E-09	41.07	C(2,1)	9.0879E-08	2.16E-09	42.13	C(2,1)	1.4631E-07	2.50E-09	58.56
11	C(2,2)	1.5663E-07	1.50E-09	104.24	C(2,2)	9.3238E-08	1.42E-09	65.66	C(2,2)	2.5441E-07	1.61E-09	157.67
12	A(1,1)	0.1064	2.66E-03	40.05	A(1,1)	0.0891	1.21E-03	73.59	A(1,1)	0.0871	2.32E-03	37.48
13	A(2,1)	0.0957	3.41E-03	28.11	A(2,1)	0.0864	2.68E-03	32.31	A(2,1)	0.0805	1.82E-03	44.16
14	A(2,2)	0.1763	2.97E-03	59.36	A(2,2)	0.1714	2.88E-03	59.63	A(2,2)	0.0961	7.07E-04	135.85
15	B(1,1)	0.3147	1.53E-03	205.17	B(1,1)	0.0898	1.02E-03	88.13	B(1,1)	0.2286	1.27E-03	180.64
16	B(2,1)	0.1085	1.03E-03	105.73	B(2,1)	0.1252	1.01E-03	123.59	B(2,1)	0.2207	7.92E-04	278.81
17	B(2,2)	0.0202	6.86E-04	29.49	B(2,2)	0.0712	1.03E-03	69.06	B(2,2)	0.1950	6.68E-04	291.86
18	**D(1,1)**	**-9.2250E-04**	**2.25E-05**	**-41.00**	**D(1,1)**	**3.6272E-03**	**9.68E-06**	**374.61**	**D(1,1)**	**2.5018E-04**	**3.51E-06**	**71.24**
19	**D(2,1)**	**-1.4031E-03**	**7.62E-06**	**-184.25**	**D(2,1)**	**1.5200E-03**	**3.62E-06**	**420.11**	**D(2,1)**	**3.2959E-04**	**2.35E-06**	**140.00**
20	**D(2,2)**	**-1.7065E-03**	**6.38E-06**	**-267.62**	**D(2,2)**	**1.0041E-03**	**3.43E-06**	**292.42**	**D(2,2)**	**2.9894E-04**	**3.79E-06**	**78.98**

TABLE XXI ECM-GARCH-X MODEL FOR INDIAN EQUITY INDEX PRODUCTS

	(NIF, NIFTY) Convergence in 122 Iterations				**(CMY, NIFTY)** Convergence in 2 Iterations				**(SIN, NIFTY)** Convergence in 10 Iterations			
	Variable	Coeff	Std Error	T-Stat	Variable	Coeff	Std Error	T-Stat	Variable	Coeff	Std Error	T-Stat
1	Constant	-1.4846E-05	4.07E-06	-3.65	Constant	-1.1418E-05	1.25E-06	-9.14	Constant	-9.0511E-06	2.32E-06	-3.90
2	***Alp(NIF)***	***-4.5470E-03***	***2.29E-03***	***-1.99***	***Alp(CMY)***	***-1.4285E-03***	***6.92E-04***	***-2.07***	**Alp(SIN)**	**-3.6116E-03**	**1.15E-03**	**-3.14**
3	DNIF{1}	0.3985	0.0199	20.04	DCMY{1}	0.3070	4.08E-03	75.23	DSIN{1}	0.0944	1.83E-03	51.59
4	DNIFTY{1}	-0.2292	0.0208	-11.00	DNIFTY{1}	-0.1120	4.18E-03	-26.81	DNIFTY{1}	0.1015	2.68E-03	37.92
5	Constant	-1.2022E-05	3.63E-06	-3.31	Constant	-1.0623E-05	9.57E-07	-11.10	Constant	-5.9238E-06	1.57E-06	-3.78
6	***Alp(NIFTY)***	***1.3707E-03***	***1.96E-03***	***0.70***	**Alp(NIFTY)**	**2.7000E-03**	**5.42E-04**	**4.98**	**Alp(NIFTY)**	**4.1474E-03**	**9.21E-04**	**4.50**
7	DNIF{1}	0.6915	0.017	40.77	DCMY{1}	0.5810	2.99E-03	194.43	DSIN{1}	0.3678	2.35E-03	156.30
8	DNIFTY{1}	-0.4005	0.0185	-21.62	DNIFTY{1}	-0.3039	3.55E-03	-85.62	DNIFTY{1}	-0.0878	2.44E-03	-35.94
9	C(1,1)	1.6597E-07	9.83E-09	16.88	C(1,1)	2.2388E-07	2.21E-09	101.46	C(1,1)	2.4282E-07	1.05E-09	231.10
10	C(2,1)	1.4591E-07	7.48E-09	19.51	C(2,1)	2.0202E-07	2.22E-09	91.04	C(2,1)	1.8541E-07	2.63E-10	704.29
11	C(2,2)	1.4877E-07	7.13E-09	20.86	C(2,2)	2.0899E-07	1.75E-09	119.49	C(2,2)	1.7469E-07	7.83E-10	223.03
12	A(1,1)	0.1617	9.05E-03	17.87	A(1,1)	0.1941	8.63E-04	224.98	A(1,1)	0.1677	4.04E-04	415.54
13	A(2,1)	0.1559	8.35E-03	18.66	A(2,1)	0.1794	4.43E-04	404.75	A(2,1)	0.1125	1.88E-04	599.37
14	A(2,2)	0.1680	9.34E-03	17.99	A(2,2)	0.1858	7.29E-04	254.69	A(2,2)	0.0995	1.91E-04	520.74
15	B(1,1)	0.4046	0.0309	13.10	B(1,1)	0.1799	3.85E-04	466.71	B(1,1)	0.2212	1.93E-04	1146.01
16	B(2,1)	0.3905	0.0276	14.14	B(2,1)	0.1678	1.86E-04	902.97	B(2,1)	0.2720	2.00E-04	1359.62
17	B(2,2)	0.3598	0.0273	13.18	B(2,2)	0.1445	2.55E-04	565.93	B(2,2)	0.2888	2.48E-04	1166.43
18	**D(1,1)**	**-2.4650E-03**	**3.45E-04**	**-7.16**	**D(1,1)**	**-3.2044E-03**	**1.53E-05**	**-209.70**	**D(1,1)**	**-4.0804E-03**	**5.29E-05**	**-77.17**
19	**D(2,1)**	**-2.8381E-03**	**2.98E-04**	**-9.52**	**D(2,1)**	**-3.9550E-03**	**8.85E-06**	**-446.66**	**D(2,1)**	**-3.0489E-03**	**1.90E-05**	**-160.51**
20	**D(2,2)**	**-3.0580E-03**	**2.89E-04**	**-10.59**	**D(2,2)**	**-4.1145E-03**	**1.69E-05**	**-243.43**	**D(2,2)**	**-2.2793E-03**	**2.28E-05**	**-99.94**

TABLE XXI ECM-GARCH-X MODEL FOR INDIAN EQUITY INDEX PRODUCTS

	(NIF, SIN) Convergence in 125 Iterations				**(CMY, SIN)** Convergence in 117 Iterations				**(NIF, CMY)** Convergence in 4 Iterations			
	Variable	Coeff	Std Error	T-Stat	Variable	Coeff	Std Error	T-Stat	Variable	Coeff	Std Error	T-Stat
1	*Constant*	*3.9323E-06*	*4.00E-06*	*0.98*	*Constant*	*7.6321E-08*	*3.84E-06*	*0.02*	*Constant*	*0.000000*	*0.000001*	*0.39*
2	**Alp(NIF)**	**-0.0309**	**9.07E-03**	**-3.40**	**Alp(CMY)**	**-0.0462**	**8.58E-03**	**-5.38**	**Alp(NIF)**	**0.028056**	**0.008111**	**3.46**
3	DNIF{1}	0.1606	0.0224	7.16	*DCMY{1}*	*6.3562E-03*	*0.0192*	*0.33*	DNIF{1}	0.116837	0.001752	66.69
4	*DSIN{1}*	*0.0314*	*0.0215*	*1.46*	DSIN{1}	0.2052	0.0183	11.21	DCMY{1}	0.077514	0.001780	43.55
5	*Constant*	*4.3878E-06*	*4.03E-06*	*1.09*	*Constant*	*4.0471E-07*	*4.02E-06*	*0.10*	*Constant*	*-0.000001*	*0.000001*	*-1.86*
6	***Alp(SIN)***	***0.0119***	***9.10E-03***	***1.31***	***Alp(SIN)***	***2.9397E-03***	***8.85E-03***	***0.33***	**Alp(CMY)**	**0.572887**	**0.007830**	**73.17**
7	DNIF{1}	0.5758	0.0226	25.53	DCMY{1}	0.3730	0.02	18.69	DNIF{1}	0.294546	0.001706	172.62
8	DSIN{1}	-0.3396	0.022	-15.45	DSIN{1}	-0.1528	0.0195	-7.85	DCMY{1}	-0.090157	0.001744	-51.68
9	C(1,1)	1.3087E-07	7.97E-09	16.42	C(1,1)	1.5521E-07	6.08E-09	25.55	C(1,1)	0.000000	0.000000	309.57
10	C(2,1)	1.2794E-07	6.92E-09	18.49	C(2,1)	1.5745E-07	5.85E-09	26.89	C(2,1)	0.000000	0.000000	2146.88
11	C(2,2)	1.4069E-07	7.71E-09	18.25	C(2,2)	1.8556E-07	7.03E-09	26.39	C(2,2)	0.000000	0.000000	299.07
12	A(1,1)	0.0932	6.97E-03	13.39	A(1,1)	0.1155	6.81E-03	16.95	A(1,1)	0.033454	0.000060	556.67
13	A(2,1)	0.1004	6.26E-03	16.05	A(2,1)	0.1174	6.68E-03	17.56	A(2,1)	0.035700	0.000032	1129.11
14	A(2,2)	0.1172	6.88E-03	17.03	A(2,2)	0.1337	7.66E-03	17.45	A(2,2)	0.038031	0.000066	578.37
15	B(1,1)	0.4617	0.0318	14.50	B(1,1)	0.2484	0.0228	10.92	B(1,1)	-0.016593	0.000051	-328.14
16	B(2,1)	0.4528	0.029	15.64	B(2,1)	0.2248	0.0216	10.43	B(2,1)	-0.005981	0.000026	-226.85
17	B(2,2)	0.4346	0.0298	14.60	B(2,2)	0.1888	0.023	8.20	B(2,2)	0.010328	0.000052	199.45
18	**D(1,1)**	**0.0494**	**0.0115**	**4.31**	**D(1,1)**	**0.1534**	**0.0112**	**13.63**	**D(1,1)**	**3.458245**	**0.001726**	**2004.09**
19	**D(2,1)**	**0.0439**	**0.0111**	**3.94**	**D(2,1)**	**0.1562**	**0.0116**	**13.47**	**D(2,1)**	**3.434148**	**0.000841**	**4084.20**
20	**D(2,2)**	**0.0430**	**0.0112**	**3.84**	**D(2,2)**	**0.1690**	**0.0128**	**13.19**	**D(2,2)**	**3.439254**	**0.001627**	**2114.05**

TABLE XXII ECM-GARCH-X MODEL FOR JAPANESE EQUITY INDEX PRODUCTS

(JNM, NIK225)			**(SSI, NIK225)**			**(JNI, NIK225)**			**(NIY, NIK225)**			**(NK, NIK225)**		
Convergence in 113 Iterations			Convergence in 98 Iterations			Convergence in 92 Iterations			Convergence in 2 Iterations			Convergence in 59 Iterations		
Variable	Coeff	T-Stat	Variable	Coeff	T-Stat	Variable	Coeff	T-Stat	Variable	Coeff	T-Stat	Variable	Coeff	T-Stat
Constant	1.49E-05	3.45	Constant	1.97E-05	4.19	*Constant*	*9.67E-06*	*1.88*	Constant	1.69E-05	16.04	Constant	1.49E-05	5.46
Alp(JNM)	***4.49E-03***	***0.73***	**Alp(SSI)**	**-0.0199**	**-3.13**	**Alp(JNI)**	**-0.0957**	**-14.97**	**Alp(NIY)**	**-0.0576**	**-38.57**	**Alp(NK)**	**-0.0685**	**-15.13**
DJNM{1}	0.0673	3.59	DSSI{1}	-0.0822	-5.15	DJNI{1}	-0.3038	-25.19	DNIY{1}	-0.0847	-35.61	DNK{1}	-0.1258	-11.73
DNIK 225{1}	-0.0630	-3.59	*DNIK 225{1}*	*0.0430*	*2.53*	DNIK 225{1}	0.2717	15.57	DNIK 225{1}	0.1161	48.05	*DNIK 225{1}*	*-4.63E-03*	*-0.87*
Constant	1.41E-05	3.83	Constant	1.58E-05	3.88	Constant	1.01E-05	2.62	Constant	1.61E-05	11.78	Constant	2.38E-05	35.37
Alp(225)	**0.0292**	**5.60**	**Alp(225)**	**0.0208**	**3.87**	**Alp(225)**	**0.0202**	**4.43**	**Alp(225)**	**0.0227**	**14.14**	**Alp(225)**	**0.0286**	**10.26**
DJNM{1}	0.5302	32.27	DSSI{1}	0.3656	26.25	DJNI{1}	0.0891	11.48	DNIY{1}	0.1835	48.85	*DNK{1}*	*-9.20E-03*	*-1.38*
DNIK 225{1}	-0.2451	-15.66	DNIK 225{1}	-0.1160	-7.56	DNIK 225{1}	0.0893	6.19	DNIK 225{1}	0.1184	23.39	DNIK 225{1}	0.1271	22.78
C(1,1)	2.70E-07	32.05	C(1,1)	3.17E-07	33.95	C(1,1)	4.47E-07	45.96	C(1,1)	3.18E-07	134.08	C(1,1)	3.19E-07	152.92
C(2,1)	2.10E-07	33.93	C(2,1)	2.30E-07	35.02	C(2,1)	2.55E-07	42.77	C(2,1)	2.22E-07	93.67	C(2,1)	2.81E-07	302.89
C(2,2)	1.93E-07	32.61	C(2,2)	2.09E-07	34.60	C(2,2)	2.23E-07	36.09	C(2,2)	1.77E-07	95.31	C(2,2)	2.26E-07	120.00
A(1,1)	0.4136	26.71	A(1,1)	0.3016	24.82	A(1,1)	0.2316	16.77	A(1,1)	0.5927	247.21	A(1,1)	0.1218	16.24
A(2,1)	0.3424	25.93	A(2,1)	0.2706	24.67	A(2,1)	0.2926	20.59	A(2,1)	0.3867	197.60	A(2,1)	0.1569	17.64
A(2,2)	0.3609	24.27	A(2,2)	0.2990	23.87	A(2,2)	0.4137	20.49	A(2,2)	0.3878	186.17	A(2,2)	0.5436	99.69
B(1,1)	0.1834	10.52	B(1,1)	0.1242	6.32	B(1,1)	0.1828	11.05	B(1,1)	0.0603	85.64	B(1,1)	-5.44E-03	-4.80
B(2,1)	0.2269	15.13	B(2,1)	0.1726	9.93	B(2,1)	0.2186	15.93	B(2,1)	0.1826	243.30	B(2,1)	-0.0912	-23.79
B(2,2)	0.2364	14.84	B(2,2)	0.1849	10.68	B(2,2)	0.2235	15.20	B(2,2)	0.3642	530.97	B(2,2)	0.1938	88.87
D(1,1)	**0.0139**	**2.34**	**D(1,1)**	**0.0400**	**6.66**	**D(1,1)**	**-0.0470**	**-12.06**	**D(1,1)**	**9.71E-03**	**17.36**	**D(1,1)**	**0.0766**	**70.55**
D(2,1)	***8.46E-03***	***1.79***	**D(2,1)**	**0.0356**	**7.64**	**D(2,1)**	**-0.0326**	**-16.62**	**D(2,1)**	**-5.23E-03**	**-27.89**	***D(2,1)***	***-4.82E-04***	***-0.53***
D(2,2)	***4.59E-03***	***1.06***	**D(2,2)**	**0.0338**	**7.77**	**D(2,2)**	**-0.0269**	**-16.77**	**D(2,2)**	**-4.57E-03**	**-27.37**	**D(2,2)**	**-9.32E-03**	**-23.99**

