Price Discovery in the Chinese Gold Market

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6 May 2016

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May 2016

[1] Acknowledgement: We are grateful to Péter Erdős, Xuezhong He, Fearghal Kearney, and Alexander Mende for providing helpful comments. Youwei Li acknowledges the support of National Natural Science Foundation of China (no. 71571197).

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Abstract

This study conducts price discovery analysis in the Chinese gold market. Our result indicates that the price discovery in Chinese gold market occurs predominantly in the futures market. The result is robust to the different measures of price discovery, namely information share, component share, and information leadership share. Partitioning the daily trades into three trading sessions, we find that the dominance of the futures market occurs in all trading sessions. We further investigate the sequential price discovery within the spot market or futures market. We find that the price discovery of gold spot market and gold futures market occur in the night trading session.

JEL: G10, G14

Keywords: Chinese gold market; Futures; Price discovery; Information share; Component share; Information leadership share; Sequential price discovery.

1. INTRODUCTION

This study investigates the price discovery for gold in China on two informationally linked markets – the spot market and the futures market. The gold spot market in China started in 2002 when Shanghai Gold Exchange was established. The gold futures market was established in 2008 at the Shanghai Futures Exchange. According to Lucey et al. (2013), the trading volume of gold contracts and its derivatives in China is ranked third largest in the world. The consumption of gold as well as the demands for investing and hedging in gold related products is growing rapidly in China due to the pace of underlying economic development. Moreover, according to the U.S. Geological Survey (2012), China is the world dominant gold producer with proven reserves that are ranked third in the world. The gold market in China is becoming more important and is of interest for investors and researchers. Lucey et al. (2014) find that the gold market in China is very disconnected from the other markets with negligible effect on or from other markets. This special characteristic makes the price discovery of gold within China an important topic.

Price discovery refers to efficient and timely incorporation of information into market prices through trading. If the price discovery process is timely and effective, then the market would be efficient (Fama, 1970). In an efficient market, prices reflect new information quickly and adequately (Lehman, 2002). In case of similar or related products traded at different markets, new information could affect these markets simultaneously. For instance, when gold contracts are traded in spot and futures markets in parallel, the price discovery can be defined as which price series is the first to fully reflect new information about the true underlying asset value. In short, price discovery studies attempt to answer the following questions: “Which gold market moves first?” and “Which gold product moves closer to the intrinsic value?”

We use three measures to study the parallel price discovery between the gold spot market and the gold futures market. The first measure is information share derived by Hasbrouck (1995). He uses the variance of the common factors innovation uncovered from a Vector Error Correction Model (VECM) to define price discovery. It measures the price variation contributed by different markets, with the proportion contributed by each market being defined as information share. The second measure is the component share measure proposed by Gonzalo and Granger (1995). Component share measures the contribution to the common factor by each market, where contribution is defined as a function of market error correction coefficients. The market error coefficients are obtained from the vector error correction model capturing only permanent shocks in asset price. Lucey et al. (2013) use both information share and component share in the study. The third measure, information leadership share, is proposed by Putniņš (2013) as an adaptation to the measures outlined in Yan and Zivot (2010). He finds that information share responds to both permanent and transitory shocks, while component share capture the transitory shocks. He suggests a new measure, information leadership share, by combining information share and component share measures and the new measure captures only the permanent shocks on the asset price. Hauptfleisch et al. (2015) use Putniņš (2013) information leadership share to confirm that New York leads the other financial centers in terms of gold price discovery. This exhibits the contrasting inferences drawn from using the unmodified Gonzalo and Granger (1995) and Hasbrouck (1995) that led to Lucey et al. (2013) concluding that in fact London was the dominant center in terms of gold price discovery.

Besides conducting parallel price discovery on gold spot and futures markets, we also carry out price discovery analysis across morning, afternoon, and night sessions of a trading day; sequential price discovery within gold spot and gold futures market. We employ three measures to compare the price discovery across trading sessions. The first sequential price discovery measure is variance ratio between two-scale realized variance and realized variance (TSRV/RV) proposed by Wang and Yang (2011). Intuitively, TSRV is a variance that is induced by pure information while RV captures both variances caused by information and microstructure noise. Therefore, the ratio TSRV/RV provides a measure for the price efficiency of a trading session. The second measure is a modified information share measure also proposed by Wang and Yang (2011). The information share of a particular trading session is its share of the total variance of the efficient price for the full trading day. The third measure for the sequential price discovery is weighted price contribution (WPC). WPC is a simple and convenient measure that uses the share of price change in different trading sessions to measure the level of efficient information, see, for example, Cao et al. (2000).

