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THE INTRADAY DYNAMIC RELATIONSHIP BETWEEN STOCK INDEX SPOT AND FUTURES MARKET IN CHINA

Mamata Parhi*
Sijia Liu**

* *University of Roehampton, London, E-mail: Mamata.Parhi@roehampton.ac.uk*
** *University of Southampton, Southampton, E-mail: sl6e14@soton.ac.uk*

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ABSTRACT

This paper investigates the intraday dynamic relationship between Chinese CSI 300 spot and futures markets with respects to the lead-lag dynamic relations of prices and the volatility spillovers effects based on 5-minute price data. Multivariate cointegration and causality tests are employed to characterize the lead-lag relationship. Furthermore, volatility spillover is modelled in our exercise by the GARCH-BEKK parameterization technique. No unique lead-lag relation (unidirectional lead-lag relation and bidirectional relation) is found in various periods. The lead-relation is from futures price to spot price during period one, whereas futures price lead to spot more profoundly than the reverse in period two. We also find that volatility spillovers are bidirectional in all the three periods, although they are asymmetric in the first and second periods. Moreover, we find that volatility spills over from cash market to futures market with greater magnitude than the reverse in the first period, while in period two futures market demonstrates greater strength in volatility spillovers. It indicates that stock index futures market tends to play a leading role between spot and futures markets but this relation is not stable.

1 INTRODUCTION

Stock index futures market is closely associated with its underlying stock market index. The introduction of this kind of derivative is believed to contribute immensely to investors, regulators and other participants (Drimbetas *et al.*, 2007; Stoll and Whaley, 1990). Moreover, it is well-known that stock index futures are helpful in terms of hedging risks, making profitable arbitrage opportunities and monitoring, and predicting the financial fluctuation (Chan, 1992). In an efficient market, the stock index spot market and its futures market should change contemporaneously because the information for the two markets is the same and is publicly available. Thus, no lead-lag relation would exist between index cash market and the corresponding futures market. However, empirical work show that cash market and futures market vary in terms of efficiencies and the way they react to information shocks (possibly due to the differences of liquidity, structure and friction costs between the two markets (Tse, 1999)). The implication is that one market may be well-informed with the new information prior to another market, and the former could motivate diffusion of its reactions to the latter (So and Tse, 2004). Such types of information flow consequently cause the lead-lag relation, involving lead-lag relation in price and volatility spillovers effects, and between cash and futures market (see Zhong *et al.*, 2004 for Mexican case). In this case, the dynamic relationships tend to reflect on the nature of the price discovery function and the pattern of information transmission between the two markets. Thus, it is no wonder that a number of important researches have been attempting to investigate the lead-lag relationship and volatility spillovers effects in various markets (developed and developing) so that the analysis of the linkage and information dissemination between the two markets could help investors to minimise risk and make a profitable trading strategy. The study is nowhere more so important than one of the largest developing markets in the world (in our case, China), whose export dynamics has been affecting the growth of even the smallest country on the earth, and yet suffers greatly from persistent incomplete information and an imperfect market structure. In this paper, we focus our investigation in the case of Chinese market.

An in-depth look into the literature reveals that the dynamic relation between stock indices spot markets and associated futures markets can be different in various financial markets due to the differences in terms of financial structure, economic environment and trading period. Lead-lag relations between index spot prices and futures prices could be divided into three types: unidirectional lead from futures prices to spot prices, unidirectional lead from spot prices to futures prices and bidirectional lead-lag relation. Those lead-lag relationships indicate the nature of information dissemination, and provide a glimpse of the price discovery process, thus informing the trading strategies to investors. The effects of volatility spillovers between index cash markets and futures markets are summarized into two streams: volatility spillovers from futures markets to spot markets and bidirectional spillovers. With the effect of volatility spillovers, investors could understand information flowing better and perform well in trading activities, involving risk management, hedging and choosing trading strategies. The majority of economic methods used in previous s are cointegration tests and GARCH type models for lead-lag relation examination and volatility spillovers investigation respectively. Precedent studies about the dynamic relationships between CSI 300 cash and futures markets describes unidirectional leading power from spot to futures price at first and bidirectional lead-lag effect later, and the volatility spillovers effect tends to be bidirectional (Yang *et al.*, 2012; Jin and Yang, 2013; Zhou *et al.*, 2014; Zhou and Wu, 2015).

While the dynamic relations between index cash and futures markets in developed countries are widely researched, especially in the USA and the UK (see for instance, Verousis *et al.*, 2015), however, many developing countries newly established stock index futures markets need proper characterisation and understanding of how the dynamic relations between the spot and futures markets evolve over time. The current literature is not well-equipped to answer such a question due to the insufficient and rigorous study of such behaviours in developing markets' context. Moreover, those nascent index futures in these markets are developing quickly and beginning to play instrumental role in financial market dynamics not only in these markets, but also across the interconnected markets around the world. The China Securities Index 300 (CSI 300) futures is one such financial characteristic, the study of which is of considerable interest to the researchers. The CSI 300 futures contracts are provided by the China Financial Futures Exchange (CFFEX) on April 16th in the year of 2010. The introduction of the first stock index futures provides more trading strategies for investors to mitigate risks, make arbitrages and forecast volatilities (Zhou and Wu, 2015).

This index futures market is more mature with higher trading volume, lower trading costs and various contracts. In this case, investigating the current lead-lag relation and volatility spillovers effect is helpful to offer new insights for potential investors and other participants in the financial market in terms of controlling risks and making profits. In addition, comparing the current dynamic relation between CSI 300 index and futures markets with those in previous developing years and the infancy year could reflect how the information transmit in different period. Therefore, it is also possible to show how the index futures market of CSI 300 develops over time.

To study these behaviours and investigate the intraday dynamic relationship, in this paper the CSI 300 index price and its current month futures contract price are collected at every 5-minute interval during three separate periods, viz.,4/16/2010-1/31/2011, 12/3/2012-6/28/2013, and 10/8/2013-7/31/2014. The 5-min data are inherently superior to the daily data because the arbitrages arising from the stock index and futures markets would disappear in hours. In this case, intraday data could describe the dynamic relationship more accurately. To unearth possible dynamic pattern and examine if the two prices share long-run cointegration relationship, multivariate cointegration test of Johansen (1988) will be employed. Moreover, the vector error correction model (VECM) mechanism would also be able to reflect on the equilibrium adjustment behaviour due to stochastic shocks and detect lead-lag relationship. However, it is suggested that only the first moment of such dynamic relation between the spot and futures prices is not sufficient to explain the information flowing between the two markets (Chan *et al.*, 1991). Chan *et al.* (1991) show that the second moment, i.e. volatility spillovers effect reveals interesting characteristics of the lead-lag relation. Accordingly, we employ a bivariate GARCH model with Baba, Engle, Kraft and Kroner (BEKK) parameterization (Engle and Kroner, 1995) technique to analyse the volatility spillovers effect not only in the short term but also in the long term. As a major departure from the literature, especially in the developing market context, we use the intraday data of futures and spot prices to detect the intraday dynamic relation. Moreover, we conceptualise three distinct phases of analyses, viz., the infancy stage, developing stage, and the current stage of CSI 300 futures market so that lead-lag relationship can be robustly modelled and explained.

1.1. The Chinese Context

When it comes to examining the lead-lad relationship between the newly established stock index futures price and its spot price in China, Yang *et al.* (2012) apply the recursive cointegration tests rather than general Johansen cointegration tests to investigate the relationship. It is found that the spot price leads the associated futures price because that the stock index futures market is immature, and the entry barriers exist accordingly. Cao *et al.* (2014) discover the bidirectional price causality between CSI 300 index and the corresponding futures markets, although futures market holds stronger leading power than spot market. Also, Zhou and Wu (2015) find the same result with Cao *et al.* (2014) through a VAR model. It may indicate that the index futures market in China has become more mature after years of development, and performs well in term of the price discovery function and improves the information dissemination effectiveness.