TABLE XXII ECM-GARCH-X MODEL FOR JAPANESE EQUITY INDEX PRODUCTS

(JNM, SSI)			**(JNM, NIY)**			**(JNM, NK)**			**(JNI, NIY)**			**(JNI, NK)**		
Convergence in 3 Iterations			Convergence in 88 Iterations			Convergence in 2 Iterations			Convergence in 81 Iterations			Convergence in 98 Iterations		
Variable	Coeff	T-Stat	Variable	Coeff	T-Stat	Variable	Coeff	T-Stat	Variable	Coeff	T-Stat	Variable	Coeff	T-Stat
Constant	*-2.91E-07*	*-0.22*	Constant	1.40E-05	3.95	Constant	1.47E-05	27.29	Constant	1.04E-05	18.42	Constant	1.55E-05	3.22
Alp(JNM)	**-0.3489**	**-44.31**	**Alp(JNM)**	**-0.0354**	**-4.63**	**Alp(JNM)**	**-0.016**	**-16.53**	**Alp(JNI)**	**-0.1860**	**-36.20**	**Alp(JNI)**	**-0.0582**	**-13.12**
DJNM{1}	0.1302	72.32	DJNM{1}	-0.071	-5.47	DJNM{1}	-0.1002	-120.03	DJNI{1}	-0.1932	-148.00	DJNI{1}	-0.2392	-22.71
DSSI{1}	*-4.28E-03*	*-2.41*	*DNIY{1}*	*0.0162*	*1.36*	DNK{1}	-0.0484	-46.91	DNIY{1}	0.1948	98.71	DNK{1}	0.0452	3.64
Constant	*-2.79E-07*	*-0.21*	*Constant*	*5.31E-06*	*1.62*	Constant	9.09E-06	9.11	Constant	3.37E-06	6.50	Constant	1.13E-05	3.01
Alp(SSI)	**0.4005**	**49.30**	**Alp(NIY)**	**0.2613**	**30.83**	**Alp(NK)**	**0.0493**	**37.53**	**Alp(NIY)**	**0.1986**	**83.76**	**Alp(NK)**	**0.0509**	**12.29**
DJNM{1}	0.1857	107.15	*DJNM{1}*	*-0.0243*	*-2.05*	DJNM{1}	-0.0147	-9.69	DJNI{1}	-0.0409	-158.19	*DJNI{1}*	*0.0117*	*1.61*
DSSI{1}	-0.0693	-40.50	DNIY{1}	-0.1275	-10.49	DNK{1}	-0.1665	-86.95	DNIY{1}	0.0208	137.64	DNK{1}	-0.1551	-11.83
C(1,1)	3.85E-07	123.35	C(1,1)	2.37E-07	49.09	C(1,1)	2.56E-07	168.98	C(1,1)	4.25E-07	159.51	C(1,1)	4.64E-07	66.32
C(2,1)	3.74E-07	819.90	C(2,1)	1.95E-07	51.57	C(2,1)	1.96E-07	130.09	C(2,1)	2.59E-07	129.94	C(2,1)	2.27E-07	56.77
C(2,2)	3.91E-07	124.86	C(2,2)	2.03E-07	47.66	C(2,2)	2.22E-07	141.42	C(2,2)	2.53E-07	128.49	C(2,2)	2.45E-07	68.36
A(1,1)	0.0303	809.27	A(1,1)	0.5290	44.49	A(1,1)	0.8107	674.50	A(1,1)	0.2167	417.53	A(1,1)	0.3075	22.02
A(2,1)	0.0287	1932.90	A(2,1)	0.5179	46.59	A(2,1)	0.4621	355.99	A(2,1)	0.3622	6219.75	A(2,1)	0.3141	23.15
A(2,2)	0.0272	814.80	A(2,2)	0.6042	37.86	A(2,2)	0.3283	216.44	A(2,2)	0.6081	469.51	A(2,2)	0.3412	17.98
B(1,1)	0.1181	368.54	B(1,1)	0.1591	17.20	B(1,1)	0.0324	189.89	B(1,1)	0.1478	840.65	*B(1,1)*	*2.71E-03*	*0.37*
B(2,1)	0.1287	730.08	B(2,1)	0.1183	19.50	B(2,1)	0.0392	335.99	B(2,1)	0.0849	511165.10	*B(2,1)*	*-5.43E-03*	*-0.78*
B(2,2)	0.1388	391.05	B(2,2)	0.0755	10.04	B(2,2)	0.0325	133.11	B(2,2)	0.0479	2775.77	*B(2,2)*	*-8.41E-03*	*-1.50*
D(1,1)	**-0.7408**	**-241.55**	**D(1,1)**	**0.0281**	**7.32**	**D(1,1)**	**1.53E-03**	**5.38**	**D(1,1)**	**-0.0322**	**-18.02**	**D(1,1)**	**0.0158**	**5.44**
D(2,1)	**-0.7732**	**-340.86**	**D(2,1)**	**0.0923**	**22.79**	**D(2,1)**	**0.0199**	**87.91**	**D(2,1)**	**-0.0216**	**-21.32**	**D(2,1)**	**0.032**	**12.57**
D(2,2)	**-0.7447**	**-138.71**	**D(2,2)**	**0.2370**	**34.55**	**D(2,2)**	**0.0844**	**225.00**	**D(2,2)**	**0.0258**	**11.88**	**D(2,2)**	**0.0816**	**26.63**

TABLE XXII ECM-GARCH-X MODEL FOR JAPANESE EQUITY INDEX PRODUCTS

	(SSI, NIY) Convergence in 2 Iterations				**(SSI, NK)** Convergence in 2 Iterations				**(NIY, NK)** Convergence in 91 Iterations			
	Variable	Coeff	Std Error	T-Stat	Variable	Coeff	Std Error	T-Stat	Variable	Coeff	Std Error	T-Stat
1	Constant	2.1292E-05	9.16E-07	23.25	Constant	2.6334E-05	6.70E-07	39.32	Constant	1.4531E-05	3.30E-06	4.40
2	**Alp(SSI)**	**-0.0407**	**2.51E-03**	**-16.20**	**Alp(SSI)**	**-0.0347**	**1.05E-03**	**-32.98**	**Alp(NIY)**	**-0.0327**	**3.74E-03**	**-8.76**
3	DSSI{1}	-0.1288	2.18E-03	-59.20	DSSI{1}	-0.1426	1.29E-03	-110.56	DNIY{1}	-0.0882	5.94E-03	-14.84
4	DNIY{1}	0.0755	2.68E-03	28.17	DNK{1}	-0.0325	1.20E-03	-26.99	DNK{1}	-0.0235	5.82E-03	-4.04
5	Constant	1.1619E-05	7.09E-07	16.39	Constant	1.7019E-05	1.18E-06	14.44	Constant	8.1357E-06	3.15E-06	2.58
6	**Alp(NIY)**	**0.2651**	**1.94E-03**	**136.93**	**Alp(NK)**	**0.0361**	**1.47E-03**	**24.48**	**Alp(NK)**	**0.0368**	**4.11E-03**	**8.95**
7	DSSI{1}	-0.0250	2.34E-03	-10.67	DSSI{1}	6.5304E-03	1.98E-03	3.30	DNIY{1}	0.0888	9.25E-03	9.60
8	DNIY{1}	-0.0754	1.93E-03	-39.19	DNK{1}	-0.1537	2.23E-03	-69.03	DNK{1}	-0.0943	1.20E-02	-7.89
9	C(1,1)	2.8174E-07	2.33E-09	121.09	C(1,1)	3.0496E-07	1.56E-09	195.15	C(1,1)	2.3297E-07	3.84E-09	60.66
10	C(2,1)	2.1002E-07	2.34E-09	89.67	C(2,1)	2.1031E-07	1.56E-09	134.70	C(2,1)	1.5828E-07	3.05E-09	51.86
11	C(2,2)	2.0535E-07	2.34E-09	87.69	C(2,2)	2.2908E-07	1.50E-09	153.19	C(2,2)	1.7170E-07	3.40E-09	50.45
12	A(1,1)	0.4608	1.08E-03	425.05	A(1,1)	0.6207	1.06E-03	585.60	A(1,1)	0.7184	0.0134	53.49
13	A(2,1)	0.5065	9.00E-04	562.46	A(2,1)	0.3810	1.49E-03	256.31	A(2,1)	0.4466	9.39E-03	47.55
14	A(2,2)	0.6117	1.26E-03	487.03	A(2,2)	0.2743	1.47E-03	186.48	A(2,2)	0.3131	6.09E-03	51.44
15	B(1,1)	0.1137	8.18E-04	139.04	B(1,1)	4.3403E-03	7.27E-04	5.97	B(1,1)	0.1108	5.34E-03	20.77
16	B(2,1)	0.0635	7.41E-04	85.72	B(2,1)	7.9511E-03	6.25E-04	12.72	B(2,1)	0.1807	5.60E-03	32.29
17	B(2,2)	0.0322	6.90E-04	46.63	B(2,2)	8.6863E-03	6.30E-04	13.79	B(2,2)	0.2623	5.74E-03	45.72
18	**D(1,1)**	**0.0256**	**1.04E-03**	**24.57**	**D(1,1)**	**0.0116**	**3.45E-04**	**33.68**	**D(1,1)**	**0.0326**	**2.13E-03**	**15.33**
19	**D(2,1)**	**0.0974**	**9.21E-04**	**105.80**	**D(2,1)**	**0.0325**	**2.65E-04**	**122.40**	**D(2,1)**	**0.0397**	**1.84E-03**	**21.50**
20	**D(2,2)**	**0.2498**	**1.52E-03**	**164.47**	**D(2,2)**	**0.0937**	**4.13E-04**	**227.11**	**D(2,2)**	**0.0723**	**2.02E-03**	**35.77**

6. PRICE DYNAMICS IDENTIFIED WITH OTHER METHODS

6.1 Innovation Accountings

6.1.1 Impulse Response Analysis

1. Model and Methodology

Innovation accountings (including impulse response analysis and variance decomposition) are useful tools to examine the dynamic relationship between the two index products on different markets. When the time path of each variable in a system is affected by the current and past realizations of the other variable, we can describe the dynamics with the structural VAR system or the primitive system:

$$y_t = b_{10} - b_{12}x_t + \gamma_{11}y_{t-1} + \gamma_{12}x_{t-1} + \varepsilon_{yt} \qquad (6.1.1)$$

$$x_t = b_{20} - b_{21}y_t + \gamma_{21}y_{t-1} + \gamma_{22}x_{t-1} + \varepsilon_{xt} \qquad (6.1.2)$$

This system assumes that: both y_t and x_t are stationary, $\{\varepsilon_{yt}\}$ and $\{\varepsilon_{xt}\}$ are uncorrelated white-noise disturbances with standard deviations of σ_y and σ_x.[28] The terms $\{\varepsilon_{yt}\}$ and $\{\varepsilon_{xt}\}$ are pure innovations (or shocks) in y_t and x_t. They are serially uncorrelated and orthogonal to each other. As long as not all coefficients are equal to zero, the effects of ε_{yt} and ε_{xt} will persistent in the system.

However, if b_{21} is not equal to zero, ε_{yt} has an indirect contemporaneous effect on x_t, and if b_{12} is not equal to zero, ε_{xt} has an indirect contemporaneous effect of y_t. So in the above structural VAR system, the regressors and the error terms are correlated, the structural system cannot be estimated

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[28] The variance and covariance matrix of ε_{yt} and ε_{xt} is: $E\varepsilon_{yt}\varepsilon_{xt} = \Sigma_\varepsilon = \begin{bmatrix} \sigma_y^2 & 0 \\ 0 & \sigma_x^2 \end{bmatrix}$

directly. Instead, the standard VAR system is estimated and can be used to identify the structural system. The standard VAR system is presented as follows:

$$y_t = a_{10} + a_{11} y_{t-1} + a_{12} x_{t-1} + e_{1t} \qquad (6.1.3)$$

$$x_t = a_{20} + a_{21} y_{t-1} + a_{22} x_{t-1} + e_{2t} \qquad (6.1.4)$$

In the standard system, the regression residuals e_{1t} and e_{2t} are linear combinations of the pure structural shocks ε_{yt} and ε_{xt}. Both e_{1t} and e_{2t} have zero means and constant variance, and are individually serially uncorrelated following the white-noise properties of ε_{yt} and ε_{xt}. But e_{1t} and e_{2t} are generally correlated.[29] The transformation between the regression residuals and the structural shocks can be written as:

$$e_{1t} = g_{11}\varepsilon_{yt} + g_{12}\varepsilon_{xt} \quad (6.1.5)$$

$$e_{2t} = g_{21}\varepsilon_{yt} + g_{22}\varepsilon_{xt} \quad (6.1.6)$$

To evaluate the effects of structural shocks on the variables contained in the VAR system over time, we can apply the VMA representation:

$$\begin{bmatrix} y_t \\ x_t \end{bmatrix} = \begin{bmatrix} \bar{y} \\ \bar{x} \end{bmatrix} + \sum_{i=0}^{\infty} \begin{bmatrix} \Phi_{11}(i) & \phi_{12}(i) \\ \phi_{21}(i) & \phi_{22}(i) \end{bmatrix} \begin{bmatrix} \varepsilon_{yt-i} \\ \varepsilon_{xt-i} \end{bmatrix} \qquad (6.1.7)$$

The four elements of $\phi_{jk}(i)$ are the functions constructed by the parameters in both the structural and the standard VAR system. They are called the impulse response functions and can be used to measure

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[29] The covariance of e_{1t} and e_{2t} can prove to be non-zero unless there are no contemporaneous effects between the variables. The variance/covariance matrix of e_{1t} and e_{2t} can be defined as: $\Sigma_e = \begin{bmatrix} var(e_{1t}) & cov(e_{1t}, e_{2t}) \\ cov(e_{1t}, e_{2t}) & var(e_{2t}) \end{bmatrix}$

the effects of ε_{yt} and ε_{xt} shocks on the entire time path of y_t and x_t series.[30] The coefficients of $\phi_{jk}(i)$ can be summarized to obtain the accumulated effects of one unit impulse in ε_{yt} and ε_{xt}. By plotting the coefficients of $\phi_{jk}(i)$ against the period term, the responses of y_t and x_t series to the shocks are visually evident.

Since the standard VAR system can be estimated consistently and asymptotically efficiently with OLS, while the structural VAR system cannot be estimated directly, the next question emerges to be that is it possible to identify the structural system from the estimated standard system. According to the formation, the structural VAR system contains more parameters than what the standard VAR system can yield. If we want to recover the information incorporated in the structural system from the estimated parameters of the standard system, we have to restrict the additional parameters in the structural system. By providing the additional restrictive equations, the structural system can be identified. One popular identification restriction is the Choleski decomposition.

In equations 6.1.5 and 6.1.6, the Choleski decomposition restricts $g_{12} = 0$, which implies that the pure shocks of ε_{xt} have no contemporaneous effect on y_t, or restricts $g_{21} = 0$, which implies that the pure shocks of ε_{yt} have no contemporaneous effect on x_t. In this sense, the Choleski decomposition requires the ordering of the variables and imposes a potential asymmetry in the system. In empirical research, the ordering of decomposition can be determined by (1) theoretical relationship which indicates that one variable has no contemporaneous effect on the other; or (2) obtaining and comparing the impulse response functions in both ordering and investigating the obvious different implications.[31]

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[30] To obtain the impulse response functions, the unobserved $\{\varepsilon_{yt}\}$ and $\{\varepsilon_{xt}\}$ series need to be identified from the regression residuals $\{e_{1t}\}$ and $\{e_{2t}\}$.

[31] Enders states that: "The importance of the ordering depends on the magnitude of the correlation coefficient between e_{1t} and e_{2t}" (Enders, 2010, p.311). If the correlation of residuals is low, then little of the variance in one variable can be explained by the other variables, so the ordering of decomposition does not makes big difference. If the correlation of residuals is significantly differently from zero, it is a good practice to obtain the dynamics under alternative ordering.

2. Empirical Evidence on Each Market

I perform the impulse response analysis to recover the pure innovations $\{\varepsilon_{yt}\}$ and $\{\varepsilon_{zt}\}$ from the possibly correlated residuals $\{e_{1t}\}$ and $\{e_{2t}\}$, and then constructed the 24 steps responses of the variables to the innovations.

The Choleski decomposition in the analysis assumes: (1) Pure shocks of the underlying index have no contemporaneous effect on the futures, since the transaction costs in the futures market are much lower than in the stock market. Informative investors are assumed to make profit with transaction costs as low as possible; (2) Pure shocks of the offshore futures have no contemporaneous effect on the onshore futures, since the underlying index is traded on the onshore market. Information is more accessible on the onshore market. (3) Pure shocks in the lower volume futures have no contemporaneous effect on the higher volume futures, since the more actively traded product tends to imbed more information. The impulse response analyses are also performed in the reverse order of variables and the similar qualitative conclusions obtained. The plots of impulse response functions are provided in Figure 17 to Figure 19.[32] Each graph exhibits the response of both products to the innovation shocks in one product.

Figure 17 has three rows of graphs describing the impulse response functions between the Chinese equity index products. The first two rows describe the impulse response functions between the two futures and the underlying index (CIF & CSI300, SFC & A50): (1) Significant response happens in 2-3 minutes; (2) Both futures and index respond to shocks in the futures more than to shocks in the index; (3) However, in the offshore pair (SFC & A50), the index responds less to shocks in the futures and the futures respond more to shocks in the index, when comparing to the onshore pair (CIF &CSI300). The

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[32] Since the impulse response function is obtained from the estimated parameters which might contain error in the system, the confidence intervals is useful and can be constructed with Monte Carlo method. However, I include the response of two variables in the same graph, to present a clearer path, I do not plot the confidence intervals which will be a band around the response path.

third row describes the impulse response between the onshore and the offshore futures (CIF & SFC): (1) Significant response happens even faster around 1 minute; (2) Both futures respond to shocks in the onshore futures much more than to shocks in the offshore futures; (3) Onshore futures hardly respond to shocks in the offshore futures.

Figure 18 has six rows of graphs describing the impulse response between the Indian equity index products. The first three rows describe the impulse response between the three futures and the underlying index (NIF & NIFTY, CMY & NIFTY, SIN & NIFTY): (1) Significant response happens in 3 minutes; (2) Both futures and index respond to shocks in the futures much more than to shocks in the index; (3) Index responds to shocks in the futures even more than to its own shocks; (4) Futures respond to shocks in the index very less. The next two rows describe the impulse response between the two onshore futures and the offshore futures (NIF & SIN, CMY & SIN): (1) Significant response happens in 2 minutes; (2) Both onshore and offshore futures respond to shocks in the onshore futures much more than to shocks in the offshore futures, and the responses to onshore shocks converge very fast; (3) The two onshore futures respond very less to shocks in the offshore futures and the higher volume onshore one (NIF) responds even less. The last row describes the impulse response functions between two onshore futures (NIF & CMY): (1) Significant response happens very fast in 1-2 minutes; (2) Response to shocks in larger volume futures (NIF) is much greater than response to shocks in lower volume futures (CMY); (3) Responses to both shocks converge and responses to NIF shocks converge faster.

Figure 19 has several panels describing the impulse response functions between the Japanese equity index products. The two rows in the first panel describe the impulse response functions between higher volume futures and the underlying index (JNM & Nik225, SSI & Nik225). The three rows in the second panel describe the impulse response functions between relative lower volume futures and the underlying index (JNI & Nik225, NIY & Nik225, and NK & Nik225). In these impulse response functions of futures and the underlying index: (1) Both futures and the underlying index respond to shocks in the futures much more than to shocks in the underlying index; (2) Index responds to shocks in the higher volume futures (JNM and SSI) more than to shocks in the lower volume futures; (3) Higher volume futures respond less to index shocks, while lower volume futures respond more to index shocks; (4) Responses tend to converge.