Our results show that the price discovery in Chinese gold occurs predominantly in the futures market. Using information share as the measure of price discovery, we find that 44.47% of price variation is contributed by the spot market while 55.53% is contributed by the futures market. This result is consistent across all of the three trading sessions. However, the result derived from the component share is more mixed. The overall component share is marginally higher in the spot market, but the result varies among the trading sessions. The result provided by information leadership share is very much similar to those provided by information share. On average, the information leadership share is 38.30% in the spot market and 61.70% in the futures market. The result is also consistent throughout the trading sessions. The overall result is consistent with prior price discovery studies on spot and derivative markets. Chan (1992) and Kawaller et al. (1987) report that S&P 500 index futures price changes lead those on spot market. One popular explanation of the dominance role of futures market is the higher liquidity and lower cost of trading compared to those of spot market. In our sample, the number of trades and trading volume in gold futures market is more than four time of those in the spot market. This seems also supported by the argument that different investors focus on different markets. For instance, that spot gold is predominantly used by slower moving longer-term investors seeking safe haven assets, whereas the futures market predominantly comprises faster moving speculative investors.

For sequential price discovery, we find that the spot market is more efficient in the afternoon trading session but overall price change or price contribution occur more in the night trading session. For the futures market, the market is more efficient in the morning trading session, and the price discovery occurs more in the night trading session. However, the price contribution for the futures market happens more in the morning trading session. The conclusions made from the three measures are not necessarily consistent because these three measures capture different aspects of price discovery.

The rest of the paper is organized as follows. In Section 2, we present the measures of price discovery and detail the econometric methods employed in the paper. Section 3 is devoted to the description and summary statistics of the data used in our study. We present our main findings in Section 4, and Section 5 concludes.

2. PRICE DISCOVERY METHODOLOGY

2.1 Information share Method

We model the dynamic relation between spot price and futures price series using Vector Error Correction Model (VECM). If the spot price and futures price are two cointegrated $I(1)$ price series, the price system can be modeled by the following VECM:

$$\Delta\begin{pmatrix} F_t \\ S_t \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix} + \alpha\beta'\begin{pmatrix} F_{t-1} \\ S_{t-1} \end{pmatrix} + \sum_{i=1}^{k}\Gamma_i\begin{pmatrix} \Delta F_{t-i} \\ \Delta S_{t-i} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{pmatrix}, \tag{1}$$

where ΔS_t and ΔF_t are the log returns of spot and futures markets, α is the error correction vector which measures the speed of adjustment, β is the cointegrating vector $(1,-1)'$, Γ is the common factor coefficient vector, e_t is a zero-mean vector of serially uncorrelated innovation with the following correlation matrix:

$$\Omega = \begin{pmatrix} \sigma_1^2 & \rho\sigma_1\sigma_2 \\ \rho\sigma_1\sigma_2 & \sigma_2^2 \end{pmatrix}. \tag{2}$$

The VECM has two components. The first component, $\alpha\beta'\begin{pmatrix} F_{t-1} \\ S_{t-1} \end{pmatrix}$, represents the long-run equilibrium between spot and futures prices. The second component, $\sum_{i=1}^{k}\Gamma_i\begin{pmatrix} F_{t-i} \\ S_{t-i} \end{pmatrix}$ captures the short-run dynamics induced by market shocks.

Hasbrouck (1995) measures price discovery as a variance that is generated by information shocks on the common factors. It focuses on the relative contribution of the price movement to total price variance in the respective markets. The market with the larger contribution to the total price variation plays a dominant role in the price discovery process. Following the notion of Hasbrouck (1995), the market with higher information share (IS) moves the price upon an information shock. Eq. (1) can be expressed in a vector moving average (VMA) form:

$$\Delta Y_t = \Psi(\mathrm{L})\,\mathrm{e}_t, \tag{3}$$

and its integrated form is:

$$Y_t = \Psi(1)\sum_{s=1}^{t}\mathrm{e}_s + \Psi^*(L)\,\mathrm{e}_t, \tag{4}$$

where Y_t is $\left(F_t, S_t\right)'$, $\Psi(L)$ and $\Psi^*(L)$ are matrix polynomials in the lag operator, L. $\Psi(1)$ is the impact matrix that is the sum of the moving average coefficients. $\Psi(1)e_t$ is the long-run effect of an information shocks on each of the prices. The weighted variance of each of the market is used to determine the price discovery. Specifically, Hasbrouck (1995) derives the information share (*IS*) of the respective markets as:

$$IS_i = \frac{\Psi_i^2\sigma_i^2}{\Psi\Omega\Psi'}, \tag{5}$$

where *i* represents the distinct markets (spot market or futures market). Under the condition of no correlation between the innovations of both markets, the covariance matrix Ω is diagonal. As a result, the contribution of the innovations on one market to the total variance can be simplified as in Eq. (6).

$$IS_i = \frac{\gamma_i^2\sigma_i^2}{\gamma_1^2\sigma_1^2 + \gamma_2^2\sigma_2^2}, \mathrm{i} = 1, 2, \tag{6}$$

γ_i measures the contribution that each market has to total innovation.