Considering studies testing the dynamic volatility relation between CSI 300 index futures market and its spot market, unidirectional and bidirectional volatility spillovers are both discovered. For example, Jin and Yang (2013) utilize a bivariate BEKK-GARCH model and collect information not only in the trading time (intraday returns) but also in non-trading times (overnight returns) to test the volatility spillover. Based on the two divided data, unidirectional spot-to-futures volatility spillover and bidirectional volatility spillover are proved to exist during trading and non-trading periods respectively (Jin and Yang, 2013). It is also suggested that such effects are more significant in trading times than non-trading times, and volatilities spill more heavily in trading period than in the non-trading one (Jin and Yang, 2013). A strong bidirectional volatility spillover is found by Zhou *et al.* (2014) through VAR model and TVP-VAR model that holds the advantage in capturing structure changes accurately. They also find that CSI futures could stabilize its cash market, since the range of volatility changing in cash market becomes narrow when volatility in futures market changes (Zhou *et al.*, 2014). Zhou and Wu (2015) use four VAR-MGARCH models to prove the bidirectional volatility spillovers, and the power of spilling from futures market to spot market is suggested to be similar to the reverse spilling effect.

In addition, it is empirically demonstrated that the index futures market is more variable in terms of conditional variance and volatility persistence. Also, the spot-to-futures volatility spillover tends to destabilize index cash market while the futures-to-spot volatility spillover tends to stabilize futures market (Zhou and Wu, 2015). Bidirectional volatility spillovers between the two associated markets are also found by Li (2015) through a VAR-BEKK-bivariate GARCH model, but the spilling power is significant from futures market to spot market than that from the later to the former. This indicates that CSI 300 index futures market holds a dominated role in terms of information disseminating compared to its spot market.

The rest of the paper is structured as follows. Section 2 presents data and preliminary observations. Section 3 discusses methodology and Section 4 presents and analyses the main results. Finally, Section 5 concludes with the main findings and their implications.

2. DATA

2.1 Sample selection

We collected intraday 5-min CSI 300 spot price (return) and its futures contracts price (return) to investigate the dynamic associations between spot and futures markets in China (data source: S&P YongHua database). The CSI 300 futures market is established in April 2010 and has been developing five years. During the five years, the dynamic relationship between the two markets may be varying due to the developments and the improvements of CSI 300 index futures market. With the purpose of investigating the current relation between the two markets in terms of price leading effects and volatility spillovers, and comparing it with previous ones to analyse the differences of roles futures market playing, three periods of sample data are chosen. Those are April 16, 2010 to January 31, 2011, September 3, 2012 to June 28, 2013 and October 8, 2014 to July 31, 2015, which reflect the infancy stage, the developing stage and the current stage of the CSI 300 index futures market respectively. In the past, daily prices or returns are the major data collected to investigate economic relationships. However, based on the high trading frequency of index and its futures, daily prices and returns tend to be unconvincing to detect the dynamic linkages between the two markets. For example, once arbitrages are discovered between the cash and futures prices, it may disappear in few minutes as millions of investors involved in the two markets. Intraday data performs much better than daily data in term of reflecting information and capturing volatility in the short horizon. Thus, to understand the dynamic relationship better, the close price of futures and spot stock index is collected in each five minutes' interval (5-min price data).

There are four futures contracts existing at one time. Empirically, the contracts in current month hold the highest liquidity and trading frequency, and therefore, price data of current month contracts is chosen to compose the futures price series. Continuous data series of the futures price is made up by collecting the price of futures contract in the current month until the expiration day, and then roll over to the contract price for next month. Because the trading session of CSI 300 index is not identical to that of CSI 300 index futures, observations of futures price in the first and the last fifteen minutes are eliminated to match futures price to its spot price. Thus, 48 pairs of observations of spot and futures close price are collected from 9:00 at mooning to 03:00 at afternoon at five minutes' intervals in one day, and after excluding weekends and holidays, the time series of three periods contains 9312, 9312 and 9745 observations respectively.

2.2. Preliminary observations

Figure 1 contains the plots of raw 5-min prices of CSI 300 index and its futures in the three stages. It is clear that the movements of two price series in the three periods are almost same in the long term, and an obvious difference only happens at the end of the stage one, January 2011, which may be due to the January effect. In addition, according to the figures, the scale of the spot price's fluctuations and the futures' are the largest in the third period compared to other two.

The continuously compounded 5-min returns, which are also the first differences of natural logarithmic prices, for the two series in each period are calculated as follows:

$$\Delta S_t = R_{s,t} = \ln(S_t) - \ln(S_{t-1}) \tag{1}$$

$$\Delta F_t = R_{f,t} = \ln(F_t) - \ln(F_{t-1}) \tag{2}$$

where Δ means the first difference, S_t means the 5-min close price of spot index at time t, F_t means the 5-min close price of index futures at time t and $R_{s(f),t}$ means the return for spot index (index futures). Figure 2 shows the plots of returns for the index and futures. It indicates that, on average, the volatilities of the two returns tend to move simultaneously, and the two return series appear to be stationary. In addition, the returns in the current stage (third period) are more variable than those in the infancy the developing stages, which is consistent with the situation that the stock market is fluctuated from October, 2014 to July, 2015.

Table 1 illustrates the descriptive statistics and autocorrelation of return series for spot index and index futures in the three stages. From the Panel A, it can be seen that, in each stage, the mean returns for index and index futures are both nearly to zero and the two volatilities (standard deviation) are also similar. It reflects that CSI 300 index futures market is associated with its spot market tightly. However, in the first period, the volatility of spot index return is larger than that of futures return, but in the second and third periods, the volatilities of spot returns are smaller. This may imply that futures market is less variable than spot market when the index futures market is newly established, but after development such futures market tends to be more volatile than its spot counterpart. It is clear that the descriptive statistics of spot return in the first period are very different from other statistics, which may be due to the fact that the spot price declines significantly during the beginning three months after the introduction of the stock index futures. The distributions of cash and futures returns are not normal in the three periods according to skewness and excess kurtosis. Moreover, the Jarque–Bera statistics are highly significant, which means the rejection of null hypothesis (normal distribution). Specifically, return series in all the three periods are leptokurtic distributed with fat tails, especially the spot one in the first period, which holds extremely high skewness and excess kurtosis compared to other series.

The features of autocorrelations in spot and futures returns are illustrated in Panel B. Ljung–Box statistics indicates the dependencies in the spot and futures return series with respect to the first moment. From tables, the Ljung–Box statistics for returns with a lag of 12, Q (12), are significant at 1% level for the cash and futures returns in three periods, except the one for cash return series in the first period. This suggests that the null hypothesis of no autocorrelation in the 5-min return series is rejected, excluding the spot return in the infancy stage.

Also, the Autoregressive Conditional Heteroscedasticity (ARCH) Lagrange Multiplier (LM) test is used to investigate the time-varying variance of cash index returns and its futures returns in the three periods. The test results describe similar explanations to the Ljung–Box statistics, that LM statistics with a lag of 12 are significant with respect to all the returns expect the spot one in the first period. It means that those return series hold ARCH-type dependences, and it can also explain economic phenomena like volatility clustering. In this case, the ARCH effects exist in those return series and it is reasonable to utilize GARCH type model to analyse such intraday volatility. In addition, the unconditional correlation coefficients between spot and futures are showed in **Table 2**, which are 0.5634, 0.8486 and 0.7707 in the three periods respectively. All the three coefficients are positive, indicating the moving directions of spot and futures return series are similar when influenced by new information in the markets. The values of correlation coefficients in the second and third periods are close to unity, but the one in the first period is just over fifty percent. This may be because that 2010 is the first year when CSI 300 index futures contracts are introduced, and the trading volume and trading frequency are quite low.

2.3. Testing (non-) Stationarity

As a supporting observation for understanding the stationary/non-stationary behaviour of the series, we present and discuss briefly the unit root test results (**Table 3**). It is clear that, in the three periods, the Augmented Dickey–Fuller (ADF) (Dickey and Fuller, 1979) and Phillips–Perron (PP) (Phillips and Perron, 1988) test statistics for the level price series of stock index and index futures are too small to reject the null hypothesis. This indicates that the level price series have a unit root, and nonstationary accordingly. However, the first differences of log prices hold extreme negative ADF and PP test statistics compared to the 1% critical value, which means the null hypotheses of a unit root are rejected at 1% significant level. Thus, the spot and futures returns series are stationary in the three periods (the level prices series are integrated of order I(1)). In addition, Table 3 also provides the test statistics of Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test (Kwaitkowski *et al.*, 1992), which is a unit root test with null hypothesis of a stationary series. It can be seen that the KPSS test statistics of spot and futures prices in level are large than critical values to reject the null hypotheses at the 1% level of significance in the three periods. When it comes to the KPSS statistics for the first difference of prices series, those test statistics are small, which means no rejection of stationary. In this case, KPSS tests support the same results of ADF and PP tests that the spot and futures price series are not stationary, but their first difference (returns) are stationary in the three periods. This is in accordance with the plots of the spot and futures prices and returns (Figures 1 and 2) in term of visual inspection.