The three rows in the third panel describe the impulse response functions between the highest volume onshore futures and the three offshore futures (JNM & SSI, JNM & NIY, and JNM & NK). (1) Both onshore and offshore futures respond to shocks in JNM much more than to shocks in the offshore futures; (2) The scale and speed of offshore futures response to JNM shocks follow the order of trading volume (SSI > NIY > NK). Higher volume offshore futures respond more and faster; (3) the lower trading volume of the offshore futures, the less and slower response of JNM to the offshore shocks; (4) Responses converge and converge faster between higher volume pairs.

The three rows in the forth panel describe the impulse response between the lower volume onshore futures and the three offshore futures (JNI & SSI, JNI & NIY, and JNI & NK). (1) Response to shocks in JNI is still larger than response to shocks in three offshore futures; (2) However, response to offshore shocks is significantly increased compared to JNM pairs; (3) the lower trading volume of the offshore futures, the less and slower response of JNI to the offshore shocks; (4) Responses converge and converge faster between higher volume pairs.

The two rows in the fifth panel describe the impulse response between two futures on different offshore market (SSI & NIY, SSI & NK). (1) Response to higher volume offshore futures SSI is larger; (2) NIY responds to shocks in SSI faster and greater than NK does; (3) SSI responds to shocks in NK much less and slower than to shocks in NIY; (4) higher volume pairs converge faster. The two rows in the last panel describe the impulse response between two futures on the same onshore (JNM & JNI) or same offshore market (NIY & NK). (1) Response to shocks in higher volume futures is larger than response to shocks in lower volume futures; (2) Higher volume pairs converge faster (responses of JNM & JNI converge faster than responses of NIY & NK do).

Overall, the insights from impulse response analysis can be summarized as follows:

Between futures and the underlying index: (1) Significant response happens in 2-3 minutes; (2) Both futures and index respond to shocks in the futures more than to shocks in the index; (3) the underlying index responds to shocks in the higher volume futures more than to shocks in the lower volume futures; (4) the higher trading volume of the futures, the less it responds to shocks in the underlying index, this phenomenon is especially clear in the Japanese pairs; (5) the responses to shocks tend to converge in the Japanese cases and reach a stable level in the Chinese and Indian cases.

Between the onshore and the offshore futures: (1) Significant response happens even faster, around 1-2 minutes; (2) Both onshore and offshore futures respond to shocks in the onshore futures much more than to shocks in the offshore futures; (3) Chinese onshore futures CIF hardly respond to shocks in the offshore futures SFC; (4) In the Indian cases of two onshore futures and one offshore futures, the higher volume onshore futures (NIF) respond less to offshore shocks than the lower volume onshore one (CMY) does; (5) In the Japanese cases of two onshore futures and three offshore futures, higher volume offshore futures respond faster to shocks in the onshore futures, while onshore futures respond less to the shocks in the lower volume offshore futures. The responses converge faster in higher volume pairs.

Between higher volume and lower volume futures: (1) Both futures respond to shocks in the higher volume futures more than to shocks in the lower volume futures; (2) Responses converge faster in higher volume pairs.

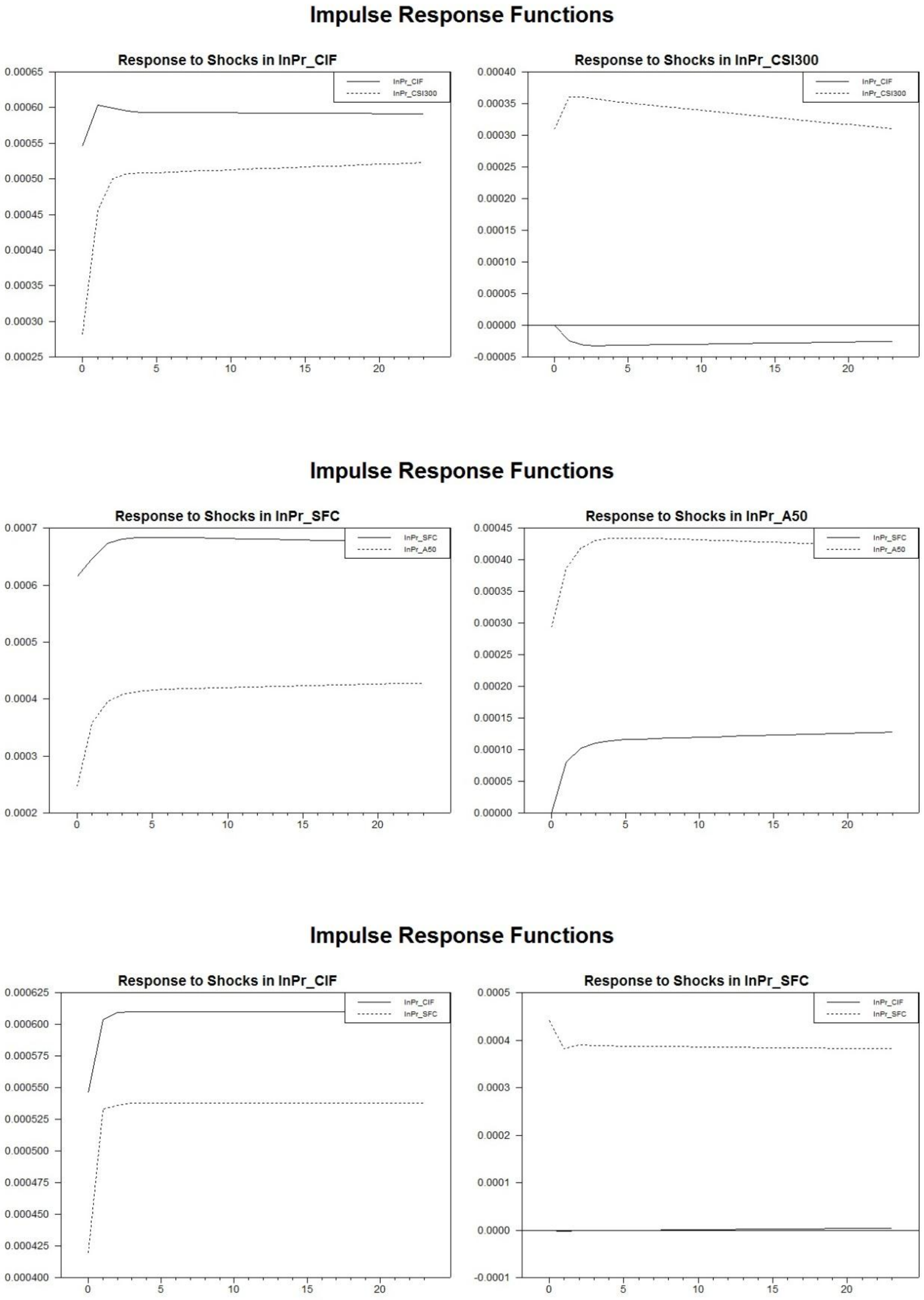


Figure 17. **Impulse Response Functions between Chinese Equity Index Products**

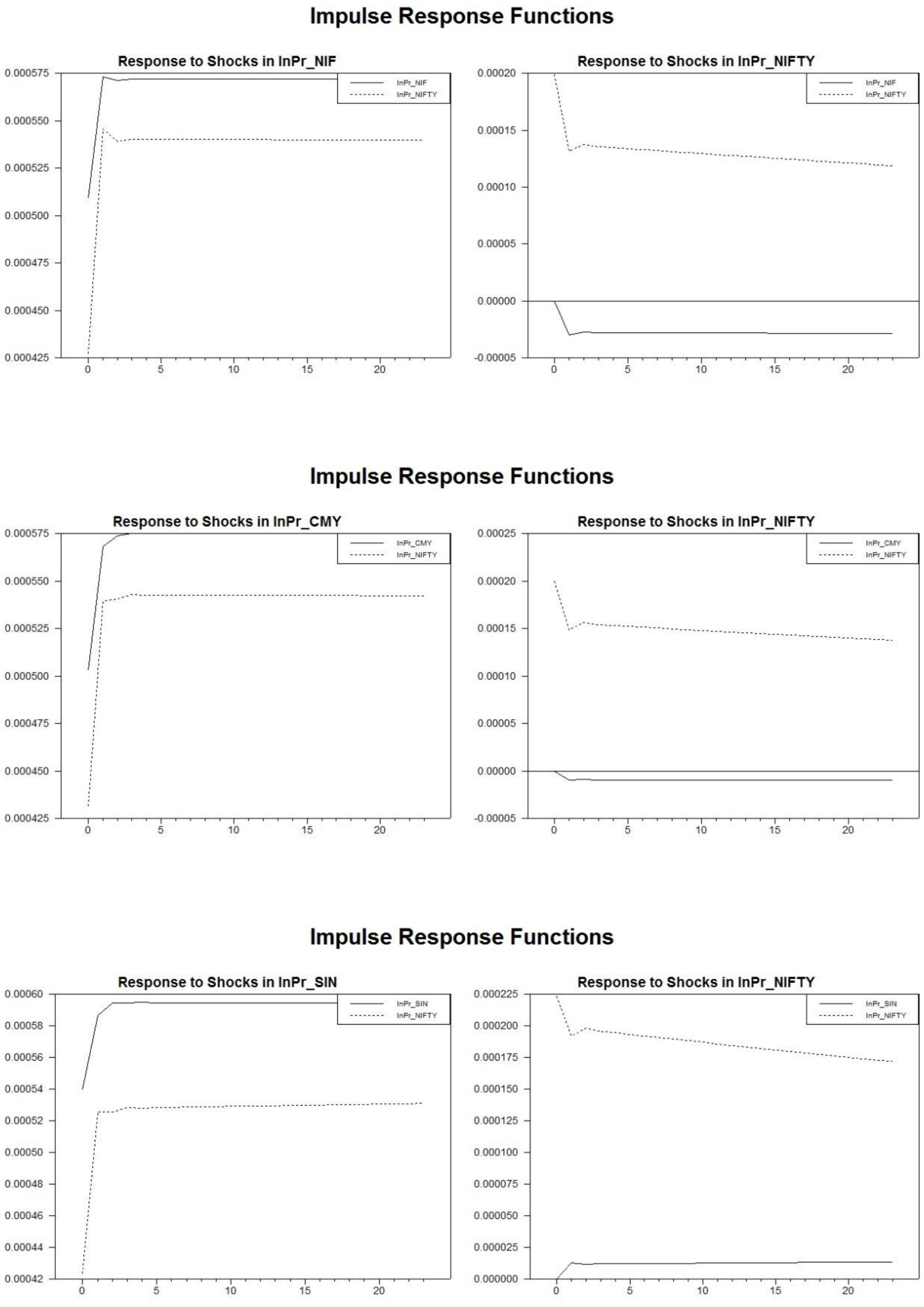
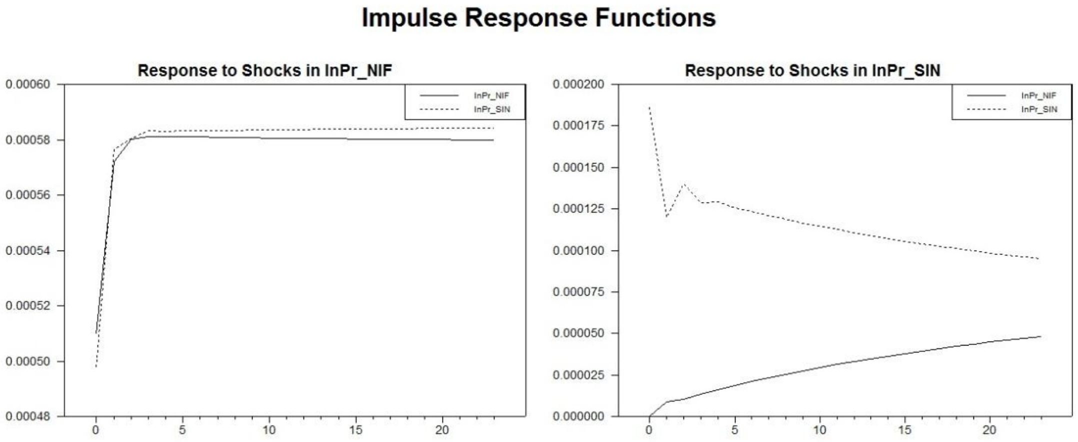
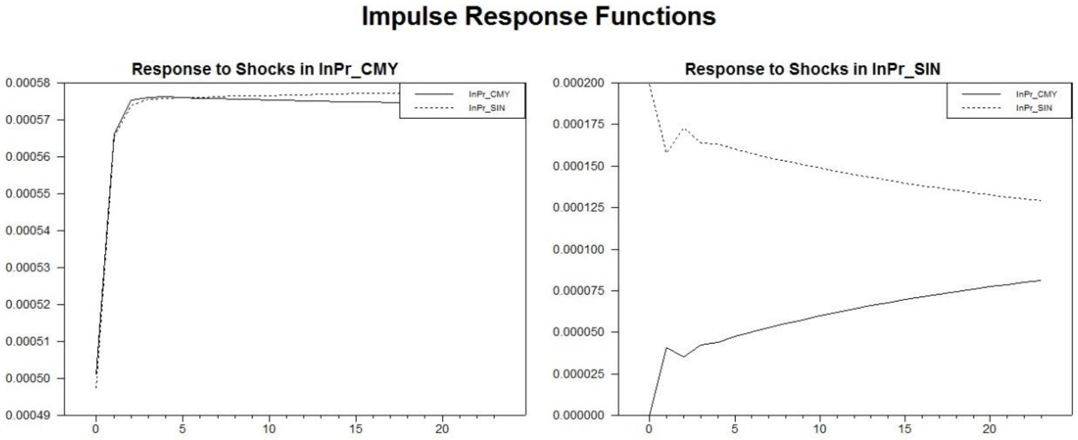