2.2 Component Share Method

The component share (*CS*) is based on Gonzalo and Grangers' (1995) permanent-transitory decomposition. The approach focuses on the components of the common factor and the error correction process. The *CS* measures the contribution to the common factor by each of the market, where contribution is defined as a function of market error correction coefficients. From the VECM system defined in Eq. (1), the two-dimensional cointegrating vector $Y_t = (F_t, S_t)'$ can be decomposed as:

$$Y_t = Af_t + g_t, \tag{7}$$

where A is a loading matrix, f_t is the common factor, g_t is the transitory component that does not have a permanent impact on Y_t. Furthermore, Gonzalo and Granger (1995) define common factor f_t as $\alpha'_\perp$. In a two-variable system, we assume $\alpha_\perp = (\gamma_1, \gamma_2)$ or the contribution of each market to the price discovery is defined as its weights to the common factor. Base on $\gamma_1\alpha_1 + \gamma_1\alpha_2 = 0$ and $\gamma_1 + \gamma_2 = 1$, the component share of the two markers is:

$$\gamma_1 = \frac{\alpha_2}{\alpha_2 - \alpha_1} \text{ and } \gamma_2 = \frac{\alpha_1}{\alpha_1 - \alpha_2}. \tag{8}$$

According to Cabrera et al. (2009), the *CS* equation does not restrict the factor weight to be positive. They propose an adjusted *CS* equation to restrict the factor weights to be positive. In the case of two markets, the *CS* of two markets is as follow:

$$CS_1 = \frac{|\gamma_1|}{|\gamma_1| + |\gamma_2|} \text{ and } CS_2 = \frac{|\gamma_2|}{|\gamma_1| + |\gamma_2|}. \tag{9}$$

2.3 Information Leadership share Method

Yan and Zivot (2010) use a structural model to analyze the responses of *IS* and *CS* to permanent and transitory shocks. They find that *CS* can only be explained by transitory shocks, while *IS* can be explained by permanent and transitory shocks. They propose a new measure by combining *IS* and *CS* that capture the pure permanent shocks. The information leadership[2] (*IL*) metric is defined as:

$$IL_1 = \left[\frac{IS_1}{IS_2}\frac{CS_2}{CS_1}\right] \text{ and } \mathrm{IL}_2 = \left[\frac{IS_2}{IS_1}\frac{CS_1}{CS_2}\right]. \tag{10}$$

[2] The term "information leadership share" developed in Yan and Zivot (2010) is coined by Putniņš (2013).

Unlike *IS* and *CS*, the *IL* is not a share measure that sum up to 1. Putniņš (2013) generalizes Yan and Zivot (2010) measure and define a model-free measure of information leadership share (*ILS*) that is more comparable to IS and CS because all the shares are summed to 1.

$$ILS_1 = \frac{IL_1}{IL_1 + IL_2} \text{ and } \mathrm{IL}S_2 = \frac{IL_2}{IL_1 + IL_2}. \tag{11}$$

Yan and Zivot (2010) assume that the price series fluctuates because of two important reasons; noise in the information environment and the speed of adjustment in response to the new information. Putniņš (2013) compares *IS*, *CS*, and *ILS* measures by a simulated series. Specifically, he studies the impact of different levels of noise and different speed of adjustment to new information on the three price discovery measures. The result of Putniņš (2013) shows that only *ILS* accurately measures which price series moves faster. *IS* and *CS* measures can accurately measure price discovery only when the two price series have similar level of noise.

2.4 Sequential Price Discovery Measures

We not only study the parallel price discovery process across the spot and future markets, but also carry out analysis on the sequential price discovery process for the spot and futures markets. There are three trading sessions in a trading day of Chinese gold market: Morning, Afternoon, and Night trading sessions. We examine the session-specific contribution to price discovery in sequential (i.e. non-overlapping) trading sessions. We utilize three sequential price discovery measures in our analysis: (1) variance ratio or TSRV/RV, (2) sequential information share, and (3) weighted price contribution or WPC.

The first measure of sequential price discovery is variance ratio between two-scale realized variance and realized variance (TSRV/RV) proposed by Wang and Yang (2011). Two-scale realized variance presented in Eq. (12) is a consistent estimator of the integrated variance proposed by Zhang et al. (2005). It measures the price variance induced purely by the information flow. On the other hand, the realized variance (RV) measures the price variance contributed not only by information, but also microstructure noise. The ratio TSRV/RV provides a measure for the price efficiency of a trading session.

$$TSRV = \frac{1}{k}\sum_{j=1}^{k} RV_{5min,j} - \frac{m-k+1}{m \times k} RV_{1min} \tag{12}$$

In Eq. (12), RV_{1min} is the realized variance based on 1-minute returns. $RV_{5min,j}$ is the realized variance based on 5-minute returns. $RV_{5min,j}$ is the 5-minute realized volatility starting from the beginning of the *j*-th 1-minute interval. $k=5$ is the number of sub-observations (1-minute) in the sub-grid interval (5-minutes), and *m* is total number of 1-mimutes observations in a trading session

Wang and Yang (2011) also propose an alternate measure to analyze the sequential price discovery. Their rationale is the same as Hasbrouck's (1995) information share. The information share of a particular trading session is its share of the total variance of the efficient price in a trading day. They use two-scale realized variance (TSRV) to measure of information flow and estimate the information share across sequential trading sessions. Specifically, in our application of three trading session. We estimate the TSRV in all three trading session within a trading day, then we compute the information share of a specific session as follows:

$$IS(TSRV)_i = \frac{TSRV_i}{TSRV_1 + TSRV_2 + TSRV_3}, i = 1, 2, 3, \tag{13}$$

where *i* represent one of the three trading sessions within a trading day.