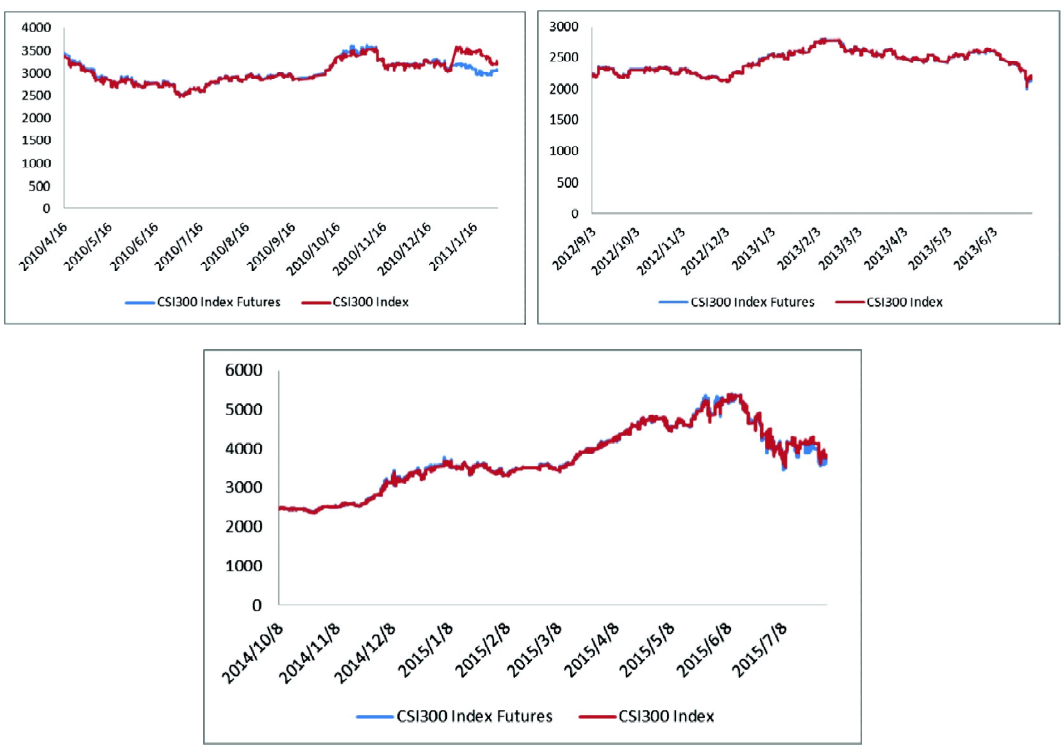

Figure 1: Prices of CSI 300 index and its futures in the three periods

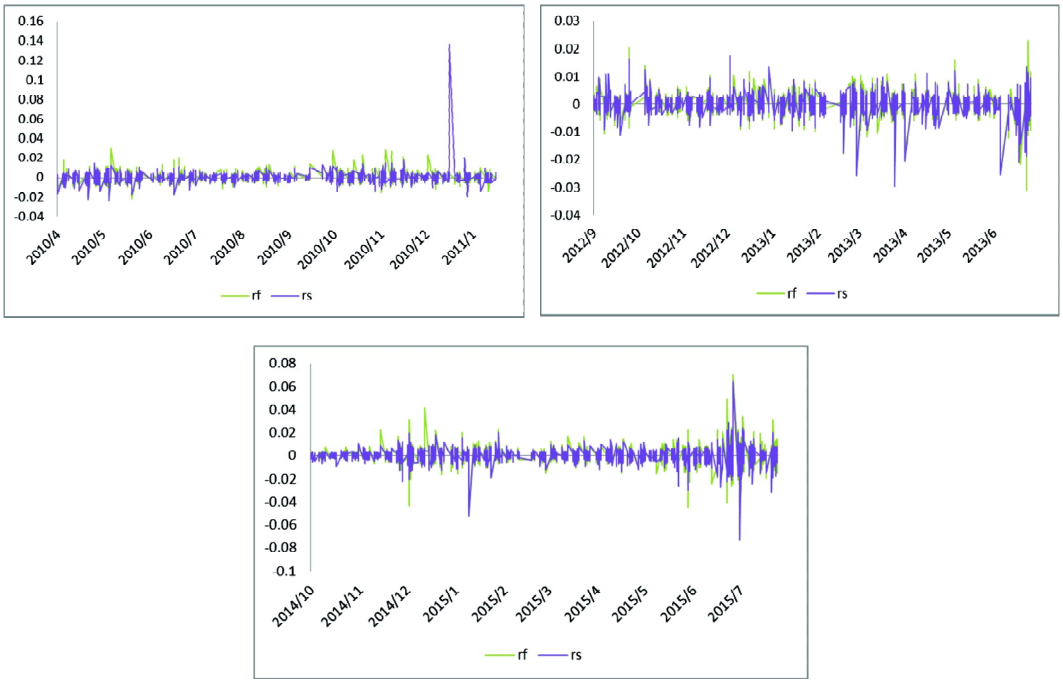

Figure 2: Returns of CSI 300 index and its futures in the three periods

Table 1: Descriptive statistics and autocorrelations of returns

	Period one		*Period two*		*Period three*	
	R_s	R_f	R_s	R_f	R_s	R_f
Panel A: Descriptive statistics						
Mean	-5.56E-06	-1.22E-05	-8.30E-09	-2.73E-06	4.53E-05	4.11E-05
Median	-4.74E-05	-6.18E-05	-1.85E-05	0.0000	0.0002	7.77E-05
Maximum	0.1365	0.0303	0.0172	0.0229	0.0644	0.0707
Minimum	-0.0242	-0.0237	-0.0299	-0.0311	-0.0731	-0.0467
Std. Dev.	0.0026	0.0023	0.0018	0.0020	0.0035	0.0039
Skewness	14.5201	1.0562	-1.1985	-0.6221	-0.9172	0.4440
Kurtosis	762.3526	23.9302	31.0365	25.9568	44.6158	33.7857
Jarque-Bera	2.24E+08***	171686.9***	307183.8***	205060.9***	704435.1***	385072.3***
Panel B: Ljung-Box statistics and ARCH effect tests						
Q (12)	7.3100	45.918***	31.105***	45.067***	62.705***	60.227***
ARCH-LM (12)	0.0009	4.1476***	4.9269***	12.2178***	13.6755***	43.9721***

Notes: Q (12) is the Ljung-Box statistic for returns with a lag of 12 and follows a distribution with 12 degrees of freedom. ARCH-LM (12) is the autoregressive conditional heteroscedasticity of residuals with a lag of 12. *** indicates 1% level of significance. In the figure, E-06 (or other numbers) indicate multiplying the value by 10-6.

Table 2: Correlation coefficients between spot and futures returns

Correlation coefficients	R_s	R_f
Period One (4/16/2010-1/31/2011)		
R_s	1.0000	0.5634
R_f	0.5634	1.0000
Period Two (12/3/2012-6/28/2013)		
R_s	1.0000	0.8486
R_f	0.8486	1.0000
Period Three (10/8/2013-7/31/2014)		
R_s	1.0000	0.7707
R_f	0.7707	1.0000

Table 3: Test statistics of (non-)stationary tests (unit root tests)

Period	*Data series*	*ADF*	*PP*	*KPSS*
Period One				
(4/16/2010-1/31/2011)	Levels (log)			
	S_t	-0.2205	-0.2181	7.4908***
	F_t	-0.5215	-0.5050	5.3443***
	First difference (log)			
	ΔS_t	-97.8252***	-97.8233***	0.2570
	ΔF_t	-99.4152***	-99.4323***	0.3173
Period Two				
(12/3/2012-6/28/2013)	Levels (log)			
	S_t	-0.0226	-0.0125	5.7287***
	F_t	-0.1547	-0.1428	5.2827***
	First difference (log)			
	ΔS_t	-93.1895***	-93.3260***	0.4000
	ΔF_t	-101.406***	-101.308***	0.4504
Period Three				
(10/8/2013-7/31/2014)	Levels (row)			
	S_t	1.3158	1.2535	10.2977***
	F_t	0.9698	1.0536	9.9751***
	First difference (log)			
	ΔS_t	-73.9500***	-104.118***	0.4323
	ΔF_t	-72.9714***	-99.7532***	0.4477

Notes: *** indicates 1% level of significance.