Figure 18. Impulse Response Functions between Indian Equity Index Products





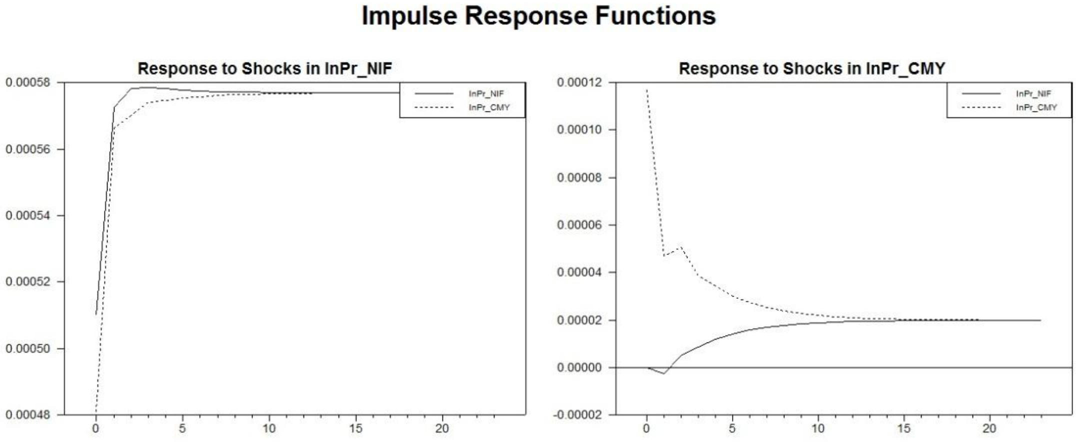


Figure 18. Impulse Response Functions between Indian Equity Index Products

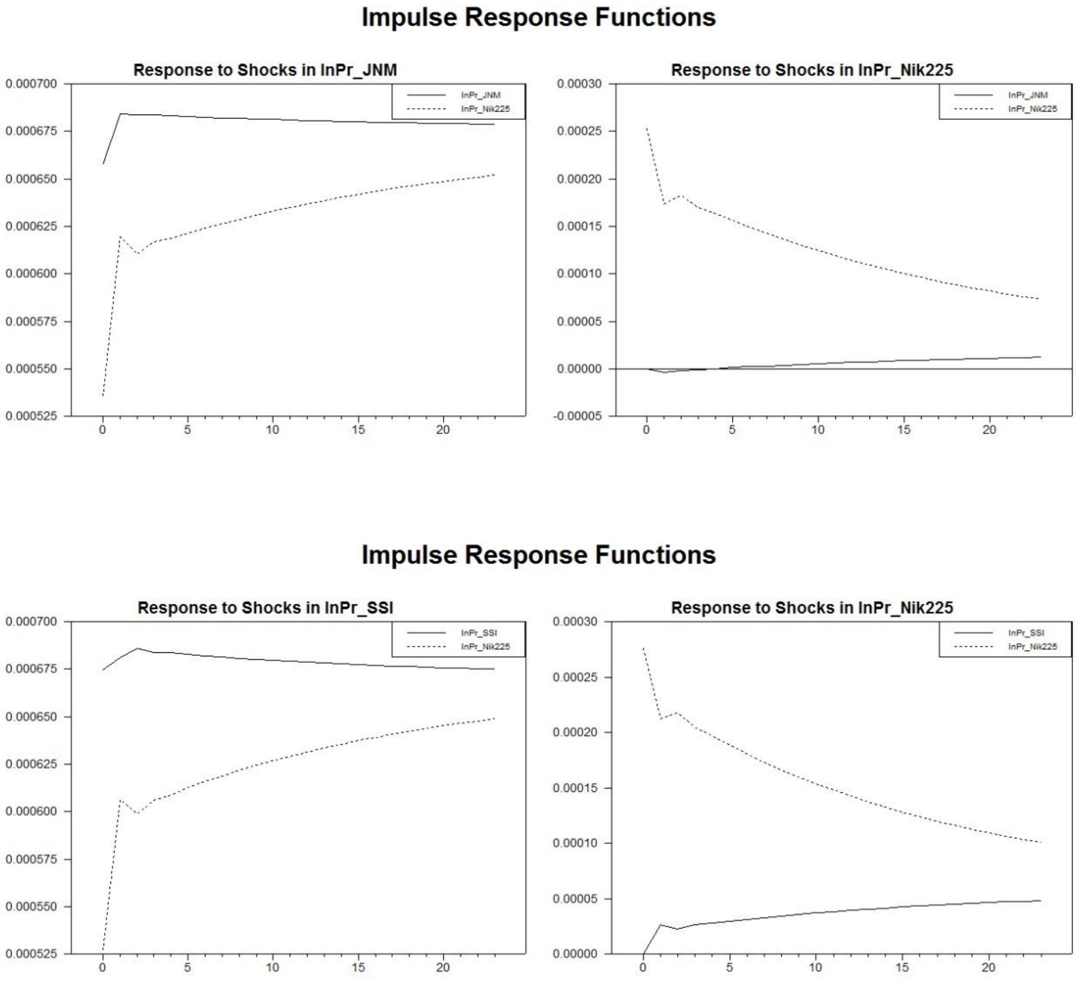


Figure 19. **Impulse Response Functions between Japanese Equity Index Products**

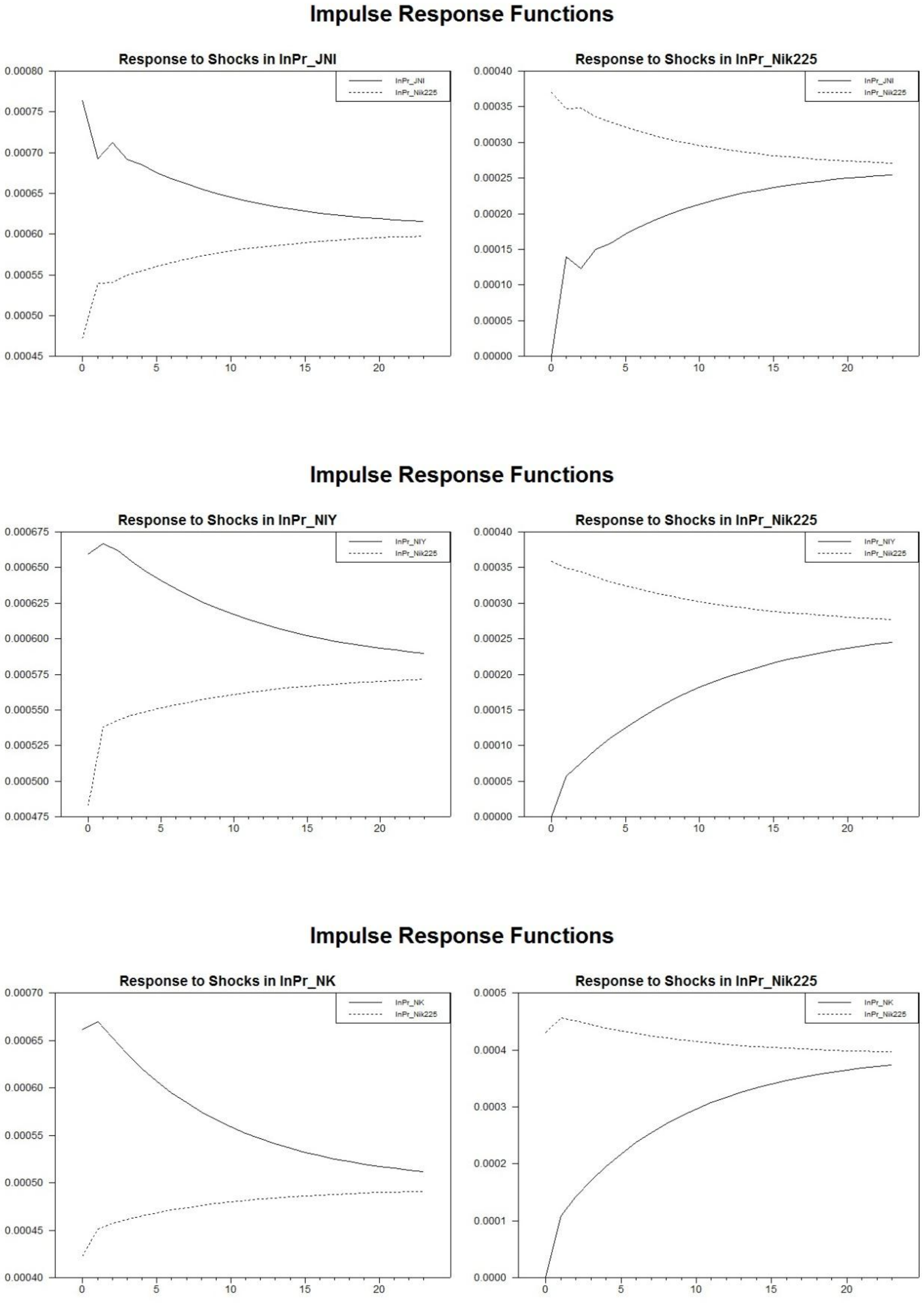


Figure 19. **Impulse Response Functions between Japanese Equity Index Products**

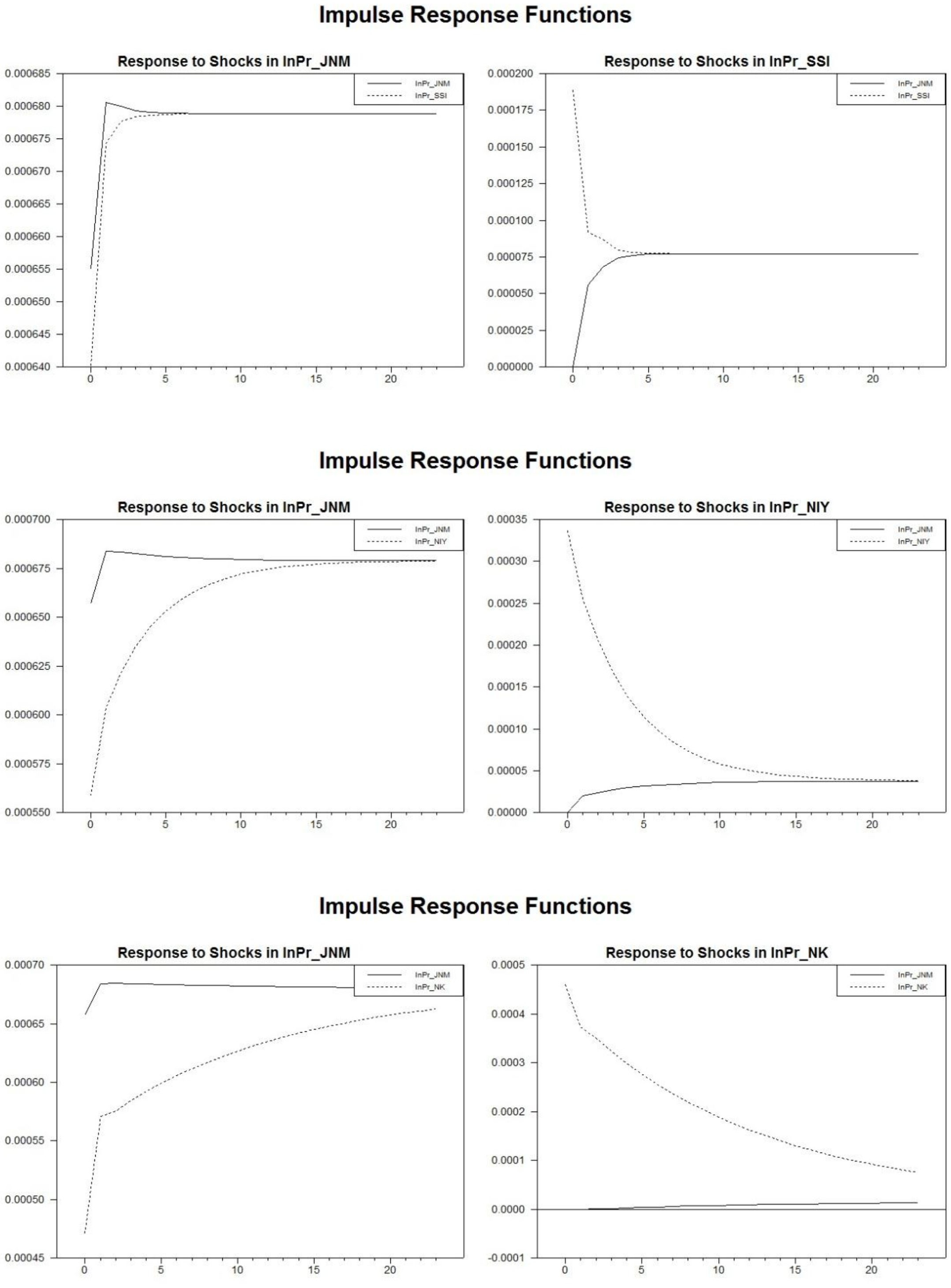


Figure 19. **Impulse Response Functions between Japanese Equity Index Products**

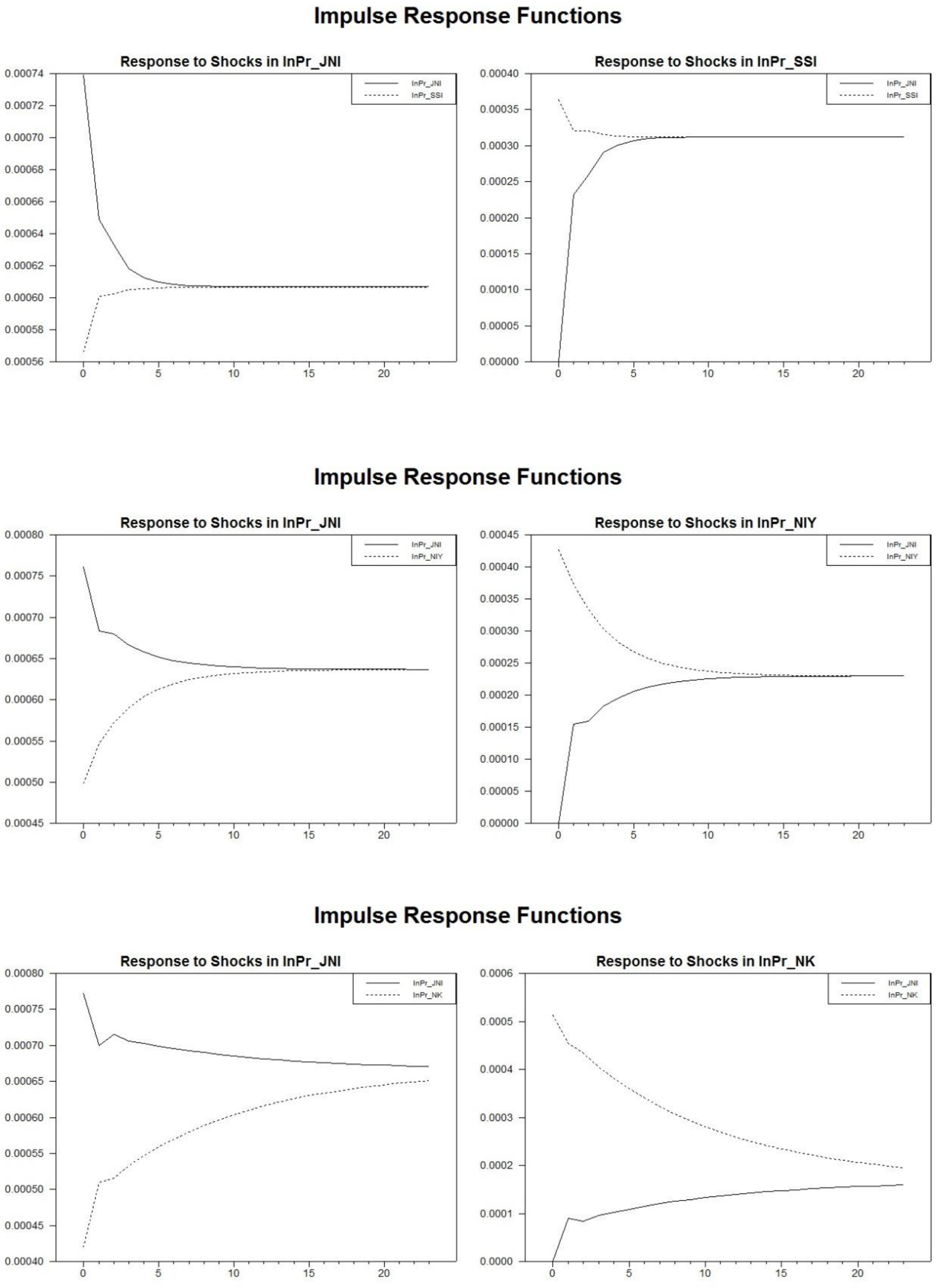


Figure 19. **Impulse Response Functions between Japanese Equity Index Products**

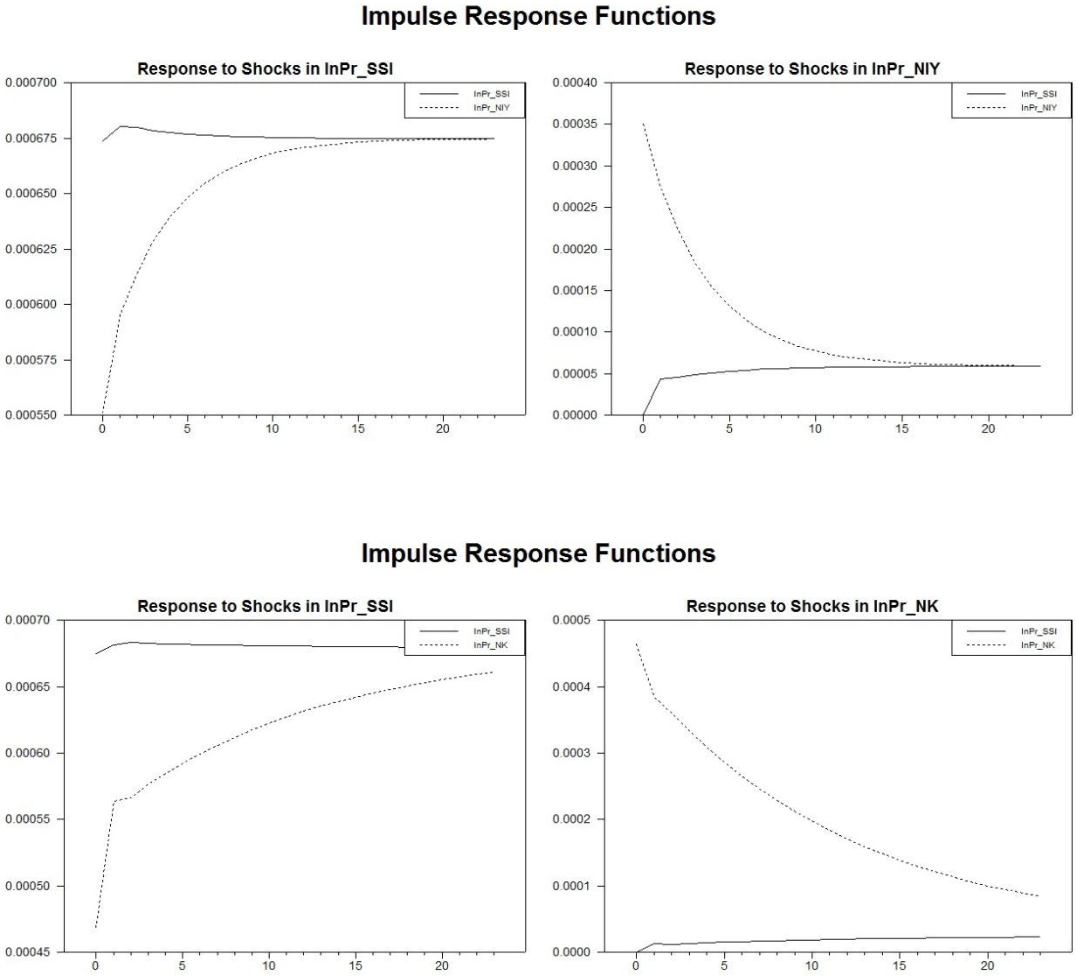


Figure 19. **Impulse Response Functions between Japanese Equity Index Products**

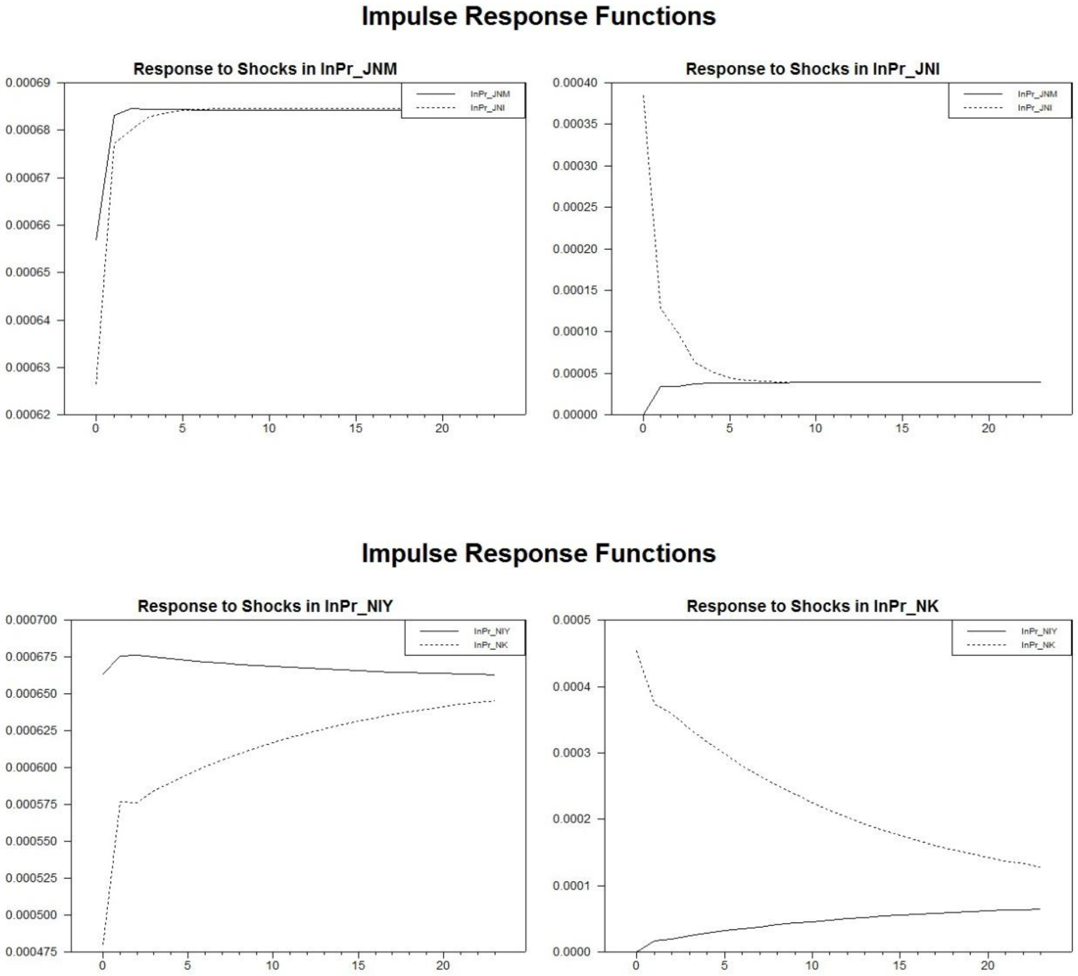


Figure 19. **Impulse Response Functions between Japanese Equity Index Products**

6.1.2 Forecast Error Variance Decomposition

Forecast error variance decomposition can be used to decompose the n-step-ahead forecast error into proportions due to its own shocks and due to the other product shocks. The variance decompositions will converge as n increases. Choleski decomposition is one of the assumed restrictions to perform the variance decomposition. The same assumptions of decomposition order as in the impulse response analysis are applied here. Numerical results are provided in TABLE XXIII to TABLE XXV, and some interesting insights are summarized as follows:

(1) Between the pair of equity index futures and the underlying index, over 99% forecast error variance in higher volume futures and over 95% forecast error variance in lower volume futures are due to its own shocks. On the other hand, a majority percentage of the forecast error variance in the underlying index is due to shocks in the futures. Separately speaking, CIF accounts for 45% - 66% of CSI300 variance and SFC accounts for 41% - 47% of A50 variance; NIF accounts for 82% - 93% of NIFTY variance, CMY accounts for 82% - 91% of NIFTY variance, and SIN accounts for 78% - 87% of NIFTY variance; JNM accounts for 81% - 92% of Nik225 variance, SSI accounts for 78% - 90% of Nik225 variance, JNI accounts for 61% - 73% of Nik225 variance, NIY accounts for 64% - 73% of Nik225 variance and NK accounts for 49% - 53% of Nik225 variance. The higher volume futures accounts for more percentage of the index variance. Overall, futures explain much more percentage of the forecast error variance than the underlying index does.

(2) Between the pair of onshore and offshore futures, over 99% of the forecast error variance in the onshore futures is due to its own shocks, except for the lower volume onshore futures JNI in Japan. For JNI, its own shocks account for 83% - 94% of its variance when pairing with SSI, account for 92% - 97% of its variance when pairing with NIY, and account for 97% - 99% when pairing with NK. On the other hand, a majority percentage of the forecast error variance in the offshore futures is due to shocks in

the onshore futures. Separately speaking, CIF accounts for 47% - 64% of SFC variance; NIF accounts for 87% - 94% of SIN variance; CMY accounts for 86% - 92% of SIN variance; JNM accounts for 92% - 97% of SSI variance, 73% - 93% of NIY variance and 51% - 78% of NK variance; JNI accounts for 70% - 77% of SSI variance, 57% - 79% of NIY variance and 40% - 66% of NK variance. Higher volume onshore futures accounts for more percentage of the offshore futures variance. Overall, onshore futures explain much more percentage of the forecast error variance than the offshore futures do.

(3) Between the pair of higher volume and lower volume futures, over 99% forecast error variance in the higher volume futures are due to its own shocks, a significant percentage of the forecast error variance in the lower volume futures are also due to the shocks in higher volume futures, e.g. NIF accounts for 94% - 99% of CMY variance, JNM accounts for 72% - 96% of JNI variance, SSI accounts for 71% - 91% of NIY variance, SSI accounts for 50% - 76% of NK variance and NIY accounts for 52% - 76% of NK variance. Overall, higher volume futures explain much more percentage of the forecast error variance than the lower volume futures do.

TABLE XXIII FORECAST ERROR VARIANCE DECOMPOSITION FOR CHINESE EQUITY INDEX PRODUCTS

Chinese Equity Index Products											
Chinese Equity Index Futures vs. Underlying Index								*Onshore vs. Offshore Equity Index Futures*			
Variance Decomposition for LNPR_CIF				**Variance Decomposition for LNPR_SFC**				**Variance Decomposition for LNPR_CIF**			
Step	Std Error	LNPR_CIF	LNPR_CSI300	Step	Std Error	LNPR_SFC	LNPR_A50	Step	Std Error	LNPR_CIF	LNPR_SFC
1	0.00054526	100.000	0.000	1	0.00061520	100.000	0.000	1	0.00054591	100	0
2	0.00081401	99.915	0.085	2	0.00089534	99.191	0.809	2	0.00081393	100	0
3	0.00101115	99.851	0.149	3	0.00112476	98.664	1.336	3	0.00101687	100	0
4	0.00117360	99.815	0.185	4	0.00131945	98.324	1.676	4	0.00118589	100	0
5	0.00131560	99.795	0.205	5	0.00149034	98.099	1.901	5	0.00133368	100	0
6	0.00144358	99.783	0.217	6	0.00164388	97.940	2.060	6	0.00146665	100	0
7	0.00156104	99.775	0.225	7	0.00178427	97.822	2.178	7	0.00158852	100	0
8	0.00167021	99.770	0.230	8	0.00191429	97.730	2.270	8	0.00170168	100	0
9	0.00177263	99.766	0.234	9	0.00203590	97.654	2.346	9	0.00180777	100	0
10	0.00186940	99.764	0.236	10	0.00215052	97.591	2.409	10	0.00190797	100	0
Variance Decomposition for LNPR_CSI300				**Variance Decomposition for LNPR_A50**				**Variance Decomposition for LNPR_SFC**			
Step	Std Error	LNPR_CIF	LNPR_CSI300	Step	Std Error	LNPR_SFC	LNPR_A50	Step	Std Error	LNPR_CIF	LNPR_SFC
1	0.00041801	45.095	54.905	1	0.00038259	41.512	58.488	1	0.00060897	47.452	52.548
2	0.00071582	55.979	44.021	2	0.00065017	44.557	55.443	2	0.00089536	57.423	42.577
3	0.00094492	60.152	39.848	3	0.00086837	45.634	54.366	3	0.00111394	60.266	39.734
4	0.00113040	62.172	37.828	4	0.00105168	46.200	53.800	4	0.00129638	61.694	38.306
5	0.00128902	63.359	36.641	5	0.00121052	46.557	53.443	5	0.00145609	62.536	37.464
6	0.00142974	64.168	35.832	6	0.00135175	46.813	53.187	6	0.00159986	63.096	36.904
7	0.00155749	64.778	35.222	7	0.00147983	47.014	52.986	7	0.00173167	63.497	36.503
8	0.00167527	65.272	34.728	8	0.00159774	47.182	52.818	8	0.00185405	63.801	36.199
9	0.00178507	65.690	34.310	9	0.00170752	47.328	52.672	9	0.00196879	64.041	35.959
10	0.00188828	66.058	33.942	10	0.00181063	47.461	52.539	10	0.00207713	64.236	35.764

TABLE XXIV FORECAST ERROR VARIANCE DECOMPOSITION FOR INDIAN EQUITY INDEX PRODUCTS

Indian Equity Index Products

Equity Index Futures vs. Underlying Index

Variance Decomposition for LNPR_NIF				**Variance Decomposition for LNPR_CMY**				**Variance Decomposition for LNPR_SIN**			
Step	Std Error	LNPR_NIF	LNPR_NIFTY	Step	Std Error	LNPR_CMY	LNPR_NIFTY	Step	Std Error	LNPR_SIN	LNPR_NIFTY
1	0.00050899	100.000	0.000	1	0.00050276	100.000	0.000	1	0.00053959	100.000	0.000
2	0.00076698	99.849	0.151	2	0.00075859	99.984	0.016	2	0.00079708	99.975	0.025
3	0.00095678	99.820	0.180	3	0.00095127	99.981	0.019	3	0.00099428	99.970	0.030
4	0.00111503	99.805	0.195	4	0.00111153	99.979	0.021	4	0.00115856	99.967	0.033
5	0.00125343	99.796	0.204	5	0.00125146	99.978	0.022	5	0.00130234	99.966	0.034
6	0.00137800	99.790	0.210	6	0.00137725	99.977	0.023	6	0.00143175	99.964	0.036
7	0.00149220	99.786	0.214	7	0.00149248	99.977	0.023	7	0.00155039	99.963	0.037
8	0.00159827	99.783	0.217	8	0.00159943	99.977	0.023	8	0.00166057	99.963	0.037
9	0.00169772	99.780	0.220	9	0.00169966	99.976	0.024	9	0.00176388	99.962	0.038
10	0.00179166	99.778	0.222	10	0.00179430	99.976	0.024	10	0.00186146	99.961	0.039
Variance Decomposition for LNPR_NIFTY				**Variance Decomposition for LNPR_NIFTY**				**Variance Decomposition for LNPR_NIFTY**			
Step	Std Error	LNPR_NIF	LNPR_NIFTY	Step	Std Error	LNPR_CMY	LNPR_NIFTY	Step	Std Error	LNPR_SIN	LNPR_NIFTY
1	0.0004711	82.217	17.783	1	0.00047555	82.299	17.701	1	0.0004785	78.215	21.785
2	0.0007328	89.429	10.571	2	0.00073445	88.472	11.528	2	0.00073614	84.011	15.989
3	0.00092	91.064	8.936	3	0.00092521	89.877	10.123	3	0.00092609	85.317	14.683
4	0.0010755	91.874	8.126	4	0.00108363	90.607	9.393	4	0.00108391	86.027	13.973
5	0.001211	92.354	7.646	5	0.00122153	91.035	8.965	5	0.00122133	86.457	13.543
6	0.0013328	92.679	7.321	6	0.00134528	91.328	8.672	6	0.00134468	86.763	13.237
7	0.0014442	92.917	7.083	7	0.00145846	91.544	8.456	7	0.00145752	86.998	13.002
8	0.0015475	93.103	6.897	8	0.00156338	91.713	8.287	8	0.00156213	87.191	12.809
9	0.0016443	93.254	6.746	9	0.0016616	91.852	8.148	9	0.00166006	87.355	12.645
10	0.0017356	93.381	6.619	10	0.00175426	91.970	8.030	10	0.00175244	87.499	12.501

TABLE XXIV FORECAST ERROR VARIANCE DECOMPOSITION FOR INDIAN EQUITY INDEX PRODUCTS

Indian Equity Index Products											
Onshore vs. Offshore Equity Index Futures								***Between Two Onshore Equity Index Futures***			
Variance Decomposition for LNPR_NIF				**Variance Decomposition for LNPR_CMY**				**Variance Decomposition for LNPR_NIF**			
Step	Std Error	LNPR_NIF	LNPR_SIN	Step	Std Error	LNPR_CMY	LNPR_SIN	Step	Std Error	LNPR_NIF	LNPR_CMY
1	0.00050984	100.000	0.000	1	0.00050097	100.000	0.000	1	0.00050990	100.000	0.000
2	0.00076643	99.986	0.014	2	0.00075718	99.711	0.289	2	0.00076678	99.999	0.001
3	0.00096139	99.979	0.021	3	0.00095159	99.681	0.319	3	0.00096037	99.997	0.003
4	0.00112344	99.970	0.030	4	0.00111323	99.622	0.378	4	0.00112122	99.992	0.008
5	0.00126495	99.960	0.040	5	0.00125429	99.580	0.420	5	0.00126154	99.984	0.016
6	0.00139214	99.949	0.051	6	0.00138107	99.535	0.465	6	0.00138763	99.977	0.023
7	0.00150865	99.937	0.063	7	0.00149718	99.493	0.507	7	0.00150309	99.969	0.031
8	0.00161679	99.925	0.075	8	0.00160495	99.451	0.549	8	0.00161023	99.962	0.038
9	0.00171813	99.911	0.089	9	0.00170596	99.410	0.590	9	0.00171064	99.955	0.045
10	0.00181383	99.897	0.103	10	0.00180135	99.368	0.632	10	0.00180545	99.950	0.050
Variance Decomposition for LNPR_SIN				**Variance Decomposition for LNPR_SIN**				**Variance Decomposition for LNPR_CMY**			
Step	Std Error	LNPR_NIF	LNPR_SIN	Step	Std Error	LNPR_CMY	LNPR_SIN	Step	Std Error	LNPR_NIF	LNPR_CMY
1	0.00053137	87.751	12.249	1	0.00053545	86.219	13.781	1	0.00049465	94.434	5.566
2	0.00079312	92.221	7.779	2	0.00079461	89.817	10.183	2	0.00075347	97.215	2.785
3	0.00099279	93.042	6.958	3	0.00099547	90.486	9.514	3	0.00094623	97.947	2.053
4	0.00115862	93.652	6.348	4	0.00116156	91.019	8.981	4	0.00110737	98.380	1.620
5	0.00130339	94.000	6.000	5	0.00130675	91.337	8.663	5	0.00124800	98.648	1.352
6	0.00143343	94.272	5.728	6	0.00143703	91.596	8.404	6	0.00137454	98.838	1.162
7	0.00155244	94.484	5.516	7	0.00155626	91.805	8.195	7	0.00149050	98.978	1.022
8	0.00166282	94.663	5.337	8	0.00166680	91.987	8.013	8	0.00159815	99.086	0.914
9	0.00176619	94.817	5.183	9	0.00177029	92.149	7.851	9	0.00169906	99.172	0.828
10	0.00186373	94.954	5.046	10	0.00186791	92.295	7.705	10	0.00179434	99.242	0.758

TABLE XXV FORECAST ERROR VARIANCE DECOMPOSITION FOR JAPANESE EQUITY INDEX PRODUCTS

Japanese Equity Index Products *Equity Index Futures vs. Underlying Index*

	Var Decomp for LNPR_JNM			Var Decomp for LNPR_SSI			Var Decomp for LNPR_JNI			Var Decomp for LNPR_NIY			Var Decomp for LNPR_NK		
Step	Std Error	LNPR_JNM	LNPR_NIK225	Std Error	LNPR_SSI	LNPR_NIK225	Std Error	LNPR_JNI	LNPR_NIK225	Std Error	LNPR_NIY	LNPR_NIK225	Std Error	LNPR_NK	LNPR_NIK225
1	0.000658	100.000	0.000	0.000675	100.000	0.000	0.000764	100.000	0.000	0.000660	100.000	0.000	0.000661	100.000	0.000
2	0.000949	99.998	0.002	0.000959	99.925	0.075	0.001040	98.193	1.807	0.000940	99.638	0.362	0.000948	98.672	1.328
3	0.001170	99.999	0.001	0.001179	99.914	0.086	0.001267	97.845	2.155	0.001152	99.331	0.669	0.001159	97.605	2.395
4	0.001355	99.999	0.001	0.001364	99.898	0.102	0.001451	97.295	2.705	0.001328	98.997	1.003	0.001333	96.551	3.449
5	0.001517	99.999	0.001	0.001526	99.886	0.114	0.001613	96.841	3.159	0.001481	98.638	1.362	0.001483	95.476	4.524
6	0.001664	99.999	0.001	0.001672	99.873	0.127	0.001757	96.381	3.619	0.001619	98.260	1.740	0.001617	94.383	5.617
7	0.001798	99.999	0.001	0.001806	99.862	0.138	0.001889	95.940	4.060	0.001745	97.867	2.133	0.001740	93.283	6.717
8	0.001923	99.999	0.001	0.001930	99.850	0.150	0.002010	95.510	4.490	0.001861	97.464	2.536	0.001853	92.185	7.815
9	0.002041	99.999	0.001	0.002047	99.839	0.161	0.002124	95.094	4.906	0.001970	97.057	2.943	0.001959	91.100	8.900
10	0.002151	99.999	0.001	0.002157	99.827	0.173	0.002231	94.692	5.308	0.002073	96.648	3.352	0.002059	90.036	9.964
	Var Decomp for LNPR_NIK225			Var Decomp for LNPR_NIK225			Var Decomp for LNPR_NIK225			Var Decomp for LNPR_NIK225			Var Decomp for LNPR_NIK225		
Step	Std Error	LNPR_JNM	LNPR_NIK225	Std Error	LNPR_SSI	LNPR_NIK225	Std Error	LNPR_JNI	LNPR_NIK225	Std Error	LNPR_NIY	LNPR_NIK225	Std Error	LNPR_NK	LNPR_NIK225
1	0.000592	81.728	18.272	0.000595	78.445	21.555	0.000600	61.828	38.172	0.000602	64.474	35.526	0.000603	49.063	50.937
2	0.000875	87.666	12.334	0.000876	84.153	15.847	0.000878	66.561	33.439	0.000880	67.586	32.414	0.000881	49.240	50.760
3	0.001082	89.099	10.901	0.001083	85.577	14.423	0.001088	67.978	32.022	0.001089	68.892	31.108	0.001090	49.744	50.256
4	0.001257	90.091	9.909	0.001258	86.663	13.337	0.001265	69.239	30.761	0.001264	69.809	30.191	0.001265	50.292	49.708
5	0.001411	90.787	9.213	0.001411	87.458	12.542	0.001420	70.220	29.780	0.001417	70.547	29.453	0.001417	50.831	49.169
6	0.001549	91.351	8.649	0.001550	88.126	11.874	0.001560	71.084	28.916	0.001555	71.181	28.819	0.001554	51.345	48.655
7	0.001677	91.827	8.173	0.001678	88.705	11.295	0.001689	71.846	28.154	0.001681	71.745	28.255	0.001680	51.832	48.168
8	0.001796	92.244	7.756	0.001796	89.221	10.779	0.001809	72.532	27.468	0.001799	72.254	27.746	0.001796	52.289	47.711
9	0.001908	92.616	7.384	0.001908	89.688	10.312	0.001922	73.155	26.845	0.001908	72.719	27.281	0.001905	52.717	47.283
10	0.002013	92.954	7.046	0.002014	90.115	9.885	0.002029	73.722	26.278	0.002012	73.148	26.852	0.002008	53.119	46.881