We employ WPC as the third sequential price discovery measure. WPC is the weighted price contribution of trading session *i* to daily price change and is widely used in conducting sequential price discovery analysis. For example, Cao et al. (2000) adopt it to conduct price discovery during the preopening period for NASDAQ. It is determined as:

$$WPC_i = \sum_{t=1}^{T} \left(\frac{r_{i,t}}{r_t} \right) \times \left(\frac{|r_t|}{\sum_{s=1}^{T} |r_s|} \right), \tag{14}$$

where $r_{i,t}$ is the log return during trading session *i* on day *t*. r_t is the overall daily return. There are three trading sessions (i.e. *i=1, 2, 3*) in each trading day in our study. The first term in parentheses is the relative contribution of the return for period *i* on day *t* to the return on day *t*, the second term in parentheses is the weighting factor for each day.

3. DATA DESCRIPTION

3.1 Gold Market in China

There are three markets in China for gold contract transaction: spot market, futures market, and OTC market. Despite being very new, the Shanghai Gold Exchange and Shanghai Futures Exchange is now the sixth and third largest hub for gold spot and futures trading worldwide. One special characteristics of gold market in China is that it is disconnected from other major gold markets. Using spillover index developed by Diebold and Yilmaz (2009) to investigate the level of integration among gold markets in London, New York, Tokyo, and Shanghai, Lucey et al. (2014) confirm that Shanghai is isolated both in term of gold price volatility and gold price return spillover. O'Connor et al. (2015) give an excellent literature review on gold as an investment.

The Shanghai Gold Exchange (SGE), the gold spot market in China, was officially established in October 2002 and it has 166 members as of October 2013. The members include domestic commercial banks, foreign financial institutions, gold production and smelting institutions, and other major gold consumption and investment firms. The total gold trading volume at the SGE was 11,614 tons in 2013, a sharp increase of 83% from the previous year. The physical delivery of gold spot contract is 38% of the trading volume. SGE is the main channel of physical gold supply. There are eight types of contracts traded on SGE, but some types of contracts have low trading activity. The dominant contract in the SGE is AU (T+D) which is a delayed gold spot contract. T+D indicates that the physical delivery of gold is delayed by D days after the transaction day. In 2013, the traded volume of AU (T+D) contract was 6,695 tons, which contributes to 58% of all gold spot contracted transacted on the SGE. The key features of AU

(T+D) are summarized in Table A.2 in the Appendix. In this study, we use AU (T+D) to represent gold spot contract in China.

Gold futures contracts trading in the Shanghai Futures Exchange (SFE) was established in January 2008. According to Futures Industry Association report by Acworth (2014), the gold futures trading volume in China increased from 3.9 million lots in 2008 to 20 million lots in 2013. In July 5, 2013, SFE starts night trading session for the gold futures contracts. The physical delivery of contract is only 0.02% of the total trading volume. The total trading volume in 2013 is 20,900 tons; SFE is the world second largest gold futures market after New York Mercantile Exchange (see Table A.1 in the Appendix). Contrary to the spot market which is used mainly as a market for physical gold trading, the futures market is served as a market for risk management. The key features of gold futures contracts are summarized in Table A.2 in the Appendix.

The over-the-counter (OTC) market for gold trading in China was established in May 2002. It is participated in predominantly by the commercial banks. The contracts traded include physical gold, account gold, gold loan, and gold derivatives. The total trading volume in the OTC market was 4,500 tons in 2013. The combined trading volume of all three gold trading platforms in China (SGE, SFE, and OTC) exceeded 35,000 tons in 2013. China is the third largest gold trading market around the world; it is ranked just behind the UK and the US. While it is unlikely that China will overtake the UK and the US in the near future, gold trading in China is fast growing and is getting more attention. For these reasons, we believe that the study of gold trading market mechanism including price discovery of the gold market in China is of interest to readers.

3.2 Data and Sample Selection

The data of spot and futures trading is the tick-by-tick records that includes time, price, volume, and open interest. All transactions are recorded in the data except the call auction periods that are before the market opening and after the market closing. The sample period of the data used in the study is from January 4, 2012 to October 18, 2013 which consists of 429 trading days. The data is obtained from the trading trial of Shanghai Gold Exchange and Shanghai Futures Exchange.[3]

The trading hours for gold spot is 9:00-11:30, 13:30-15:30, and 21:00-2:30 on Monday to Friday except there is no night trading on Friday. The trading hours for gold futures is 9:00-11:30, 13:00-15:00, and 21:00-2:30 on Monday to Friday. The night trading of futures starts from July 5, 2013. In order to conduct price discovery analysis on gold price across spot and future markets, we employ the data from trading times that are common across both markets. In another words, we use the trading hours of futures market as the benchmark but we remove night trading for Friday. We also label the three trading sessions as morning, afternoon, and night in our empirical analysis.