3. METHODOLOGY

In this section we briefly present the estimation method. We will only present the main idea with respect to our hypotheses. The details of these methods can be studied in the cited papers. The dynamic relations examined in this paper are the first moment between CSI 300 stock index price and its futures price (lead-lag relationship), and the second moment dynamic relation between the spot and futures returns of CSI index (volatility spillovers effect). Cointegration tests, involving Engle and Granger's cointegration test (Engle and Granger, 1987) and Johansen cointegration test (Johansen, 1988), and Granger causality test (Granger, 1969) are used to investigate the first moment lead-lag relation between index and its futures prices. A multivariate GARCH model with Baba, Engle, Kraft and Kroner (BEKK) parameterization (Engle and Kroner, 1995) is constructed to analyse the second moment variance connection between cash returns and futures returns.

3.1. Multivariate approach to cointegration test

Because Engle-Granger cointegration test inherits foremost limitation of being limited to the bi-variate case, in large empirical literature in finance and economics, a multivariate approach to is employed, thanks to the seminal contribution by Johansen (1988). Johansen (1988) examines the cointegration based on the vector autoregressive (VAR) model, which could test the long term relation between more than two time-series. This procedure utilizes Maximum Likelihood method and is suggested to be more powerful than Engle and Granger approach. The principles followed by Johansen cointegration test are almost same as those followed by Engle and Granger test, and one precondition is that the time series must be nonstationary at level and cointegrated at the same order. The integration order could be examined by unit root tests like ADF and PP. Then, the VAR model with k lags containing spot price and futures price could be set up:

$$Y_t = A_0 + \Sigma_{i=1}^{k} A_i Y_{t-i} + \varepsilon_t \tag{10}$$

where Y_t is the vector containing nonstationary spot and futures prices $\begin{bmatrix} S_t \\ F_t \end{bmatrix}$, A_0 is the (2×1) column intercept vector, A_i is the (2×2) matrix of coefficients and ε_t is the (2×1) column white noise error term. In a Johansen cointegration test, it is necessary to transform this VAR, i.e. equation (10), to a vector error correction model (VECM):

$$\Delta Y_t = G_0 + \Pi Y_{t-k} + \Sigma_{i=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \varepsilon_t \tag{11}$$

where $\Pi = \Sigma_{j=1}^{k} G_i - I$ and $\Gamma_i = \Sigma_{j=1}^{i} G_j - I$. The Π matrix, which reflects the long-run equilibrium between cash and futures markets, is examined in the Johansen test to find the cointegration relationship. Specially, the Π matrix can be interpreted as a product of two sets of coefficients, i.e. $\Pi = \alpha\beta'$, where β is the matrix of cointegration coefficients and is the matrix measuring the adjusting speed of cointegrating vector. The Γ_i matrices indicate the short run dynamics when disequilibria accrue. In addition, the lag length chosen in the Johansen cointegration test and Engle and Granger test can significantly affect the results of cointegration. Schwarz's Bayesian Information Criterion (SBIC) (Schwarz, 1978) is used to choose the suitable length of lag k.

Then, according to Granger, a VECM should be constructed to depict the dynamic relation in both long and short terms. The VECM is estimated under OLS approach to test the leading or lagging patterns between spot and futures prices:

$$\Delta S_t = \alpha_{S,0} + \Sigma_{i=1}^{p-1} \alpha_{S,i} \Delta S_{t-i} + \Sigma_{i=1}^{p-1} \beta_{S,i} \Delta F_{t-i} + \alpha_S Z_{t-1} + \epsilon_{S,t} \tag{14}$$

$$\Delta F_t = \alpha_{f,0} + \Sigma_{i=1}^{p-1} \alpha_{f,i} \Delta S_{t-i} + \Sigma_{i=1}^{p-1} \beta_{f,i} \Delta F_{t-i} + \alpha_f Z_{t-1} + \epsilon_{f,t} \tag{15}$$

where Z_{t-1} is the error correction term from cointegration equation, α_s and α_f are coefficients reflecting the speed of adjustments to equilibrium and $\beta_{s,i}$ and $\alpha_{f,i}$ are coefficients measuring the short-term causal relation. Specially, if α_s (α_f) is significant, it is suggested that the futures (spot) price leads the spot (futures) price in the long term. Otherwise there would be no long-term causality from futures price to spot price. When it comes to the short-term causality, the futures (spot) price lead to the spot (futures) one in short run if one or more than one $\beta_{s,i}$ ($\alpha_{f,i}$) is significant. No short-run lead-lag relation exists if none of $\beta_{s,i}$ or $\alpha_{f,i}$ is significant. If α_s and α_f are all significant there is bidirectional long-term causality between the two prices, and similarly, bidirectional short-term lead-lag relationship exists when at least one $\beta_{s,i}$ and at least one $\alpha_{f,i}$ are significant. The significance hypotheses of α_s and α_f are tested by t-test statistics while the significance of $\beta_{s,i}$ and $\alpha_{f,i}$ are examined by Wald test (joint test) through F-test statistics.

3.2. Bivariate GARCH models with BEKK

Empirically, it is suggested that the VAR model established to depict the dynamic relationship between index and its futures markets tends to be serial correlated with respect to squared residuals. The ARCH–LM (12) test statistics illustrated in the data section are significant at 1% level. This ARCH effect suggests that volatility clustering exists in the two time-series. In addition, from the statistical description of data, it is clear all the returns series in the two markets and three periods are time-varying and hold the distribution features of sharp peak and heavy tail. In this case, it is rational to construct a bivariate GARCH with BEKK parameterization (Engle and Kroner, 1995) model to investigate the second moments of dynamics, i.e. volatility spillovers, between the futures market and its underlying cash market. This model is outstanding in terms of capturing the time-varying fluctuation characters of returns series, ensuring the covariance matrix is positive definite without any constraints and reducing the parameters' number. A bivariate BKEE-GARCH (1,1) is thus selected:

$$R_t = \mu + R_{t-1} + \varepsilon_t \tag{16}$$

$$\varepsilon_t \mid \Omega_{t-1} \sim N(0, H_t)$$

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon_{t-1}'A + B'H_{t-1}B \tag{17}$$

where equation (16) and (17) are the conditional mean equation and variance equation respectively. Here, R_t is a vector of spot and futures returns at time t $[R_{s,t}\ R_{f,t}]'$, μ is a vector of long-run drift $[\mu_{s,t}\ \mu_{f,t}]'$, ε_t is the error vector $[\varepsilon_{s,t}\quad \varepsilon_{f,t}]'$ with $\varepsilon_t \mid \Omega_{t-1} \sim N(0, H_t)$, H_t, is the conditional variance-covariance matrix of residual based on the information before time t, C is the constants matrix, A is the matrix of coefficients reflecting the association between the past squared errors and the conditional variance (ARCH effect) and B is the matrix which contains coefficients expressing the degree of volatility persistence in the conditional variance (GARCH effect). It is suggested that the diagonal factors of matrix A reflects the power of own previous shocks influencing current variance and that diagonal parameters of matrix B depicts how significant the own historical volatility affecting the current one. The parameters that are important to be tested in are those off-diagonal ones in matrices A and B, which indicates the volatility spillovers effect between the index cash and futures markets.