TABLE XXV FORECAST ERROR VARIANCE DECOMPOSITION FOR JAPANESE EQUITY INDEX PRODUCTS

Japanese Equity Index Products

Onshore JNM Futures vs. Offshore Equity Index Futures

Variance Decomposition for LNPR_JNM				**Variance Decomposition for LNPR_JNM**				**Variance Decomposition for LNPR_JNM**			
Step	Std Error	LNPR_JNM	LNPR_SSI	Step	Std Error	LNPR_JNM	LNPR_NIY	Step	Std Error	LNPR_JNM	LNPR_NK
1	0.00065505	100.000	0.000	1	0.00065721	100.000	0.000	1	0.00065754	100.000	0.000
2	0.00094626	99.648	0.352	2	0.00094854	99.954	0.046	2	0.00094887	100.000	0.000
3	0.00116724	99.425	0.575	3	0.00116939	99.927	0.073	3	0.00116996	100.000	0.000
4	0.00135256	99.270	0.730	4	0.00135425	99.905	0.095	4	0.00135528	100.000	0.000
5	0.00151536	99.166	0.834	5	0.00151643	99.886	0.114	5	0.00151799	99.999	0.001
6	0.00166228	99.093	0.907	6	0.00166264	99.870	0.130	6	0.00166473	99.999	0.001
7	0.00179723	99.040	0.960	7	0.00179684	99.855	0.145	7	0.00179944	99.999	0.001
8	0.00192274	99.001	0.999	8	0.00192158	99.842	0.158	8	0.00192465	99.998	0.002
9	0.00204053	98.970	1.030	9	0.00203862	99.830	0.170	9	0.00204211	99.997	0.003
10	0.00215189	98.945	1.055	10	0.00214923	99.820	0.180	10	0.00215310	99.996	0.004
Variance Decomposition for LNPR_SSI				**Variance Decomposition for LNPR_NIY**				**Variance Decomposition for LNPR_NK**			
Step	Std Error	LNPR_JNM	LNPR_SSI	Step	Std Error	LNPR_JNM	LNPR_NIY	Step	Std Error	LNPR_JNM	LNPR_NK
1	0.00066732	92.010	7.990	1	0.00065226	73.362	26.638	1	0.00065796	51.221	48.779
2	0.00095314	95.146	4.854	2	0.00092479	79.111	20.889	2	0.00094722	61.016	38.984
3	0.00117268	96.247	3.753	3	0.00113336	82.778	17.222	3	0.00116211	65.050	34.950
4	0.00135713	96.851	3.149	4	0.00130990	85.477	14.523	4	0.00134018	67.923	32.077
5	0.00151938	97.223	2.777	5	0.00146664	87.539	12.461	5	0.00149520	70.242	29.758
6	0.00166591	97.473	2.527	6	0.00160952	89.150	10.850	6	0.00163424	72.233	27.767
7	0.00180055	97.652	2.348	7	0.00174191	90.429	9.571	7	0.00176146	73.991	26.009
8	0.00192581	97.787	2.213	8	0.00186590	91.461	8.539	8	0.00187955	75.569	24.431
9	0.00204340	97.891	2.109	9	0.00198293	92.306	7.694	9	0.00199036	76.999	23.001
10	0.00215458	97.975	2.025	10	0.00209403	93.006	6.994	10	0.00209520	78.301	21.699

TABLE XXV FORECAST ERROR VARIANCE DECOMPOSITION FOR JAPANESE EQUITY INDEX PRODUCTS

Japanese Equity Index Products

Onshore JNI Futures vs. Offshore Equity Index Futures

Variance Decomposition for LNPR_JNI				**Variance Decomposition for LNPR_JNI**				**Variance Decomposition for LNPR_JNI**			
Step	Std Error	LNPR_JNI	LNPR_SSI	Step	Std Error	LNPR_JNI	LNPR_NIY	Step	Std Error	LNPR_JNI	LNPR_NK
1	0.00073910	100.000	0.000	1	0.00076112	100.000	0.000	1	0.00077219	100.000	0.000
2	0.00101045	94.733	5.267	2	0.00103455	97.760	2.240	2	0.00104625	99.248	0.752
3	0.00122036	91.859	8.141	3	0.00124841	96.826	3.174	3	0.00127034	99.058	0.942
4	0.00139846	89.483	10.517	4	0.00142669	95.924	4.076	4	0.00145659	98.851	1.149
5	0.00155617	87.760	12.240	5	0.00158327	95.163	4.837	5	0.00162067	98.674	1.326
6	0.00169930	86.467	13.533	6	0.00172453	94.502	5.498	6	0.00176841	98.505	1.495
7	0.00183128	85.486	14.514	7	0.00185435	93.932	6.068	7	0.00190387	98.345	1.655
8	0.00195437	84.724	15.276	8	0.00197518	93.440	6.560	8	0.00202958	98.192	1.808
9	0.00207016	84.119	15.881	9	0.00208873	93.014	6.986	9	0.00214734	98.045	1.955
10	0.00217981	83.628	16.372	10	0.00219622	92.645	7.355	10	0.00225848	97.903	2.097
Variance Decomposition for LNPR_SSI				**Variance Decomposition for LNPR_NIY**				**Variance Decomposition for LNPR_NK**			
Step	Std Error	LNPR_JNI	LNPR_SSI	Step	Std Error	LNPR_JNI	LNPR_NIY	Step	Std Error	LNPR_JNI	LNPR_NK
1	0.00067286	70.760	29.240	1	0.00065650	57.637	42.363	1	0.00066259	40.117	59.883
2	0.00095770	74.334	25.666	2	0.00093265	62.984	37.016	2	0.00095138	48.151	51.849
3	0.00117590	75.555	24.445	3	0.00114389	66.884	33.116	3	0.00116625	51.605	48.395
4	0.00135942	76.340	23.660	4	0.00132272	69.951	30.049	4	0.00134518	54.534	45.466
5	0.00152095	76.848	23.152	5	0.00148118	72.387	27.613	5	0.00150144	57.033	42.967
6	0.00166690	77.206	22.794	6	0.00162519	74.347	25.653	6	0.00164214	59.269	40.731
7	0.00180105	77.469	22.531	7	0.00175818	75.943	24.057	7	0.00177135	61.294	38.706
8	0.00192589	77.669	22.331	8	0.00188233	77.257	22.743	8	0.00189168	63.142	36.858
9	0.00204310	77.825	22.175	9	0.00199917	78.351	21.649	9	0.00200491	64.835	35.165
10	0.00215395	77.951	22.049	10	0.00210983	79.270	20.730	10	0.00211231	66.391	33.609

TABLE XXV FORECAST ERROR VARIANCE DECOMPOSITION FOR JAPANESE EQUITY INDEX PRODUCTS

Japanese Equity Index Products

	Between onshore Equity Index Futures							*Between Offshore Equity Index Futures*				
	Variance Decomposition for LNPR_JNM			**Variance Decomposition for LNPR_SSI**			**Variance Decomposition for LNPR_SSI**			**Variance Decomposition for LNPR_NIY**		
Step	Std Error	LNPR_JNM	LNPR_JNI	Std Error	LNPR_SSI	LNPR_NIY	Std Error	LNPR_SSI	LNPR_NK	Std Error	LNPR_NIY	LNPR_NK
1	0.00065667	100.000	0.000	0.00067370	100.000	0.000	0.00067501	100.000	0.000	0.00066361	100.000	0.000
2	0.00094824	99.873	0.127	0.00095829	99.793	0.207	0.00095931	99.983	0.017	0.00094703	99.968	0.032
3	0.00117005	99.833	0.167	0.00117577	99.714	0.286	0.00117769	99.978	0.022	0.00116391	99.949	0.051
4	0.00135604	99.800	0.200	0.00135837	99.657	0.343	0.00136124	99.973	0.027	0.00134565	99.929	0.071
5	0.00151943	99.779	0.221	0.00151887	99.613	0.387	0.00152269	99.969	0.031	0.00150518	99.908	0.092
6	0.00166687	99.763	0.237	0.00166374	99.576	0.424	0.00166849	99.966	0.034	0.00164899	99.886	0.114
7	0.00180229	99.751	0.249	0.00179681	99.545	0.455	0.00180243	99.963	0.037	0.00178091	99.863	0.137
8	0.00192822	99.742	0.258	0.00192058	99.518	0.482	0.00192701	99.960	0.040	0.00190345	99.840	0.160
9	0.00204642	99.735	0.265	0.00203676	99.495	0.505	0.00204394	99.957	0.043	0.00201834	99.816	0.184
10	0.00215815	99.729	0.271	0.00214661	99.475	0.525	0.00215447	99.954	0.046	0.00212685	99.793	0.207
	Variance Decomposition for LNPR_JNI			**Variance Decomposition for LNPR_NIY**			**Variance Decomposition for LNPR_NK**			**Variance Decomposition for LNPR_NK**		
Step	Std Error	LNPR_JNM	LNPR_JNI	Std Error	LNPR_SSI	LNPR_NIY	Std Error	LNPR_SSI	LNPR_NK	Std Error	LNPR_NIY	LNPR_NK
1	0.00073494	72.615	27.385	0.00065276	71.173	28.827	0.00065932	50.454	49.546	0.00066073	52.778	47.222
2	0.00100756	83.800	16.200	0.00092500	76.821	23.179	0.00094831	59.714	40.286	0.00095329	61.941	38.059
3	0.00121962	88.286	11.714	0.00113275	80.625	19.375	0.00116216	63.518	36.482	0.00117047	65.343	34.657
4	0.00139922	90.895	9.105	0.00130864	83.495	16.505	0.00133949	66.341	33.659	0.00135064	67.777	32.223
5	0.00155818	92.548	7.452	0.00146484	85.717	14.283	0.00149385	68.660	31.340	0.00150742	69.725	30.275
6	0.00170237	93.688	6.312	0.00160724	87.467	12.533	0.00163232	70.676	29.324	0.00164790	71.397	28.603
7	0.00183528	94.518	5.482	0.00173919	88.866	11.134	0.00175905	72.473	27.527	0.00177624	72.879	27.121
8	0.00195920	95.147	4.853	0.00186276	90.001	9.999	0.00187670	74.094	25.906	0.00189513	74.217	25.783
9	0.00207574	95.640	4.360	0.00197937	90.934	9.066	0.00198711	75.570	24.430	0.00200643	75.437	24.563
10	0.00218607	96.037	3.963	0.00209006	91.711	8.289	0.00209161	76.920	23.080	0.00211148	76.557	23.443

6.2 Dynamics in the Frequency Domain

6.2.1 Model and Methodology

Geweke (1982, 1984) proposed a procedure to decompose the dynamic relationship between multiple time series on the frequency domain. In his model, the linear dependence between series is the sum of the linear feedback from the first series to the second, the linear feedback from the second series to the first, and the instantaneous linear feedback between the two. With this method, not only the strength but also the direction and the periodization of the feedback between the series can be investigated. Series can interact at high frequency, middle frequency and low frequency, which are equivalent to short-run, medium-run and long-run time period.

Suppose there are two time series of X and Y. First, each series can be represented in the autoregressive form of AR(i), with which disturbances vector of u_{1t} and v_{1t} are no longer correlated with lag X and lag Y. Autocorrelation has been filtered out, but cross correlation may still exist.

$$x_t = \sum_{i=1}^{\infty} E_{1i} x_{t-i} + u_{1t}, \quad var(u_{1t}) = \Theta_1 \ \ (6.2.1)$$

$$y_t = \sum_{i=1}^{\infty} G_{1i} y_{t-i} + v_{1t}, \quad var(v_{1t}) = \Phi_1 \ \ (6.2.2)$$

Second, by using the VAR system, x_t and y_t can be linearly projected on both lag X and lag Y. In such case, the correlation of u_{2t} and $v_{2t}$with both lag X and lag Y have been filtered out, only contemporaneous correlation might exist.

$$x_t = \sum_{i=1}^{\infty} E_{2i} x_{t-i} + \sum_{i=1}^{\infty} F_{2i} y_{t-i} + u_{2t}, \quad var(u_{2t}) = \Theta_2 \ \ (6.2.3)$$

$$y_t = \sum_{i=1}^{\infty} G_{2i} y_{t-i} + \sum_{i=1}^{\infty} H_{2i} x_{t-i} + v_{2t}, \quad var(v_{2t}) = \Phi_2 \ \ (6.2.4)$$

Third, the assumption of contemporaneous correlation between u_{2t} and v_{2t} can be eliminated by the projection of a linear transfer function.

$$x_t = \sum_{i=1}^{\infty} E_{3i} x_{t-i} + \sum_{i=0}^{\infty} F_{3i} y_{t-i} + u_{3t}, \quad var(u_{3t}) = \Theta_3 \quad (6.2.5)$$

$$y_t = \sum_{i=1}^{\infty} G_{3i} y_{t-i} + \sum_{i=0}^{\infty} H_{3i} x_{t-i} + v_{3t}, \quad var(v_{3t}) = \Phi_3 \quad (6.2.6)$$

Finally, x_t can be linear represented by lag X and all Y values, y_t can be linear represented by lag Y and all X values.

$$x_t = \sum_{i=1}^{\infty} E_{4i} x_{t-i} + \sum_{i=-\infty}^{\infty} F_{4i} y_{t-i} + u_{4t}, \quad var(u_{4t}) = \Theta_4 \quad (6.2.7)$$

$$y_t = \sum_{i=1}^{\infty} G_{4i} y_{t-i} + \sum_{i=-\infty}^{\infty} H_{4i} x_{t-i} + v_{4t}, \quad var(v_{4t}) = \Phi_4 \quad (6.2.8)$$

If the last projection exists and all coefficients are square summable, equations from (6.2.1) to (6.2.8) imply that: $|\Theta_1| \geq |\Theta_2| \geq |\Theta_3| \geq |\Theta_4|$ and $|\Phi_1| \geq |\Phi_2| \geq |\Phi_3| \geq |\Phi_4|$.

Geweke (1982) defines $F_{Y\to X}$ as the measure of linear feedback from Y to X, $F_{X\to Y}$ as the measure of linear feedback from X to Y, $F_{X\cdot Y}$ as the measure of instantaneous linear feedback, and $F_{X,Y}$ as the total linear dependence between series X and Y, which is the sum of $F_{Y\to X}$, $F_{X\to Y}$ and $F_{X\cdot Y}$.

His theorem 1 proves that:

$$F_{X,Y} = \ln(|\Theta_1|/|\Theta_4|) = \ln(|\Phi_1|/|\Phi_4|) \,;\, F_{X\to Y} = \ln(|\Phi_1|/|\Phi_2|) = \ln(|\Theta_3|/|\Theta_4|)$$

$$F_{Y\to X} = \ln(|\Theta_1|/|\Theta_2|) = \ln(|\Phi_3|/|\Phi_4|) \,;\, F_{X\cdot Y} = \ln(|\Theta_2|/|\Theta_3|) = \ln(|\Phi_2|/|\Phi_3|)$$

And $F_{X,Y} = F_{Y\to X} + F_{X\to Y} + F_{X\cdot Y}$

His theorem 2 proves that:

$$\frac{1}{2\pi}\int_{-\pi}^{\pi} f_{Y\rightarrow X}(\lambda)d\lambda \leq F_{Y\rightarrow X} \text{ and } \frac{1}{2\pi}\int_{-\pi}^{\pi} f_{X\rightarrow Y}(\lambda)d\lambda \leq F_{X\rightarrow Y}$$

Where $f_{Y\rightarrow X}(\lambda)$ is the measure of linear feedback from Y to X at frequency λ, and $f_{X\rightarrow Y}(\lambda)$ is the measure of linear feedback from X to Y at frequency λ.

Construct the VAR systems from equations (6.2.3), (6.2.6), and from equations (6.2.5), (6.2.4)

$$\begin{bmatrix} E_2(L) & F_2(L) \\ H_3(L) & G_3(L) \end{bmatrix}\begin{pmatrix} x_t \\ y_t \end{pmatrix} = \begin{pmatrix} u_{2t} \\ v_{3t} \end{pmatrix} \quad (6.2.9) \qquad \begin{bmatrix} E_3(L) & F_3(L) \\ H_2(L) & G_2(L) \end{bmatrix}\begin{pmatrix} x_t \\ y_t \end{pmatrix} = \begin{pmatrix} u_{3t} \\ v_{2t} \end{pmatrix} \quad (6.2.10)$$

Where: $E_2(L) = I - \sum_{i=1}^{\infty} E_{2i}L^i$, $G_3(L) = I - \sum_{i=1}^{\infty} G_{3i}L^i$, $E_3(L) = I - \sum_{i=1}^{\infty} E_{3i}L^i$, $G_2(L) = I - \sum_{i=1}^{\infty} G_{2i}L^i$, L is the conventional lag operator.

Suppose x_t and y_t contain k_1 and k_2 variables each, since $cov(u_{2t}, v_{3t}) = 0$ in (6.2.9), all the instantaneous feedback has been combined with the feedback from X to Y in the last k_2 equations, the first k_1 equations only express the feedback from Y to X. This rule is symmetric for system (6.2.10) in which the last k_2 equations only express the feedback from X to Y.