There are twelve gold futures contracts traded on the futures market at any one time; each contract has a different maturity time ranging from one to twelve months. There are two common methods to construct a single time series of price data from multiple contracts with different maturities. The first commonly used method is to use the nearest-to-maturity contract as the representative contract in constructing the price series. This method is outlined in Booth et al. (1999) and is based on the rationale that the expiring contract has more information contained in its price. They splice the price of nearest-to-maturity futures contracts conditional on liquidity. This method is employed in recent empirical research such as Shastri et al. (2008), Chen and Gau (2010), Cabrera et al. (2009), and Covrig et al. (2004). The second commonly used method is utilizes only recently issued or on-the-run contracts instead of expiring contracts. Fricke et al. (2011) present the method that uses on-the-run contract with the highest trading volume in combining prices of multiple contracts into a single price series. Both methods examine the trading activity or liquidity when combining prices of different contracts.

However, the trading of Chinese gold futures has an obvious peculiarity. The contracts are dominated by two types of contracts that mature in June and December. Table 1 shows the trading statistics for the contracts with maturity in June and December for each trading month. The contracts with maturity in June and December contribute about 99% of the trading volume in each and every month.

[3] The dataset is provided by Wenhua Information Systems Limited, a Chinese financial data provider.

From January to April 2012, the contract with highest trading volume is the contract that matures in June 2012. However, the relative trading volume of the June 2012 contract declines in April 2012, with the turnover ratio decreasing from 98.2% of total market volume in January to 31.7% in April 2012. As for the December 2012 contract, the volume increases from 1.5% of total market volume in January to 67.9% in April. In summary, the dominant contract is the June 2012 contract from January-March 2012, and it switches to December 2012 contract from April-October 2012. The dominant contract switches back to the June contract in November 2012. Therefore, we construct the time series of return of futures contract from the contracts with June and December maturity. Specifically, we combine the two series conditional on trading volume of the contract. This method is similar to Booth et al. (1999) but with slight modification to disregard contracts other than June and December.

3.3 Determine the Sampling Interval

When constructing a continuous times-series of return for spot and futures markets, we need to sample the price from each market at a fixed time interval. We want to sample the price information as frequently as possible to ensure the information is up-to-date, but we also want to wait for a longer interval to allow new trades to happen in between our sampling exercise. We analyze our data with time intervals of 10-second, 30-second, 1-minute, 2-minute, 3-minute, 5-minute, 10-minute, and 15-minute and compute the non-trading probability in these intervals. We need to find an appropriate sampling interval for the spot and futures price series in our study.

Table 2 presents the trading frequency and the non-trading probability within each time interval. Our first observation is that the trading of futures is more active than those of spot. On average, there is about 24 trades per minute in the futures market, and only slightly more than 3 trades per minute in the spot market. In the 1-minute interval, the non-trading probabilities are 13.7% in the spot market and 0.2% in futures market, respectively. The non-trading probability reduces as we choose a longer interval. In 5-minute intervals, the non-trading probabilities reduce to 0.9% in the spot market and to almost 0% in the futures market. Among the three trading sessions in a day, the session with the highest non-trading probability is night session for the spot market and morning session for the futures market. We choose to sample the price from each market at 1-minute intervals because it has reasonably low non-trading probabilities for both markets. We also replicate the main result using 5-minute interval and it is qualitatively unchanged.

3.4 Summary Statistics

We report the descriptive statistics of data used in our analysis in Table 3. The summary statistics for gold spot trading is reported in Panel A while those of futures trading is reported in Panel B. The gold spot and futures price decline by 20% during our sample period, therefore we expect to see a negative average daily return. The average 1-minute log return of the spot market is -1.022×10^{-6}, and that of the futures market is -1.934×10^{-6}. While both the average returns of spot and futures returns are negative, the average 1-minute return of the spot market is positive in the afternoon trading session and the return of the futures market is positive in the afternoon and night trading sessions. Looking at the realized volatility (RV) and two-scale realized volatility (TSRV), the spot market has higher RV and TSRV compared to the futures market. Furthermore, the night trading session has the highest RV and TSRV, followed by the morning trading session, and the afternoon trading session has the lowest RV and TSRV. This is applicable to both spot and futures markets.

On the trading activity, there are 1,434 trades per day on average for the spot market with average trading volume of 22,047 contracts. The number of trades and volume are fairly evenly spread across all three trading sessions. The night trading session has the highest number of trades but it has lowest number of contracts transacted, indicating that night trading sessions have small trade size. Looking at the futures market, the night trading has much higher trading activities in term of number of trades and volume. The night trading sessions has the number of trades and trading volume that is more than four times of that of morning or afternoon trading sessions. The figures for the three separate trading sessions may not be added up to be the all-day figures because there is only 53 days with night trading session out of the 429 trading days in our sample.