The conditional variance-covariance matrix H_t is equivalent to:

$$\begin{bmatrix} h_{ss,t} & h_{sf,t} \\ h_{fs,t} & h_{ff,t} \end{bmatrix} = \begin{bmatrix} c_{ss} & 0 \\ c_{fs} & c_{ff} \end{bmatrix}' \begin{bmatrix} c_{ss} & 0 \\ c_{fs} & c_{ff} \end{bmatrix}$$

$$+ \begin{bmatrix} a_{ss} & a_{sf} \\ a_{fs} & a_{ff} \end{bmatrix}' \begin{bmatrix} \varepsilon_{s,t-1}^2 & \varepsilon_{s,t-1}\varepsilon_{f,t-1} \\ \varepsilon_{f,t-1}\varepsilon_{s,t-1} & \varepsilon_{f,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{ss} & a_{sf} \\ a_{fs} & a_{ff} \end{bmatrix}$$

$$+ \begin{bmatrix} b_{ss} & b_{sf} \\ b_{fs} & b_{ff} \end{bmatrix}' \begin{bmatrix} h_{ss,t-1} & h_{sf,t-1} \\ h_{fs,t-1} & h_{ff,t-1} \end{bmatrix} \begin{bmatrix} b_{ss} & b_{sf} \\ b_{fs} & b_{ff} \end{bmatrix} \tag{18}$$

Specially, equation (18) can be rewritten to:

$$h_{ss,t} = c_{ss}^2 + a_{ss}^2\,\varepsilon_{s,t-1}^2 + 2a_{ss}a_{fs}\,\varepsilon_{s,t-1}\varepsilon_{f,t-1} + a_{fs}^2\varepsilon_{f,t-1}^2 + b_{ss}^2h_{ss,t-1} + 2b_{ss}b_{fs}\,h_{sf,t-1} + b_{fs}^2\,h_{ff,t-1}$$

$$h_{ff,t} = c_{ff}^2 + c_{fs}^2 + a_{sf}^2\,\varepsilon_{s,t-1}^2 + 2a_{sf}a_{ff}\,\varepsilon_{s,t-1}\varepsilon_{f,t-1} + a_{ff}^2\varepsilon_{f,t-1}^2 + b_{sf}^2h_{ss,t-1} + 2b_{sf}b_{ff}\,h_{sf,t-1} + b_{ff}^2\,h_{ff,t-1}$$

$$h_{sf,t} = h_{fs,t} = c_{ss}c_{fs} + a_{ss}a_{sf}\,\varepsilon_{s,t-1}^2 + (a_{fs}a_{sf} + a_{ss}\,a_{ff})\,\varepsilon_{s,t-1}\,\varepsilon_{f,t-1} + a_{fs}\,a_{ff}\,\varepsilon_{f,t-1}^2 + b_{ss}\,b_{sf}\,h_{ss,t-1} + (b_{sf}\,b_{fs} + b_{ss}b_{ff})h_{sf,t-1} + b_{fs}b_{ff}\,h_{ff,t-1} \quad (19)$$

Here, $h_{ss,t}$ and $h_{ff,t}$ represent the conditional variance with respects to the spot index return and the associated futures return respectively, and $h_{sf,t}$ and $h_{fs,t}$ are the conditional covariance between the spot and futures return series. In addition, the maximum likelihood is calculated through the following equation:

$$I(\theta) = -T\ln(2\pi) - \frac{1}{2}\Sigma_{i=1}^{T}(\ln|H_t|) + \varepsilon_t' H_t \varepsilon_t \quad (20)$$

In this case, three Wald tests are proposed to detect the volatility spillover effect between cash and futures returns of CSI 300 index. The first test, which aims to find the spilling effect from futures return to cash return, holds the null hypothesis of $a_{fs} = b_{fs} = 0$. From equation (19), it is clear that, if a_{fs} and b_{fs} are zero, the cash return would only relate to its own past shocks (squared residual) and historical volatility (conditional variance). Thus, no factors from futures returns would influence the spot one, which means that the volatility spill from the former return to the later one. For similar reasons, with $H_0 : a_{sf} = b_{sf} = 0$, the second test is performed to investigate whether the volatility spillovers effect exists from cash return to futures return. The null hypothesis of the third test is $a_{fs} = b_{fs} = a_{sf} = b_{sf} = 0$. Rejection of this null hypothesis indicates that there is no volatility spillovers effect between spot and futures returns of CSI 300 index.

4. EMPIRICAL RESULTS AND ANALYSIS

4.1. Results of Engle-Granger approach

As demonstrated in Table 3, the logarithm series of spot and futures prices are nonstationary but those series become stationary after the first differencing, indicating the prices series are I(1). This makes it rational to examine whether the two series are cointegrated, i.e., whether the combination of the two nonstationary series would be stationary. According to Engle and Granger cointegration test (Engle and Granger, 1987) described in the methodology section, the residual from the regression based on the cost-of-carry model is saved to test the stationarity. The estimations of regression's coefficients and the unit root tests statistics are listed in **Table 4**. It is clear that, in the first period, the ADF and PP test statistics are less negative than the critical values at 5% significance level, suggesting that the residual of cointegrating regression is not stationary. However, when it comes to the second and third periods, the null hypotheses of a unit root are significantly rejected at 1% level for both ADF and PP tests, which means that the residuals are stationary. Therefore, the cash and futures prices are cointegrated in the second and third periods while no cointegration is discovered in the first period.

This indicates that long term equilibrium relations between spot and futures prices of CSI 300 index exist in the developing and current stages, but in the infancy stage, there is no lead-lag relation between the two prices. This may be explained by the newly establishment of the stock index futures market, which is tend to be accompanied with irrational economic phenomena such as low transaction volume, influent trading and high friction costs. Since none of the spot index price, its futures price or their combination is stationary, the regression of the cost-of-carry model for the cash stock index and its futures prices in the first period is spurious. Specially, in the first period, although the estimated coefficients are significant and the value of is nearly to one, this relation is false and no real lead-lag relation performs in the long run.

It is suggested that if two series are cointegrated, the lead-lag relation could be discovered at least one direction (Engle and Granger, 1987). In the second and third periods, the leading or lagging effects could be examined by constructing error correction models. However, Engle-Granger method is only used to test whether cointegration exist between CSI 300 index spot and futures prices. More investigations involving the directions and power of lead-lag relations would be analysed through Johansen cointegration tests.

4.2. Results of causality tests

Since the stock index cash price and the associated futures price are cointegrated in the second and third periods, the Granger causality test could be utilized to detect the leading and lagging effects in a simple way. The advantages of this causality test are that the test statistics are easy to calculate and only one procedure needs to be performed. There are two hypotheses in the test which aim to investigate the causality from spot price to its futures price and the causality from futures price to the associated spot price respectively. The test statistics and the p values are presented in Table 5. Following the results in this

Table 4: Estimated cointegrating equation and unit root tests statistics

Period one (4/16/2010-1/31/2011)
Panel A: Cointegrating equation

Coefficient	*Estimated value*	*P value*
a	1.253148***	0.0000
b	0.842978***	0.0000

Panel B: Unit root tests on residuals $\hat{u}_t$

ADF	PP	Critical value (5%)
-2.58	-2.44	–3.34

Period two (12/3/2012-6/28/2013)
Panel A: Cointegrating equation

Coefficient	*Estimated value*	*P value*
a	0.030762***	0.0000
b	0.996148***	0.0000

Panel B: Unit root tests on residuals $\hat{u}_t$

ADF	*PP*	*Critical value (1%)*
-4.12***	-9.07***	–3.90

Period three (10/8/2013-7/31/2014)
Panel A: Cointegrating equation

Coefficient	*Estimated value*	*P value*
a	0.048916***	0.0000
b	0.994016***	0.0000

Panel B: Unit root tests on residuals $\hat{u}_t$

ADF	*PP*	*Critical value (1%)*
-6.22***	-7.27***	–3.90

Notes: The critical value here is not standard t-distributed and is proposed by Engle and Yoo (1987) for the Engle-Granger cointegration test on regression residuals. *** indicates 1% level of significance.

table, in the second period, the null hypothesis of the spot price not Granger causing its futures price cannot be refused at the 5% level. However, the test statistic for the other hypothesis which examining whether futures price leading its underlying spot price is extremely significant at the 1% level. This means that, in the second period, the futures price Granger causes its spot price while the spot price does not Granger cause the corresponding futures price. On the other hand, in the third period, the two null hypotheses are both rejected at 1% significance level, suggesting that CSI 300 index spot price Granger causes the futures price and vice versa. Those results demonstrate that a unidirectional leading relation from spot to futures prices exist in the developing stage of CSI 300 index futures market, which means that futures market acts as a dominated function in the price discovery process. Currently, the lead-lag relation becomes bidirectional and both spot and futures markets perform powerful in term of the price discovery function.