The existence of the joint autoregressive projection for X and Y assures the above matrix can be inverted into VMA form.

$$\begin{pmatrix} x_t \\ y_t \end{pmatrix} = \begin{bmatrix} E_2^*(L) & F_2^*(L) \\ H_3^*(L) & G_3^*(L) \end{bmatrix}\begin{pmatrix} u_{2t} \\ v_{3t} \end{pmatrix} \quad (6.2.11) \qquad \begin{pmatrix} x_t \\ y_t \end{pmatrix} = \begin{bmatrix} E_3^*(L) & F_3^*(L) \\ H_2^*(L) & G_2^*(L) \end{bmatrix}\begin{pmatrix} u_{3t} \\ v_{2t} \end{pmatrix} \quad (6.2.12)$$

From the first k_1 equations in (6.2.11), the decomposition of the spectral density at frequency $\lambda \in (-\pi, \pi)$ of x_t, which is $S_X(\lambda)$ can be obtained: $S_X(\lambda) = \tilde{E}_2^*(\lambda)\Theta_2\tilde{E}_2^*(\lambda)' + \tilde{F}_2^*(\lambda)\Phi_3\tilde{F}_2^*(\lambda)'$

Where $\tilde{E}_2^*(\lambda)$ and $\tilde{F}_2^*(\lambda)$ are the Fourier transforms of $E_2^*(\lambda)$ and $F_2^*(\lambda)$, and the $(')$denotes the transposition of the relevant matrix. Geweke's measure of $f_{Y\rightarrow X}(\lambda)$ can be defined as

$$f_{Y\rightarrow X}(\lambda) = \ln(|S_X(\lambda)|/\tilde{E}_2^*(\lambda)\Theta_2\tilde{E}_2^*(\lambda)')$$

If Y adds nothing to the explanation of X at frequency λ, then $S_X(\lambda) = \tilde{E}_2^*(\lambda)\Theta_2\tilde{E}_2^*(\lambda)'$ and $f_{Y\rightarrow X}(\lambda) = 0$.

Symmetrically, from the last k_2 equations in (6.2.12), the decomposition of spectral density for y_t can be expressed as: $S_Y(\lambda) = \tilde{H}_2^*(\lambda)\Theta_3\tilde{H}_2^*(\lambda)' + \tilde{G}_2^*(\lambda)\Phi_2\tilde{G}_2^*(\lambda)'$, and subsequently,

$$f_{X\rightarrow Y}(\lambda) = \ln(|S_Y(\lambda)|/\tilde{G}_2^*(\lambda)\Phi_2\tilde{G}_2^*(\lambda)')$$

In addition to the previous methods studying the dynamic relationship between the pairs of equity index products, Geweke's procedure can further demonstrate the frequency information. Low frequency implies long-run dynamics and high frequency implies short-run dynamics. Applying this method, we can see the direction, strength and frequency of the prices interaction.

6.2.2 Empirical Evidence

Empirical results are provided in TABLE XXVI to TABLE XXVIII, and implications are summarized as follows:

(1) Between the pairs of equity index futures and the underlying index, the largest feedback is the instantaneous dynamics, e.g. 77.7% for CIF and CSI300, 73% for SFC and A50, from 87.2% to 84% for Indian futures and the underlying index, and from 91.0% to 69.7% for Japanese futures and the

underlying index. It seems that the higher trading volume of the futures, the larger instantaneous feedback with the underlying index.

Analyzing the direction of feedback, it is obvious that when the trading volume of the futures is relatively higher, the feedback from futures to index is larger than the reverse feedback. The higher volume futures tends to lead in the dynamic relationship with the underlying index (see results in the pairs of CIF, NIF, CMY, SIN, JNM, SSI and their underlying index). When the trading volume of the futures is relatively lower, the feedback from index to futures is larger than the reverse feedback. So the underlying index tends to lead in the dynamic relationship with the lower volume futures (see results in the pairs of SFC, JNI, NIY, NK and their underlying index).

Analyzing the frequency (1/period) of the feedbacks, there are measureable feedbacks at high frequency (short-run, within 5 minutes). Since the interval of trading data is 1 minute, the relatively larger feedbacks tend to happen at lower frequencies which are more than 5 minutes in most cases, and there are some large feedbacks even after 20 minutes between futures and the underlying index.

(2) Between the pairs of onshore and offshore equity index futures, the largest feedback is also the instantaneous dynamics. 73% for CIF and SFC, 91.6% for NIF and SIN, 90.6% for CMY and SIN, 95.5%, 84.7% and to 70.5% for JNM and three Japanese offshore futures (SSI, NIY and NK), and 82.3%, 73.2% and 60.7% for JNI and SSI, NIY, NK. First, the instantaneous feedbacks between the onshore and then offshore futures are larger than the instantaneous feedbacks between the futures and the underlying index, except for the case of CIF and SFC which are based on different indices. Second, when fix the offshore futures of SIN, or fix the onshore futures of JNM and JNI, the larger trading volume of the other futures in the pair, the larger instantaneous feedbacks in the system.

Analyzing the direction of feedback, when the trading volume of onshore futures is higher (in the case of CIF, NIF, CMY and JNM), the feedback from onshore futures to offshore futures is larger than the reverse feedback. Interestingly, when fix the offshore futures (SIN), the larger volume of onshore futures (NIF > CMY), the larger feedback from onshore futures to offshore futures (e.g. 4.4% from NIF to SIN > 3.0% from CMY to SIN). When fix the onshore futures JNM, the lower volume of offshore futures, (SSI > NIY > NK), the larger feedback from onshore futures to offshore ones (e.g. 2.6% from JNM to SSI, 3.2% from JNM to NIY, and 4.4% from JNM to NK). The situation for the lower volume onshore futures JNI has some difference. In the pairs of JNI and three offshore futures, JNI is the secondary onshore futures in terms of trading volume, while SSI and NIY are the primary offshore futures at the SGX and the CME market. Moreover, the trading volume of SSI exceeds the trading volume of JNI. Therefore, the feedback from the primary futures on each offshore market (SSI and NIY) to the secondary onshore futures (JNI) is larger than the reverse feedback. When pairing with the secondary offshore futures NK at the CME, the feedback from JNI to NK is larger than the reverse. As SSI is traded more actively than NIY, feedback from SSI to JNI (7.8%) is larger than the feedback from NIY to JNI (4.2%).

In short, the higher volume onshore futures tend to lead the dynamics with the offshore futures. When the onshore futures are traded at a lower volume, it tends to be leaded by the more active or primary offshore futures in the dynamics.

The feedbacks in the system tend to spread over different frequencies (periods). Among all, the Chinese and Japanese pairs of onshore and offshore futures tend to have some larger feedback in the longer period (more than 10 minutes), while the Indian pairs of onshore and offshore futures have some larger feedback in the shorter period (2-3 minutes) as well as in the longer period (more than 10 minutes). However, the long-run feedback between onshore and offshore futures is smaller than the long-run feedback between futures and the underlying index. It also shows that the system of onshore and offshore futures tends to display larger feedbacks in the shorter period than the system of futures and the underlying index does.

(3) Between the pairs of higher volume and lower volume futures, the instantaneous feedback is the largest among the three feedbacks. 96.1% for NIF and CMY, 83.1% for SSI and NIY, 69.6% for SSI and NK, 83.5% for JNM and JNI, and 71.3% for NIY and NK. The instantaneous feedback between futures on the same market is large and may override the effect of trading volume. It consistently shows that the feedback from higher volume futures to lower volume futures is larger than the reverse feedback. For the pair of NIF and CMY, relatively larger feedback tends to happen in the short-run (within 3 minutes). For the Japanese pairs, there are some relatively larger feedbacks in the long-run (more than 10 minutes).

TABLE XXVI

GEWEKE FREQUENCY DECOMPOSITION FOR CHINESE EQUITY INDEX PRODUCTS

Chinese Equity Index Products					
	X: CSI300	**Y: CIF**		**X: A50**	**Y: SFC**
	F(Y to X)	**0.039 (3.8%)**		F(Y to X)	0.017 (1.7%)
	F(X to Y)	0.020 (1.9%)		**F(X to Y)**	**0.019 (1.9%)**
	F(X.Y)	1.501 (77.7%)		F(X.Y)	1.311 (73.0%)
PERIOD	f(Y to X)	f(X to Y)	PERIOD	f(Y to X)	f(X to Y)
2	0.008 (0.8%)	0.010 (1.0%)	2	0.001 (0.1%)	0.002 (0.2%)
2.222	0.008 (0.7%)	0.004 (0.4%)	2.222	0.001 (0.1%)	0.002 (0.2%)
2.5	0.009 (0.9%)	0.006 (0.6%)	2.5	0.001 (0.1%)	0.005 (0.5%)
2.857	0.008 (0.8%)	0.004 (0.4%)	2.857	0.002 (0.2%)	0.004 (0.4%)
3.333	0.008 (0.8%)	0.004 (0.4%)	3.333	0.000 (0.0%)	0.004 (0.4%)
4	0.007 (0.7%)	0.001 (0.1%)	4	0.001 (0.1%)	0.002 (0.2%)
5	0.008 (0.8%)	0.002 (0.2%)	5	0.002 (0.2%)	0.002 (0.2%)
6.667	0.014 (1.3%)	0.002 (0.2%)	6.667	0.000 (0.0%)	0.004 (0.4%)
10	0.039 (3.8%)	0.004 (0.4%)	10	0.004 (0.4%)	0.007 (0.7%)
20	0.047 (4.6%)	0.001 (0.1%)	20	0.002 (0.2%)	0.008 (0.8%)
Infinite	0.415 (34.0%)	0.025 (2.5%)	Infinite	0.166 (15.3%)	0.010 (1.0%)
	X: CIF	**Y: SFC**		**X: CSI300**	**Y: A50**
	F(Y to X)	0.015 (1.5%)		**F(Y to X)**	**0.019 (1.9%)**
	F(X to Y)	**0.027 (2.7%)**		F(X to Y)	0.016 (1.6%)
	F(X.Y)	1.311 (73.0%)		F(X.Y)	2.735 (93.5%)
PERIOD	f(Y to X)	f(X to Y)	PERIOD	f(Y to X)	f(X to Y)
2	0.001 (0.1%)	0.011 (1.1%)	2	0.003 (0.3%)	0.002 (0.2%)
2.222	0.001 (0.1%)	0.010 (1.0%)	2.222	0.002 (0.2%)	0.001 (0.1%)
2.5	0.000 (0.0%)	0.015 (1.5%)	2.5	0.004 (0.4%)	0.003 (0.3%)
2.857	0.000 (0.0%)	0.011 (1.1%)	2.857	0.004 (0.4%)	0.003 (0.3%)
3.333	0.001 (0.1%)	0.013 (1.3%)	3.333	0.004 (0.4%)	0.002 (0.2%)
4	0.000 (0.0%)	0.004 (0.4%)	4	0.001 (0.1%)	0.000 (0.0%)
5	0.001 (0.1%)	0.007 (0.7%)	5	0.002 (0.2%)	0.001 (0.1%)
6.667	0.000 (0.0%)	0.012 (1.2%)	6.667	0.010 (1.0%)	0.005 (0.5%)
10	0.000 (0.0%)	0.019 (1.9%)	10	0.005 (0.5%)	0.002 (0.2%)
20	0.000 (0.0%)	0.018 (1.8%)	20	0.012 (1.2%)	0.005 (0.5%)
Infinite	0.206 (18.7%)	0.000 (0.0%)	Infinite	0.332 (28.3%)	0.156 (14.4%)

TABLE XXVII

GEWEKE FREQUENCY DECOMPOSITION FOR INDIAN EQUITY INDEX PRODUCTS

India Equity Index Products						
	X: NIFTY	**Y: NIF**	**X: NIFTY**	**Y: CMY**	**X: NIFTY**	**Y: SIN**
	F(Y to X)	**0.059 (5.7%)**	**F(Y to X)**	**0.044 (4.3%)**	**F(Y to X)**	**0.037 (3.7%)**
	F(X to Y)	0.020 (2.0%)	F(X to Y)	0.017 (1.7%)	F(X to Y)	0.017 (1.7%)
	F(X.Y)	2.043 (87.0%)	F(X.Y)	2.053 (87.2%)	F(X.Y)	1.832 (84.0%)
PERIOD	f(Y to X)	f(X to Y)	f(Y to X)	f(X to Y)	f(Y to X)	f(X to Y)
2	0.042 (4.1%)	0.001 (0.1%)	0.045 (4.4%)	0.001 (0.1%)	0.032 (3.2%)	0.001 (0.1%)
2.222	0.041 (4.0%)	0.003 (0.3%)	0.020 (2.0%)	0.000 (0.0%)	0.021 (2.1%)	0.001 (0.1%)
2.5	0.047 (4.6%)	0.006 (0.6%)	0.028 (2.7%)	0.002 (0.2%)	0.017 (1.7%)	0.001 (0.1%)
2.857	0.044 (4.3%)	0.004 (0.4%)	0.022 (2.2%)	0.000 (0.0%)	0.020 (2.0%)	0.000 (0.0%)
3.333	0.046 (4.5%)	0.004 (0.4%)	0.038 (3.7%)	0.002 (0.2%)	0.017 (1.7%)	0.000 (0.0%)
4	0.032 (3.2%)	0.003 (0.3%)	0.017 (1.7%)	0.000 (0.0%)	0.014 (1.3%)	0.001 (0.1%)
5	0.021 (2.1%)	0.001 (0.1%)	0.020 (1.9%)	0.001 (0.1%)	0.009 (0.9%)	0.003 (0.3%)
6.667	0.050 (4.9%)	0.006 (0.6%)	0.030 (3.0%)	0.001 (0.1%)	0.028 (2.7%)	0.000 (0.0%)
10	0.043 (4.2%)	0.006 (0.6%)	0.028 (2.7%)	0.001 (0.1%)	0.019 (1.9%)	0.001 (0.1%)
20	0.046 (4.5%)	0.004 (0.4%)	0.028 (2.8%)	0.001 (0.1%)	0.023 (2.2%)	0.001 (0.1%)
Infinite	0.168 (15.5%)	0.003 (0.3%)	0.146 (13.5%)	0.001 (0.1%)	0.157 (14.5%)	0.000 (0.0%)
	X: NIF	**Y: SIN**	**X: CMY**	**Y: SIN**	**X: NIF**	**Y: CMY**
	F(Y to X)	0.017 (1.7%)	F(Y to X)	0.024 (2.3%)	F(Y to X)	0.018 (1.8%)
	F(X to Y)	**0.045 (4.4%)**	**F(X to Y)**	**0.031 (3.0%)**	**F(X to Y)**	**0.044 (4.3%)**
	F(X.Y)	2.481 (91.6%)	F(X.Y)	2.363 (90.6%)	F(X.Y)	3.243 (96.1%)
PERIOD	f(Y to X)	f(X to Y)	f(Y to X)	f(X to Y)	f(Y to X)	f(X to Y)
2	0.002 (0.2%)	0.031 (3.0%)	0.006 (0.6%)	0.030 (2.9%)	0.001 (0.1%)	0.018 (1.7%)
2.222	0.001 (0.1%)	0.032 (3.1%)	0.010 (1.0%)	0.012 (1.2%)	0.002 (0.2%)	0.035 (3.4%)
2.5	0.000 (0.0%)	0.025 (2.5%)	0.006 (0.6%)	0.010 (1.0%)	0.002 (0.2%)	0.030 (3.0%)
2.857	0.000 (0.0%)	0.026 (2.6%)	0.010 (1.0%)	0.009 (0.9%)	0.003 (0.3%)	0.042 (4.1%)
3.333	0.000 (0.0%)	0.035 (3.5%)	0.003 (0.3%)	0.021 (2.1%)	0.000 (0.0%)	0.018 (1.8%)
4	0.000 (0.0%)	0.029 (2.8%)	0.010 (1.0%)	0.011 (1.1%)	0.002 (0.2%)	0.027 (2.7%)
5	0.001 (0.1%)	0.023 (2.2%)	0.004 (0.4%)	0.016 (1.6%)	0.001 (0.1%)	0.017 (1.7%)
6.667	0.001 (0.1%)	0.026 (2.6%)	0.007 (0.7%)	0.012 (1.2%)	0.001 (0.1%)	0.027 (2.6%)
10	0.000 (0.0%)	0.034 (3.3%)	0.003 (0.3%)	0.019 (1.9%)	0.001 (0.1%)	0.021 (2.0%)
20	0.001 (0.1%)	0.030 (2.9%)	0.006 (0.6%)	0.014 (1.4%)	0.000 (0.0%)	0.023 (2.3%)
Infinite	0.024 (2.3%)	0.019 (1.9%)	0.035 (3.4%)	0.015 (1.5%)	0.003 (0.3%)	0.020 (2.0%)