From the summary statistics, we figure out that the futures market is a more active market compared to the spot market. The futures market also has less return volatility in term of RV and TSRV. Looking across the three different trading sessions, the night trading session in highly active especially in the futures market and it is a more volatile trading session compared to the other two.

4. RESEARCH FINDINGS

4.1 Stationarity and Cointegration Test

Before we determine the cointegration relationship between the spot and the futures markets, we conduct stationarity tests on the gold price series. We implement the Augmented Dickey-Fuller (ADF) test on the price and return series of the spot and the futures markets. The null hypothesis of the ADF test is the presence of unit root in the series or the series is non-stationary.

Panel A of Table 4 presents the result of ADF test. We fail to reject the null hypothesis for the price series of both spot and futures markets, indicating that the price series are non-stationary. The result is robust to different trading sessions. We carry out the same test on the returns series of the spot and futures markets. We find that both returns series of spot and futures markets are stationary. The null hypothesis of the ADF test is rejected at 1% significance level for the overall returns series as well as individual trading session series.

Next, we utilize the Johansen (1991) test to determine whether the gold spot and futures price series are cointegrated and to establish the number of cointegrating vectors. We examine the number of unique cointegration vectors using both the trace and maximum eigenvalue tests. The null hypothesis of $r=0$ cointegration vector is rejected by both of the test statistics except for the night trading session. Furthermore, the null hypothesis of $r=1$ is not rejected by both of the tests, implying that the system has one cointegration vector in the price series. The spot and futures contract should have common stochastic trend because both of them share the identical underlying asset and arbitrage activity prevents the prices from deviating away from each other.

4.2 Price Discovery of Gold Market

We investigate the contribution of each market to the price discovery process of the gold market in China using three price discovery measured discussed in Section 2. We estimate the information share (*IS*), component share (*CS*), and information leadership share (*ILS*) for every trading day and report the summary statistics for our sample period. The proportion is the proportion of price discovery that occurs in that specific market. We repeat the analysis for individual trading sessions (morning, afternoon, and night) with results reported in Panels B, C, and D.

The information share attributed to the spot and futures markets are 44.17% and 55.53%, respectively. This indicates more of the price discovery of gold occurs in the futures market. The median and proportion numbers show a similar conclusion. Turning to Panel B-C, we find that price discovery occurs in the futures market during all three trading sessions. The difference in information share between the spot and futures market is greatest in the night trading session. The information share attributed to the spot and futures markets during the night trading sessions are 35.81% and 64.19%, respectively. While it is suggested by the sequential price discovery analysis in the following section that the night market contains more information, the sample size of night market trading activity is only 53 out of the full 429 days. In summary, the result for the information share reveals that the futures market dominates the price discovery of gold in China, and the result is robust to individual trading sessions.

We also provide additional evidence on price discovery using the component share approach. Contrary to the finding using information share, the component share method reveals that more price discovery occurs in the spot market. However, the component share in the spot market is just slightly more than 50%. The component share attributed to the spot and futures markets are 51.64% and 48.36%, respectively. Looking into the three trading sessions, the higher overall component share in the spot market is driven by the afternoon trading session. The morning and night trading sessions have higher component share in the futures market that is consistent with the finding using information share method. In any case, the difference is small except for the night trading session. The component share provides evidence that the spot market contributes more to the price discovery process, the magnitude is small and it is not consistent across three trading sessions.

Finally, we refer to the price discovery analysis using information leadership share measure. The information leadership share reveals a similar result as those of information share; that the price discovery process occurs more in the futures market than in the spot market. The overall information leadership share for the spot and futures markets are 38.30% and 61.70%, respectively. The results in the different sessions also confirm the dominant role of futures markets in all three trading sessions.

All results except the afternoon trading session using component share show that more price discovery occurs in the futures market. The different results shown by the component share method are probably due to the magnitude of the difference and the aspects captured by the different measures. In the price discovery analysis using component share, the components shares are around 50% for both spot and futures markets except for the night trade session. Therefore, the argument that the spot market dominates the price discovery process in futures market is weak despite the spot market having marginally higher component share. Furthermore, Yan and Zivot (2010) compare and contrast information share, component share, and information leadership share. They argue that information share is a metric that captures both permanent and transitory shocks, while component share responds more to transitory shocks. Information leadership share, on the other hand, responds only to permanent shocks. Following the precise definition of price discovery put forward by Hasbrouck (1995), price discovery can be defined as "who moves first". According to a simulation study conducted by Putniņš (2013), information leadership share is the best measure to capture such immediate responses to permanent price shocks. In summary, our results suggest that the futures market contributes more to the price discovery of gold markets in China.