Although the Granger causality test is a good test to find the causal relation between spot and futures prices preliminarily, it cannot provide further explanation or investigation about the details. In addition, the selection of the length of lag in the test is of great importance to influence the test result. For example, the test statistic may be not significant with one lag, but it is possible to be significant with five lags. Here, the lag length of the Granger causality test is chosen by the Akaike information criterion (AIC). However, the Granger causality tests could only provide a rough view of the lead-lag relationship between CSI 300 index price and futures price and further investigation could be done in Johansen's approach and the VECM model.

4.3. Results of Johansen cointegration tests

Johansen cointegration test also requires that the cash and futures prices series are integrated at the same order. The results of Johansen methods for the three periods are showed in Table 6, where means the number of cointegrating vectors. In the Johansen cointegration test, intercept but no trend is assumed in CE and the number of lags is decided thorough Schwarz's Bayesian Information Criterion (SBIC). Specially, the optimal numbers of lags chosen for the three periods are five, five and three respectively.

From Table 6, in the first period, λ_{trace} and λ_{max} statistics are smaller than the related 5% critical values respectively in the first test, indicating that the null hypothesis of no cointegration is not refused significantly. Thus, the spot and futures prices are not able to have equilibrium in the long run during the infancy stage. When it comes to the developing and current stages, the null hypotheses of $r = 0$ in trace tests and maximum eigenvalue tests are significantly rejected at 1% level while the test statistics with null hypotheses of less than one cointegrating vector are larger than the corresponding 5% critical values. This means that cointegrating relation exists in the two prices and the number of cointegrating vector is one. Therefore, those test results show that the cash and futures prices have long-run stable equilibrium relation in the second and third periods but no such cointegration exists in the first period. This conclusion is consistent with what provided by the Engle-Granger approach.

4.4. Construction of VECM

Since one cointegrating vector for spot and futures prices is proved to be present significantly in the developing and current stages, the VECM could be constructed accordingly. The length of lags in the model, which is five in period two and three in period three, is also selected on the basis of SBIC. Tables 7 and 8 illustrate the estimations of VECM in the second and third period respectively. In the second period, Z_{t-1} is estimated to be positive but not significant at 5% level in the regression for ΔS_t. The error correction term Z_{t-1} reflects the effect of previous long-term equilibrium, and the coefficient of Z_{t-1} in the regression of spot price being not significant means that futures price does not lead spot price in the long-term relation. However, test statistics for coefficients of ΔF_{t-i} (i= 1, 2 … 5) are all larger than the critical values at 5% level, suggesting that futures price leads the spot price by all the five lags. Therefore, based on the 5-min data, futures price in the second period is believed to lead its spot price by at least 25 minutes. On the regression for ΔF_t, estimation of Z_{t-1} is not significant either, and none of the coefficients for the lagged differenced spot price is significant at 5% level. This depicts that futures price does not lag to the underlying spot price in the long and short terms.

When it comes to the third period, estimated Z_{t-1} is positive and significant at 1% level in spot price's regression, which means that the adjustment of long-term equilibrium is upward and futures price leads to spot one in the long run. Test statistics of ΔF_{t-1} (17.640) and ΔF_{t-2} (4.2609) are significantly larger than 1% critical value (2.3263) while that of ΔF_{t-3} (0.9061) is smaller than 10% critical value (1.2816), meaning that spot price lags to futures price only two lags, approximately 10 minutes. With respect to the regression of ΔF_t, Z_{t-1} is not significant in the regression but ΔS_{t-1} is significant at 1% level. Therefore, spot price is believed to lead to the associated futures by at least 5 minutes in the short run relation.

In addition, those estimations in Tables 7 and 8 also reflect that the spot and futures price is regressed to their own previous prices by different lags, suggesting the feature of individual dependence.

4.5. Lead-lag relationship analysis

The empirical results from VECM are in accordance to the findings of Granger causality tests. In the first period, no leading or lagging effect is discovered. After about two years developing, short-run leading relation from futures price to its index price is found in the second stage. Currently, bilateral lead-lag relation exists not only in the short but also in the long terms during the third stage, where futures price lead to the spot one stronger than the revers. It is clear that, after two years developing, CSI 300 index futures market becomes to hold the domination in terms of price discovery.

No lead-lag relationship exists in the infancy stage of CSI 300 index futures market. Even more, there is no long-term equilibrium between cash and futures prices (no cointegration). This may be resulted from the immaturity of futures market, which involves low trading frequency and low trading volume specially. In the developing stages, lead-lag relations are significantly discovered from futures price to the spot one. Lead-lag relation between CSI 300 stock index spot price and its futures prices indicates new information flowing with different speed in the two markets. Chan (1992) proves that one interpretable reason for this unidirectional leading relation that short selling is less restricted in index futures market. Jiang *et al.* (2012) also suggest that it is rational for futures price leading to spot price because of the less restriction of short selling in index futures market and higher trading frequency accordingly. In addition, this leading relation is suggested to disappear after eliminating the effects from short sale and different trading frequency (Shyy *et al.*, 1996), which proves the natural leading from futures to spot price. Therefore, index futures price tends to be used to forecast spot price in terms of managing risk, making hedge and arbitrage. It is possible for arbitragers to make profits, particular in the second period, since the leading gap is at least 25 minutes. In the third period, in addition to the futures-to-spot lead-lag relation, a leading effect from spot price to futures price is also found, although it is weaker than the former one.

As illustrated in Figure 1, spot and futures prices are stable in the second period but fluctuate in the third period. Since a bidirectional lead-lag relation is discovered rather than a unidirectional relation in the third period, it may indicate that with a huge volatility, information could disseminate not only from futures market to spot market but also reverse. The interaction between the two related markets may become mutual in an unstable period but the leading power of futures price is still stronger than that of spot price.

4.6. Results of GARCH-BEKK model

As mentioned in the methodology section, the matrix H_t in a BEKK-GARCH (1,1) model describes the volatility spillovers between spot index and its futures markets. Parameters in matrix A represent the term to which past shocks affect current variance and parameters in matrix B depict the degree of volatility association and persistence.

Table 9 demonstrates the estimations of those elements in the variance equation. Table 10 presents the Wald test statistics. Apparently, the diagonal parameters of matrices

A and B (a_{ss}, a_{ff}, b_{ss} and b_{ff}) in the three periods are all statistically significant at 1% level except a_{ff} in the third period. Therefore, in the first and second periods, current volatilities of cash and futures returns would be influenced not only by previous information shock happened in their own markets, but also by historical volatilities attributed to their own. Whiles, in the third period, conditional variance of futures return is not related to its past innovations but other characteristics are same with first and second periods. When it comes to the off-diagonal elements in matrices, a_{sf}, a_{fs}, b_{sf} and a_{fs} included, they are all not zero at 1% significance level, which indicates that bidirectional volatility spillovers between index cash and associated futures returns are found in all three periods. Specially, in the first period, the absolute values of a_{sf} (0.47091) and b_{sf} (-0.31239) are larger than a_{fs} (-0.38669) and b_{fs} (0.19921) respectively, reflecting that shocks transmits more quickly and the volatility remains more robustly from spot return to the corresponding futures return than reverse. This means that the bidirectional volatility spillover is strong from spot to futures market. Oppositely, the absolute values of a_{sf} (-0.38819) and b_{sf} (0.40959) are smaller than a_{fs} (0.41295) and b_{fs} (-0.58842) respectively in the second period, which means that volatility spills more powerful from futures to the underlying spot markets than from spot to futures ones. In the third period, the difference between the absolute values of estimated a_{sf} (a_{fs}) and b_{sf} (b_{fs}) is smaller than 0.05. It demonstrates that - although the effects of previous shock and volatility linkage are discovered to hold differential strength with respects to spilling directions - the differences of strength are too small compared to those in the previous periods.