TABLE XXVIII

GEWEKE FREQUENCY DECOMPOSITION FOR JAPANESE EQUITY INDEX PRODUCTS

Japanese Equity Index Products (Futures and the underlying index)						
	X: Nik225	**Y: JNM**	**X: Nik225**	**Y: SSI**		
	F(Y to X)	**0.042 (4.1%)**	**F(Y to X)**	**0.037 (3.6%)**		
	F(X to Y)	0.013 (1.3%)	F(X to Y)	0.014 (1.4%)		
	F(X.Y)	2.409 (91.0%)	F(X.Y)	2.217 (89.1%)		
PERIOD	f(Y to X)	f(X to Y)	f(Y to X)	f(X to Y)		
2	0.033 (3.2%)	0.001 (0.1%)	0.028 (2.8%)	0.000 (0.0%)		
2.222	0.028 (2.8%)	0.000 (0.0%)	0.021 (2.0%)	0.001 (0.1%)		
2.5	0.027 (2.7%)	0.000 (0.0%)	0.020 (2.0%)	0.001 (0.1%)		
2.857	0.018 (1.8%)	0.001 (0.1%)	0.012 (1.2%)	0.002 (0.2%)		
3.333	0.014 (1.3%)	0.000 (0.0%)	0.010 (1.0%)	0.002 (0.2%)		
4	0.019 (1.9%)	0.001 (0.1%)	0.013 (1.3%)	0.003 (0.3%)		
5	0.023 (2.2%)	0.001 (0.1%)	0.021 (2.1%)	0.001 (0.1%)		
6.667	0.040 (3.9%)	0.001 (0.1%)	0.032 (3.1%)	0.002 (0.2%)		
10	0.039 (3.9%)	0.000 (0.0%)	0.043 (4.2%)	0.001 (0.1%)		
20	0.061 (5.9%)	0.000 (0.0%)	0.048 (4.7%)	0.003 (0.3%)		
Infinite	0.101 (9.6%)	0.000 (0.0%)	0.088 (8.4%)	0.001 (0.1%)		
	X: Nik225	**Y: JNI**	**X: Nik225**	**Y: NIY**	**X: Nik225**	**Y: NK**
	F(Y to X)	0.023 (2.3%)	F(Y to X)	0.016 (1.6%)	F(Y to X)	0.014 (1.4%)
	F(X to Y)	**0.052 (5.0%)**	**F(X to Y)**	**0.023 (2.3%)**	**F(X to Y)**	**0.036 (3.5%)**
	F(X.Y)	1.552 (78.8%)	F(X.Y)	1.636 (80.5%)	F(X.Y)	1.195 (69.7%)
PERIOD	f(Y to X)	f(X to Y)	f(Y to X)	f(X to Y)	f(Y to X)	f(X to Y)
2	0.005 (0.5%)	0.040 (3.9%)	0.003 (0.3%)	0.000 (0.0%)	0.001 (0.1%)	0.006 (0.6%)
2.222	0.013 (1.3%)	0.029 (2.9%)	0.004 (0.4%)	0.002 (0.2%)	0.001 (0.1%)	0.006 (0.6%)
2.5	0.005 (0.5%)	0.035 (3.4%)	0.003 (0.3%)	0.001 (0.1%)	0.001 (0.1%)	0.008 (0.8%)
2.857	0.010 (1.0%)	0.022 (2.2%)	0.001 (0.1%)	0.004 (0.4%)	0.002 (0.2%)	0.014 (1.4%)
3.333	0.003 (0.3%)	0.036 (3.5%)	0.001 (0.1%)	0.006 (0.6%)	0.000 (0.0%)	0.014 (1.4%)
4	0.007 (0.7%)	0.032 (3.2%)	0.002 (0.2%)	0.004 (0.4%)	0.001 (0.1%)	0.011 (1.1%)
5	0.009 (0.9%)	0.037 (3.6%)	0.001 (0.1%)	0.009 (0.9%)	0.002 (0.2%)	0.011 (1.1%)
6.667	0.018 (1.8%)	0.047 (4.6%)	0.002 (0.2%)	0.014 (1.4%)	0.004 (0.4%)	0.011 (1.1%)
10	0.017 (1.7%)	0.054 (5.2%)	0.006 (0.6%)	0.017 (1.6%)	0.010 (1.0%)	0.008 (0.8%)
20	0.023 (2.3%)	0.064 (6.2%)	0.007 (0.7%)	0.030 (3.0%)	0.003 (0.3%)	0.053 (5.2%)
Infinite	0.037 (3.6%)	0.080 (7.7%)	0.016 (1.6%)	0.107 (10.2%)	0.004 (0.4%)	0.280 (24.4%)

TABLE XXVIII

GEWEKE FREQUENCY DECOMPOSITION FOR JAPANESE EQUITY INDEX PRODUCTS

Panel C-2: Japanese Equity Index Products (Onshore and offshore futures)						
	X: JNM	**Y: SSI**	**X: JNM**	**Y: NIY**	**X: JNM**	**Y: NK**
	F(Y to X)	0.017 (1.7%)	F(Y to X)	0.013 (1.3%)	F(Y to X)	0.013 (1.3%)
	F(X to Y)	**0.026 (2.6%)**	**F(X to Y)**	**0.033 (3.2%)**	**F(X to Y)**	**0.045 (4.4%)**
	F(X.Y)	3.100 (95.5%)	F(X.Y)	1.877 (84.7%)	F(X.Y)	1.221 (70.5%)
PERIOD	f(Y to X)	f(X to Y)	f(Y to X)	f(X to Y)	f(Y to X)	f(X to Y)
2	0.004 (0.4%)	0.013 (1.3%)	0.000 (0.0%)	0.001 (0.1%)	0.000 (0.0%)	0.020 (2.0%)
2.222	0.004 (0.4%)	0.011 (1.1%)	0.001 (0.1%)	0.004 (0.4%)	0.000 (0.0%)	0.012 (1.2%)
2.5	0.002 (0.2%)	0.010 (1.0%)	0.001 (0.1%)	0.005 (0.5%)	0.000 (0.0%)	0.019 (1.9%)
2.857	0.006 (0.6%)	0.013 (1.3%)	0.000 (0.0%)	0.006 (0.6%)	0.000 (0.0%)	0.020 (2.0%)
3.333	0.003 (0.3%)	0.012 (1.2%)	0.001 (0.1%)	0.009 (0.9%)	0.000 (0.0%)	0.020 (2.0%)
4	0.003 (0.3%)	0.019 (1.9%)	0.002 (0.2%)	0.007 (0.7%)	0.000 (0.0%)	0.017 (1.7%)
5	0.007 (0.6%)	0.012 (1.1%)	0.000 (0.0%)	0.017 (1.6%)	0.001 (0.1%)	0.018 (1.8%)
6.667	0.002 (0.2%)	0.020 (2.0%)	0.002 (0.2%)	0.025 (2.5%)	0.001 (0.1%)	0.015 (1.5%)
10	0.011 (1.1%)	0.009 (0.9%)	0.001 (0.1%)	0.024 (2.4%)	0.004 (0.4%)	0.014 (1.4%)
20	0.004 (0.4%)	0.022 (2.2%)	0.000 (0.0%)	0.055 (5.3%)	0.000 (0.0%)	0.065 (6.3%)
Infinite	0.006 (0.6%)	0.019 (1.8%)	0.000 (0.0%)	0.157 (14.6%)	0.000 (0.0%)	0.353 (29.7%)
	X: JNI	**Y: SSI**	**X: JNI**	**Y: NIY**	**X: JNI**	**Y: NK**
	F(Y to X)	**0.081 (7.8%)**	**F(Y to X)**	**0.043 (4.2%)**	F(Y to X)	0.027 (2.6%)
	F(X to Y)	0.017 (1.7%)	F(X to Y)	0.025 (2.5%)	**F(X to Y)**	**0.037 (3.7%)**
	F(X.Y)	1.729 (82.3%)	F(X.Y)	1.317 (73.2%)	F(X.Y)	0.935 (60.7%)
PERIOD	f(Y to X)	f(X to Y)	f(Y to X)	f(X to Y)	f(Y to X)	f(X to Y)
2	0.063 (6.1%)	0.003 (0.3%)	0.032 (3.2%)	0.000 (0.0%)	0.009 (0.9%)	0.014 (1.3%)
2.222	0.051 (5.0%)	0.005 (0.5%)	0.022 (2.2%)	0.005 (0.5%)	0.011 (1.1%)	0.011 (1.1%)
2.5	0.060 (5.8%)	0.004 (0.4%)	0.031 (3.0%)	0.002 (0.2%)	0.014 (1.4%)	0.009 (0.9%)
2.857	0.037 (3.6%)	0.008 (0.8%)	0.018 (1.8%)	0.007 (0.7%)	0.009 (0.9%)	0.013 (1.3%)
3.333	0.050 (4.9%)	0.002 (0.2%)	0.025 (2.4%)	0.002 (0.2%)	0.010 (1.0%)	0.013 (1.3%)
4	0.051 (5.0%)	0.007 (0.7%)	0.028 (2.8%)	0.004 (0.4%)	0.013 (1.3%)	0.018 (1.8%)
5	0.066 (6.4%)	0.004 (0.4%)	0.022 (2.2%)	0.011 (1.1%)	0.009 (0.9%)	0.017 (1.7%)
6.667	0.081 (7.8%)	0.006 (0.6%)	0.033 (3.2%)	0.016 (1.6%)	0.020 (2.0%)	0.014 (1.4%)
10	0.100 (9.5%)	0.003 (0.3%)	0.039 (3.8%)	0.016 (1.5%)	0.029 (2.8%)	0.010 (1.0%)
20	0.107 (10.2%)	0.006 (0.6%)	0.046 (4.5%)	0.034 (3.4%)	0.019 (1.9%)	0.056 (5.4%)
Infinite	0.150 (13.9%)	0.003 (0.3%)	0.054 (5.2%)	0.099 (9.4%)	0.021 (2.1%)	0.292 (25.3%)

TABLE XXVIII

GEWEKE FREQUENCY DECOMPOSITION FOR JAPANESE EQUITY INDEX PRODUCTS

Panel C-3: Japanese Equity Index Products (Two futures either onshore or offshore)

	X: SSI	**Y: NIY**		**X: SSI**	**Y: NK**
	F(Y to X)	0.015 (1.5%)		F(Y to X)	0.013 (1.3%)
	F(X to Y)	**0.032 (3.1%)**		**F(X to Y)**	**0.043 (4.2%)**
	F(X.Y)	1.781 (83.1%)		F(X.Y)	1.190 (69.6%)
PERIOD	f(Y to X)	f(X to Y)	PERIOD	f(Y to X)	f(X to Y)
2	0.002 (0.2%)	0.003 (0.3%)	2	0.000 (0.0%)	0.021 (2.1%)
2.222	0.003 (0.3%)	0.003 (0.3%)	2.222	0.001 (0.1%)	0.013 (1.3%)
2.5	0.003 (0.3%)	0.003 (0.3%)	2.5	0.000 (0.0%)	0.017 (1.7%)
2.857	0.002 (0.2%)	0.005 (0.5%)	2.857	0.000 (0.0%)	0.015 (1.5%)
3.333	0.002 (0.2%)	0.006 (0.6%)	3.333	0.000 (0.0%)	0.019 (1.8%)
4	0.007 (0.7%)	0.005 (0.5%)	4	0.003 (0.3%)	0.014 (1.4%)
5	0.000 (0.0%)	0.018 (1.7%)	5	0.000 (0.0%)	0.018 (1.8%)
6.667	0.003 (0.3%)	0.024 (2.4%)	6.667	0.002 (0.2%)	0.013 (1.3%)
10	0.001 (0.1%)	0.024 (2.4%)	10	0.004 (0.4%)	0.014 (1.4%)
20	0.002 (0.2%)	0.051 (5.0%)	20	0.000 (0.0%)	0.062 (6.0%)
Infinite	0.002 (0.2%)	0.150 (14.0%)	Infinite	0.000 (0.0%)	0.341 (28.9%)
	X: JNM	**Y: JNI**		**X: NIY**	**Y: NK**
	F(Y to X)	0.014 (1.4%)		F(Y to X)	0.014 (1.3%)
	F(X to Y)	**0.088 (8.4%)**		**F(X to Y)**	**0.039 (3.8%)**
	F(X.Y)	1.804 (83.5%)		F(X.Y)	1.249 (71.3%)
PERIOD	f(Y to X)	f(X to Y)	PERIOD	f(Y to X)	f(X to Y)
2	0.000 (0.0%)	0.077 (7.4%)	2	0.000 (0.0%)	0.021 (2.1%)
2.222	0.004 (0.4%)	0.052 (5.0%)	2.222	0.001 (0.1%)	0.014 (1.4%)
2.5	0.002 (0.2%)	0.071 (6.9%)	2.5	0.000 (0.0%)	0.023 (2.3%)
2.857	0.004 (0.4%)	0.045 (4.4%)	2.857	0.000 (0.0%)	0.016 (1.6%)
3.333	0.001 (0.1%)	0.059 (5.8%)	3.333	0.000 (0.0%)	0.014 (1.4%)
4	0.002 (0.2%)	0.062 (6.0%)	4	0.001 (0.1%)	0.021 (2.1%)
5	0.002 (0.2%)	0.074 (7.1%)	5	0.001 (0.1%)	0.009 (0.9%)
6.667	0.002 (0.2%)	0.098 (9.3%)	6.667	0.003 (0.3%)	0.011 (1.1%)
10	0.002 (0.2%)	0.095 (9.1%)	10	0.006 (0.6%)	0.010 (1.0%)
20	0.001 (0.1%)	0.124 (11.7%)	20	0.002 (0.2%)	0.053 (5.1%)
Infinite	0.000 (0.0%)	0.164 (15.1%)	Infinite	0.007 (0.6%)	0.239 (21.3%)

7. CONCLUSIONS

The previous research on price discovery between onshore and offshore equity index futures and between equity index futures and the underlying index mostly focus on the products of one country. The conclusions are limited to specific sample and no unified conclusions have been reached yet. This study extends the previous research by covering a much wider range of products and markets. 10 most actively cross-traded equity index futures and 4 underlying equity indices on China, Indian, Japan, Singapore and the US markets are paired and studied to explore the leading product in the price discovery. By applying various methods including cointegration test, (moving) error correction model, ECM-GARCH-X model, impulse response analysis, forecast error variance decomposition and Geweke frequency decomposition, consistent conclusions are reached and complement each other.

(1) When several futures contracts in different maturities and currencies are traded on the onshore and offshore markets, the trading volume of contracts in common months (like quarterly months for all contacts) is much higher than the trading volume of contracts in specific months (like serial months for some contracts). The trading volume of contracts in domestic currency is higher than the trading volume of contracts in foreign currency on the offshore market. It indicates that the futures contracts in same patterns (e.g. contract month and currency) are preferred by investors than other contracts design, since it might facilitate the arbitrage among products on different markets (as shown by the trading statistics of the five Japanese equity index futures).

(2) Comparing the average daily open-interest to volume (OIV) ratio on different markets, the OIV ratio on the offshore markets tends to be higher than the OIV ratio on the onshore market, which implies that there tend to be more long-run holding strategies on the offshore market.

(3) When the onshore and offshore futures are based on different underlying indices, the cointegration and the error correction adjustment (dynamic reversion to long-run equilibrium) between them are not as significant as in the case of two futures based on the same underlying index (as shown by Chinese onshore futures CIF and offshore futures SFC which are based on different indices). It seems that the trading activities might drive two futures prices based on the same underlying index more closely in line with each other.

(4) The individual log price series are non-stationary and significant cointegration is found between the pairs of equity index products. The finding of cointegrated long-run price equilibrium is consistent with the fair price model and the one price law. The long-run price equilibrium between two futures is more significant and much closer to a one to one fair relationship than the long-run price equilibrium between the futures and the underlying index. The two more actively traded futures tend to have more significant long-run equilibrium and meander more narrowly around the equilibrium prices.

(5) There are stable error correction representations to specify the price discovery between equity index products over the studying period. It shows that the trading activities will drive the short-run dynamics revert to the long-run price equilibrium. The actively traded futures (CIF, NIF, CMY, SIN, JNM and SSI) tend to lead the underlying index, while the less actively traded futures (SFC, JNI, NIY and NK) tend to be leaded by the underlying index in the price discovery between futures and index. In the price discovery between onshore and offshore futures, the actively traded onshore futures (NIF, CMY and JNM) tend to lead the less actively traded offshore futures (SIN, SSI, NIY and NK). While the lower volume onshore futures (JNI) tend to be leaded by the higher volume offshore futures (SSI at the SGX) and the primary offshore futures (NIY at the CME), but it (JNI) still leads the lowest volume offshore futures (NK). However, the error correction adjustment between CIF and SFC which are based on different underlying indices is insignificant. Meanwhile, higher volume futures always lead the lower volume futures in the prices discovery.

(6) The ECM-GARCH-X models jointly estimate the conditional mean price and the conditional volatility in the dynamic system. The estimation of conditional mean equations generates the consistent conclusions of the leading product in the price discovery as in the standard (moving) error correction models. The estimation of conditional variance and covariance equations demonstrate that the squared deviations from long-run price equilibrium have significant impacts on the uncertainty in the dynamic system. It tends to increase the uncertainty in the system of two futures, while decrease the uncertainty in the system of futures and the underlying index. There is significant information transmission through volatility spillover between the pair of equity index products. It shows that previous unpredictable price shocks and previous conditional volatility positively impact on current conditional volatility. But the unpredictable price shocks have fast decay in conditioning future volatility, as suggested by the summation of two GARCH terms much smaller than unity.

(7) Impulse response acts fast between equity index futures and the underlying index (2-3 minutes), and even faster between two futures (1-2 minutes). Both futures and index respond to shocks in the futures more than to shocks in the index, both onshore and offshore futures respond to shocks in the onshore futures more than to shocks in the offshore futures, and both higher and lower volume futures respond to shocks in the higher volume futures more than to shocks in the lower volume futures. The scale and speed of response obviously indicate that the higher trading volume of the futures, the more leading role it plays. Forecast error variance decomposition shows that futures dominate the underlying index, onshore futures dominate the offshore futures and higher volume futures dominate the lower volume futures in explaining much more percentage of the forecast error variance in the system. Again trading volume determines the influential power.

(8) Finally, the dynamic interaction between pairs of equity index products is decomposed in the frequency domain. The instantaneous feedback between the two products is very large. It is even larger between the two futures than between the futures and the underlying index. When the futures (CIF, NIF,

CMY, SIN, JNM and SSI) have a relatively higher trading volume, the feedback from futures to index is larger than the reverse. When the futures (SFC, JNI, NIY and NK) have a relatively lower trading volume, the feedback from index to futures is larger than the reverse. When the trading volume of onshore futures is higher (in the cases of CIF, NIF, CMY and JNM), the feedback from onshore futures to offshore futures is larger than the reverse. When the trading volume of onshore futures is relatively lower (in the case of JNI), the feedback from primary offshore futures (SSI and NIY) to lower volume onshore one is larger than the reverse. The feedback from higher volume futures to lower volume futures is always larger than the reverse. Trading volume plays an important role in determining the direction and strength of feedback. Finally, there are more high frequency feedbacks between two futures than between futures and the underlying index.

Overall, the results of this study reveal that trading volume is a critical factor in determining which of two related equity index products will lead in the price discovery. Previous studies find it is either the futures lead the underlying index (in most cases), or the underlying index leads the futures (in case of newly listed futures or using daily data), and it is mostly the offshore futures lead the onshore futures since the international exchanges are generally more advanced and experienced. Here I find the price discovery is not necessarily unilateral and the trading volume is an important factor in determining the leader of price discovery. The more actively traded products will play a more dominant role in maintain the price equilibrium. The intuitive implication for an exchange to launch a leading product is to attract investors and raise the trading volume.

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