4.3 Sequential Price Discovery Process

In Table 6, Panel A reports the price discovery and market efficiency of the gold spot market in non-overlapping trading sessions. First, we examine and compare the market efficiency across three different trading session using ratio TSRV/RV. The ratio has the highest value (0.64) in the afternoon trading session, and the ratio is statistically different from the ratios of the morning and night trading sessions. However, the information share is highest in the night trading session with a value of 59%. The night trading session alone contributes more than 50% of the daily price discovery. Statistical tests show that the information share in the night trading session is statistically different from those of the morning and afternoon sessions. WPC also shows similar results to those of information share where the night trading sessions contribute most of the overall daily price change. The WPC is 60% in the night trading session, and the values are 20% for both the morning and afternoon sessions.

The data used in the Panel A includes trading data from Friday, but there is no night trading on Friday. Therefore, including the morning and afternoon sessions but not the night session on Friday underestimates the information share and WPC in the night session. We remove all Friday data and repeat the same analysis in Panel B. The information share and WPC increase after removing Friday data, but the result remains qualitatively unchanged.

In Table 7, we analyze the price discovery and market efficiency of the gold futures market in non-overlapping trading sessions. The TSRV/RV ratio has the value of 0.49 which is the highest among all three trading sessions in the morning, indicating that the futures market is more efficient in the morning session. However, the value is not very different from the afternoon and night sessions. Looking at the *t*-statistics, the TSRV/RV ratio in the morning session is not statistically different from the ratio for the afternoon session. Turning to information share, the night trading session alone contributes 45% of the price discovery while the morning and afternoon sessions contribute 30% and 26%, respectively[4]. Looking at the WPC, the morning session alone contributes 45% of the daily price change which is higher than those contributed by the afternoon and night sessions. The result from WPC is not consistent with the result from information share, and it is also very different from the WPC result of the spot market. We repeat the same analysis after removing Friday data. The result is reported in Panel B and it is qualitatively similar to the main analysis.

[4] The sum is 101% because of rounding error.

In summary, the spot market is more efficient in the afternoon trading session but price discovery and price contribution occurs more in the night trading session. For the futures market, the market is more efficient in the morning trading session, and the price discovery occurs more in the night trading session. However, the price contribution for the futures market happens more in the morning trading session. The results from the three measures are not necessarily consistent because these three measures capture different aspects of price discovery. The ratio TSRV/RV measures the market efficiency or the amount of noise in the trading session. Information share captures the effective information reflected in the price. WPC measures the proportion of price change in the trading session out of the daily total price change. Finally, we limit most of our inference to the spot market because there is only 52 trading days that have all three trading sessions in the future markets.

5. CONCLUSION

The Chinese gold market is increasingly important because of its rapid growth in recent years. It is the third biggest gold markets in the world since 2013. This study examines the price discovery of gold market in China. We find that the price discovery occurs more in the futures market than in the spot market. In other words, gold price in the gold future market contain more up-to-date information. Within the spot market, the sequential price discovery analysis reveals that the afternoon trading session contains less noise but that price discovery occurs more in the night market. In the future market, the morning trading session contains less noise and the price discovery process occurs in the night market according to the information share method.

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Appendix Table A.1
Trading Volume of Gold Contracts around the World

This table summarizes the annual trading volume in terms of weight for all the gold contracts traded on the major commodity exchanges in year 2012 and 2013. The volume includes all gold spots and gold derivatives contracts transacted.

Ranking			Volume (10,000 tons)		
2013	2012	Market	2013	2012	Change (%)
1	1	London OTC Market	17.74	15.36	15.49
2	2	New York Mercantile Exchange	14.74	13.67	7.83
3	5	Shanghai Futures Exchange	2.08	0.59	252.54
4	4	Tokyo Commodity Exchange	1.27	1.21	4.96
5	3	Multi Commodity Exchange	1.06	1.26	-15.87
6	6	Shanghai Gold Exchange	0.58	0.32	81.25
7	7	NYSE Euronext	0.11	0.12	-8.33
8	8	Dubai Gold and Commodities Exchange	0.044	0.055	-18.18

Appendix Table A.2
Key Features of Gold Spot and Futures Contracts in China

This table summarizes the key features in contract specifications and market structures of the Chinese gold spot and futures markets.

	Spot	Futures
Product Symbol	AU (T+D)	AU
Trading Venue	Shanghai Gold Exchange	Shanghai Futures Exchange
Trading Hours	Monday to Friday 9:00am — 11:30am 1:30pm — 3:30pm 9:00pm — 2:30am (except Friday)	Monday to Friday 9:00am — 11:30am 1:30pm — 3:00pm 9:00pm — 2:30am (except Friday), from 7/3/2013
Contract Size	1000g per board lot	1000g per board lot
Price Quotation	Chinese Yuan (CNY) per gram	Chinese Yuan (CNY) per gram
Minimum Fluctuation	CNY 0.01 per gram	CNY 0.01 per gram
Daily Price Fluctuation Limit	No more than ± 7% of the previous day's settlement price.	No more than ± 5% of the previous day's settlement price.
Minimum Trading Deposit	15%- 20% of the contract value	7% of the contract value
Termination of Trading	Every trading day	15th day of the delivery month
Listed Contracts	n/a	January to December
Settlement	Physical	Physical
Delivery Period		5 business day after the last trading day
Grade and Quality Specifications	Gold delivered under this contract shall assay to a minimum of 995 fineness	Gold delivered under this contract shall assay to a minimum of 995 fineness
Extension Cost	Unilateral commission 0.13%, 0.02% of the contract value per day. Daily payment according to the business day	Futures companies charge CNY 40 per lot, exchange charges 0.02% of transaction amount