Apart from the comparison of the magnitude of the volatility spillovers, it can also be demonstrated that such a power is variable in different periods. The average absolute values of off-diagonal coefficients of matrices A and B in the second period tend to the largest among the three periods and those in the third period tend to be the smallest. This reflects that volatility spills most profoundly in the developing stage and least profoundly in current period between the cash and futures returns.

Table 5: Granger causality tests

Period two (12/3/2012-6/28/2013)		Period three (10/8/2013-7/31/2014)	
Panel A: $H_0 : S_t$ does not Granger cause F_t			
F-Statistic	P value	F-Statistic	P value
1.63159*	0.0577	1.99384***	9.E-05
Panel B: $H_0 : F_t$ does not Granger cause S_t			
F-Statistic	P value	F-Statistic	P value
31.1452***	1.E-87	10.6113***	1.E-71

Notes: * and *** indicate the 10% and 1% level of significance respectively.

Table 6: Johansen cointegration tests results

	Null	*Alternative*	*Test statistics*	*Critical value (5%)*
Period one (4/16/2010-1/31/2011)				
Trace test	r = 0	r > 0	9.5425	15.494
	r ≤ 1	r > 1	2.9088	3.8414
Maximum	r = 0	r = 1	6.6336	14.264
eigenvalue test	r = 1	r = 2	2.9088	3.8414
Period two (12/3/2012-6/28/2013)				
Trace test	r = 0	r > 0	24.761***	15.494
	r ≤ 1	r > 1	1.4193	3.8414
Maximum	r = 0	r = 1	23.342***	14.264
eigenvalue test	r = 1	r = 2	1.4193	3.8414
Period three (10/8/2013-7/31/2014)				
Trace test	r = 0	r > 0	55.839***	15.494
	r ≤ 1	r > 1	3.0405	3.8414
Maximum	r = 0	r = 1	52.798***	14.264
eigenvalue test	r = 1	r = 2	3.0405	3.8414

Notes: *** indicates 1% level of significance.

Table 7: Vector error correction model estimates in the second period

Dependent variable	ΔS_t	*T-test statistics*	ΔF_t	*T-test statistics*
Z_{t-1}	0.0070*	1.5069	-0.0045	-0.8639
ΔS_{t-1}	-0.3665***	-16.665	0.0118	0.4752
ΔS_{t-2}	-0.1437***	-6.1414	0.0434*	1.6360
ΔS_{t-3}	-0.0624***	-2.6511	0.0423*	1.5855
ΔS_{t-4}	-0.0653***	-2.8334	-0.0131	-0.5030
ΔS_{t-5}	-0.0279*	-1.3773	0.0097	0.4218
ΔF_{t-1}	0.4032***	20.672	-0.0573***	-2.5947
ΔF_{t-2}	0.1817***	8.3564	-0.0313	-1.2693
ΔF_{t-3}	0.0906***	4.1066	-0.0222	-0.8898
ΔF_{t-4}	0.0470**	2.1687	-0.0227	-0.9229
ΔF_{t-5}	0.0335**	1.7246	-0.0018	-0.0843

Notes: *, ** and *** indicate 10%, 5% and 1% level of significance respectively. The critical value for t-test statistics are 1.2816, 1.6449 and 2.3263 at 10%, 5% and 1% level of significance respectively.

Table 8: Vector error correction model estimates in the third period

Dependent variable	ΔS_t	*T-test statistics*	ΔF_t	*T-test statistics*
Z_{t-1}	0.0110***	3.7508	-0.0028	-0.8332
ΔS_{t-1}	-0.2883***	-17.333	0.0538***	2.8283
ΔS_{t-2}	-0.1053***	-6.0660	0.0084	0.4271
ΔS_{t-3}	0.0143	0.8723	0.0266*	1.4160
ΔF_{t-1}	0.2579***	17.640	-0.0442***	-2.6447
ΔF_{t-2}	0.0651***	4.2609	-0.0500***	-2.8601
ΔF_{t-3}	0.0133	0.9061	-0.0098	-0.5848

Notes: *, ** and *** indicate 10%, 5% and 1% level of significance respectively. The critical value for t-test statistics are 1.2816, 1.6449 and 2.3263 at 10%, 5% and 1% level of significance respectively.

Table 9: Estimations of the variance equation in GARCH-BEKK model

	Period one	*Period two*	*Period three*
c_{ss}	0.00071***	0.00067***	0.00028***
c_{fs}	0.00054***	0.00075***	0.00042***
c_{ff}	-0.00000	0.00000	-0.00000
a_{ss}	-0.39599***	0.53199***	0.52438***
a_{sf}	0.47091***	-0.38819***	-0.29021***
a_{fs}	-0.38669***	0.41295***	0.26342***
a_{ff}	0.58519***	-0.15378***	0.01802
b_{ss}	1.07560***	0.45815***	0.76638***
b_{sf}	-0.31239***	0.40959***	0.19292***
b_{fs}	0.19921***	-0.58842***	-0.23809***
b_{ff}	0.76270***	1.31641***	1.12811***

Notes: *** indicates 1% level of significance.

Table 10: Test statistics of Wald test

First period		*Second period*		*Third period*	
Chi-Square	*F-statistic*	*Chi-Square*	*F-statistic*	*Chi-Square*	*F-statistic*
Hypothesis 1: $H_0 : a_{fs} = b_{fs} = 0$					
3046.3***	1523.1***	414.51***	207.25***	1286.3***	643.19***
Hypothesis 2: $H_0 : a_{sf} = b_{sf} = 0$					
3926.5***	1963.2***	344.86***	172.43***	890.43***	445.21***
Hypothesis 3: $H_0 : a_{fs} = b_{fs} = a_{sf} = b_{sf} = 0$					
7053.4***	1763.3***	439.58***	109.89***	1357.7***	339.43***

Notes: *** indicates 1% level of significance.

4.7. Volatility spillovers effects analysis

Therefore, bidirectional volatility spillovers significantly exist according to the results of GARCH-BEKK model. To make such results more robust, Wald tests are utilized to jointly examine the presence of volatility spillovers. The Chi-Square statistics and F-statistics are showed in Table 10. The three null hypotheses mean no volatility spilling from futures return to spot return, no volatility spilling from spot return to futures return and no volatility spillover between the two returns respectively. It is obvious that the statistics for the three hypotheses tests are significant at 1% level in the three stages, suggesting the rejections of all the null hypotheses. Therefore, bilateral volatility spillovers effects are proved to perform between cash and futures markets robustly. This result verifies the visual analysis based on the coefficient estimations of GARCH-BEKK model.

According to the results of GARCH-BEKK model and the Wald tests, the strengths and directions of the volatility spillovers effects in the three periods could be seen clearly. Bidirectional volatility spilling effects reflect that the mutual information flowing while the differential strengths of such effect with respect to the spillover direction indicate the differences of information dissemination in spot and futures markets. In the infancy stage of CSI 300 index futures market, it is proved that the volatility spills from spot returns to its futures returns more strongly than the volatility spills from futures returns to the spot one. On the contrary, index futures return contributes more to the volatility spillover effect than the spot return dose, i.e. more profound volatility spilling from futures to cash price than the reverse in the developing stage. Currently, the power degrees of volatility spillover effect from futures return to spot return and that in the opposite direction are similar.

Compared to the first moment dynamic relations (lead-lag relations) between the two markets, the second ones (volatility spillovers effects) produce similar demonstration for the information flowing. The information transmissions between CSI 300 index spot and futures markets are proved to be bidirectional and asymmetric in the three periods. Specifically, the dissemination of new information in the index spot market produces higher efficiency than the futures market in the first period, while the index futures return tends to reflect news more quickly than its spot index return in the second period. It is worth to note that a significant spot-to-futures volatility spillover effect is discovered in the first period but no lead-lag relationship between futures and spot prices is found. It suggests that volatilities association tends to be stronger and more robust than price lead-lag relation, even when no price lead or lag relation exists between the two markets (Chan *et al.*, 1991).

In the infancy stage of CSI 300 index futures market, the futures market does not play the dominated function well in term of price discovery and volatility forecast. However, in the second period, when the futures market has been developed for few years, index futures market is proved to lead its corresponding spot market with respects to both price lead-lag relation and volatility spillover. This means that the efficiency of information dissemination in futures market increases as the market develops. Min and Najand (1999) states that the trading volume is demonstrated to be able to explain the information flowing in term of the volatility of market. The average trading volume of the CSI 300 index futures in the first period is extremely small compared to that of the spot index, since the futures market is newly established. Thus, it may result the strong volatility spillovers effect from spot to futures market and the weak one with inverse direction in the infancy stage of futures market. When it comes to the second period and the third period, the gaps between the volume of spot index and that of the futures become smaller than that in the infancy stage. In addition, the magnitude of gap in the second period is the smallest, which may interpret why the bidirectional volatility spillovers effect turns out to be profound from futures to spot market than the reverse in the developing stage of CSI 300 index futures market. However, in current period, the leading role of futures market becomes not significant. In other words, the two markets tend to be equally interacted in the third period, when the magnitude of the fluctuation of price is extremely large.

5. CONCLUSION

This paper investigates the dynamic relationship between the Chinese CSI 300 stock index futures and the underlying spot markets to find how the new information disseminates in three different periods. The dynamic relationship could provide profit suggestions for investors in terms of managing risks and choosing trading strategies. Two aspects of the dynamic relation reflect the information transmission, which are lead-lag relationships of the two prices and the volatility spillovers effects between the two returns. Intraday index price and its futures contract price in current month are collected at every five minutes as the examined data. The first moment dynamic relation between the two prices, lead or lag effect, is detected through Engle and Granger's cointegration test (Engle and Granger, 1987) and Johansen cointegration test (Johansen, 1988). In addition, the Granger causality test (Granger, 1969) is used to show the price causal relation intuitionally and the construction of VECM describes the lead-lag relation in detail. The volatility spillovers effect between the returns of the spot and futures markets, i.e. the second moment dynamic relationship, is reflected by the GARCH-BEKK model (Engle and Kroner, 1995), which could capture both the short-term and long-term dynamics. Four major findings are obtained in this paper.

Firstly, in the infancy stage of the CSI 300 index futures market, no leading or lagging effect is discovered. After about two years developing, short-run leading relation from futures price to spot price is found in the second period by about 25 minutes. Currently, bilateral lead-lag relation exists both in the short term and long term in the third period, where futures price lead to the spot one (10 minutes) stronger than the revers (5 minutes). It is clear that, after two years developing, CSI 300 index futures market becomes to play the dominate role in terms of price discovery. This is consistent with many previous literatures which show the unidirectional leading effect from futures to spot prices or the stronger leading effect of futures price in the bidirectional lead-lag relation. Secondly, bidirectional volatility spillovers effects are discovered in all the three periods. Specifically, the spilling power is stronger from spot market to futures market than the reverse in the infancy stage, while the volatility spills from futures market to the spot more profoundly in the second period. In the current period, the strengths of two direction's spilling effects are similar. Those results are in accordance with many prevenient researches such as those done by Chan *et al.* (1991), Kuo *et al.* (2008) and Kang *et al.* (2013), and it is indicated that the information not only transmits from futures market to cash market, but also transmit in the opposite direction.

Thirdly, the individual dependences are discovered between the spot and futures prices in the three periods. Moreover, the volatility of spot or futures market is dependent to its own previous values and the past shocks in the three periods, except that the historical shocks in the futures market not affect the current volatility of futures market in the third period. It means that the mean and variance of spot and futures prices (returns) are not only mutual affected but also individual influenced.

Fourthly, the results of the price lead-lag relations and volatility spillovers effects suggest that, the futures market dominates the spot market in the second period, but does not in the infancy stage and less significantly in the present stage. This implies that during the infancy period of the CSI 300 index futures market, it is not able to predict either spot or futures market according to another one. However, after few years' development, it is possible to hedge the risk and make arbitrage based on the investigated lead-lag relation from futures market to spot market. It is worth noting that the dominate role of futures market becomes less significant in the current fluctuated period, suggesting that the CSI 300 index futures market is still not perfect mature.

REFERENCE

Bollerslev, T. (1986). Generalized autoregressive conditional heteroskedasticity. *Journal of econometrics*, *31*(3), 307-327.

Cao, G., Han, Y., Cui, W., & Guo, Y. (2014). Multifractal detrended cross-correlations between the CSI 300 index futures and the spot markets based on high-frequency data. *Physica A: Statistical Mechanics and its Applications*,*414*, 308-320.

Chan, K. (1992). A further analysis of the lead-lag relationship between the cash market and stock index futures market. *Review of financial studies*, *5*(1), 123-152.

Chan, K., Chan, K. C., & Karolyi, G. A. (1991). Intraday volatility in the stock index and stock index futures markets. *Review of Financial Studies*, *4*(4), 657-684.

Chen, Y. L., & Gau, Y. F. (2009). Tick sizes and relative rates of price discovery in stock, futures, and options markets: Evidence from the Taiwan Stock Exchange. *Journal of Futures Markets*, *29*(1), 74-93.

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American statistical association*, *74*(366a), 427-431.

Drimbetas, E., Sariannidis, N., & Porfiris, N. (2007). The effect of derivatives trading on volatility of the underlying asset: evidence from the Greek stock market. *Applied Financial Economics*, *17*(2), 139-148.

Engle, R. F. (1982). Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom inflation. *Econometrica: Journal of the Econometric Society*, 987-1007.

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica: journal of the Econometric Society*, 251-276.

Engle, R. F., & Kroner, K. F. (1995). Multivariate simultaneous generalized ARCH. *Econometric theory, 11(01),* 122-150.

Green, C. J., & Joujon, E. (2000). Unified tests of causality and cost of carry: the pricing of the French stock index futures contract. *International Journal of Finance & Economics*, *5*(2), 121.

Jin, F., & Yang, J. (2013). Volatility spillovers between the stock index futures and its underlying spot market in China. *International Conference on Management Science & Engineering* (20th), 1627-1632.

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of economic dynamics and control*, *12*(2), 231-254.

Kwiatkowski, D.; Phillips, P. C. B.; Schmidt, P.; Shin, Y. (1992), "Testing the null hypothesis of stationarity against the alternative of a unit root", *Journal of Econometrics*, **54.**

Phillips, P. C. B.; Perron, P. (1988), "Testing for a Unit Root in Time Series Regression", *Biometrika*. **75** (2): 335–346.

Shyy, G., Vijayraghavan, V., & Scott Quinn, B. (1996). A further investigation of the lead lag relationship between the cash market and stock index futures market with the use of bid/ask quotes: The case of France. *Journal of Futures Markets*, *16*(4), 405-420.

So, R. W., & Tse, Y. (2004). Price discovery in the Hang Seng index markets: index, futures, and the tracker fund. *Journal of Futures Markets*, *24*(9), 887-907.

Stoll, H. R., & Whaley, R. E. (1990). The dynamics of stock index and stock index futures returns. *Journal of Financial and Quantitative Analysis*, *25*(04), 441-468.

Tao, J., & Green, C. J. (2012). Asymmetries, causality and correlation between FTSE100 spot and futures: A DCC-TGARCH-M analysis. *International Review of Financial Analysis*, *24*, 26-37.

Tse, Y. (1999). Price discovery and volatility spillovers in the DJIA index and futures markets. *Journal of Futures markets*, *19*(8), 911-930.

Verousis, T., O. Gwilym & X. Chen (2015). The intraday determination of liquidity in the NYSE LIFFE equity option markets. *European Journal of Finance,* 1164-1188.

Yang, J., Yang, Z., & Zhou, Y. (2012). Intraday price discovery and volatility transmission in stock index and stock index futures markets: Evidence from China. *Journal of Futures Markets, 32(2)*, 99-121.

Zhao, H. (2010). Dynamic relationship between exchange rate and stock price: Evidence from China. *Research in International Business and Finance*, *24*(2), 103-112.

Zhong, M., Darrat, A. F., & Otero, R. (2004). Price discovery and volatility spillovers in index futures markets: Some evidence from Mexico. *Journal of Banking & Finance*, *28*(12), 3037-3054.

Zhou, B., & Wu, C. (2015) Intraday dynamic relationships between CSI 300 index futures and spot markets: a high-frequency analysis. *Neural Computing and Applications*, 1-11.

Zhou, Z., Dong, H., & Wang, S. (2014). Intraday Volatility Spillovers between Index Futures and Spot Market: Evidence from China. *Procedia Computer Science*, *31*, 721-730.

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