Table 1
Trading Volumes of Futures Contracts Maturing in June and December

There are 12 futures contracts with different maturity traded at any one time in the futures markets. This table presents the trading volume of two most active contracts – contract that matures in June, and contract that matures in December. Volume is the total number of contracts traded in the month. Proportion trading volume ratio of the specific contract to the total market volume. Sample period is January 2012 – October 2013.

	June Future Contract		December Future Contract	
Month	Volume	Proportion	Volume	Proportion
Jan 2012	69447	**98.2%**	1032	1.5%
Feb 2012	49618	**96.7%**	1576	3.1%
Mar 2012	47680	**92.6%**	3659	7.1%
Apr 2012	14778	31.7%	31611	**67.9%**
May 2012	1229	2.1%	56375	**97.5%**
Jun 2012	68	0.1%	53847	**99.3%**
Jul 2012	110	0.2%	46036	**99.4%**
Aug 2012	407	1.0%	38705	**98.6%**
Sep 2012	2627	5.1%	48564	**94.4%**
Oct 2012	9587	23.8%	30215	**75.1%**
Nov 2012	32671	**85.4%**	5281	13.8%
Dec 2012	42900	**98.8%**	143	0.3%
Jan 2013	33042	**98.8%**	191	0.6%
Feb 2013	32170	**96.4%**	1007	3.0%
Mar 2013	31014	**93.8%**	1923	5.8%
Apr 2013	56974	**64.5%**	30926	35.0%
May 2013	8443	7.9%	98225	**91.7%**
Jun 2013	521	0.6%	87129	**98.7%**
Jul 2013	220	0.1%	310357	**99.7%**
Aug 2013	991	0.3%	395261	**99.5%**
Sep 2013	2216	0.9%	238573	**98.8%**
Oct 2013	5109	2.2%	231562	**97.5%**

Table 2
Trading Frequencies and Non-Trading Probabilities

This table reports the trading frequencies and non-trading probabilities for the different time intervals in the Chinese gold spot market (Panel A) and gold futures market (Panel B). Each trading day is divided into multiple of fixed time intervals. The first column is the time interval and it ranges from 10 seconds to 15 minutes. The second column presents average number of trades in the specific fixed time interval. The last four columns present the non-trading probability in the gold markets for the corresponding time interval in the respective trading sessions (morning, afternoon, night, and whole day). Sample period is January 2012 – October 2013.

Panel A: Gold Spot

Interval	Trading Frequency	Non-Trading Probability (%)			
		Morning	Afternoon	Night	All
10-second	0.52	63.4%	54.4%	69.7%	60.7%
30-second	1.56	32.2%	21.7%	44.5%	29.8%
1-minute	3.12	14.6%	7.3%	28.6%	13.7%
2-minute	6.22	4.2%	1.4%	15.9%	4.7%
3-minute	9.35	1.7%	0.4%	10.3%	2.3%
5-minute	15.58	0.4%	0.1%	4.8%	0.9%
10-minute	30.63	0.0%	0.0%	1.7%	0.2%
15-minute	46.62	0.0%	0.0%	0.6%	0.1%

Panel B: Gold Futures

Interval	Trading Frequency	Non-Trading Probability (%)			
		Morning	Afternoon	Night	All
10-second	3.97	10.1%	6.6%	7.2%	8.5%
30-second	11.90	1.2%	0.6%	0.9%	1.0%
1-minute	23.80	0.3%	0.2%	0.1%	0.2%
2-minute	47.44	0.1%	0.1%	0.0%	0.1%
3-minute	71.36	0.1%	0.0%	0.0%	0.1%
5-minute	118.87	0.1%	0.0%	0.0%	0.0%
10-minute	233.67	0.0%	0.0%	0.0%	0.0%
15-minute	355.65	0.0%	0.0%	0.0%	0.0%

Table 3
Summary Statistics of Gold Spot and Futures Trading

This table reports the summary statistics of average return, realized volatility (RV), two-scale realized variance (TSRV), daily number of trades, and daily trading volume for gold spot trading (Panel A) and gold futures trading (Panel B). The return is sampled at 1-minute interval. RV and TSRV are calculated from the sampled return on the daily basis. The summary statistics are calculated using full day trading or divided the full day into three trading sessions (morning, afternoon, and night). Sample period is January 2012 – October 2013.

Panel A: Gold Spot

		N	Mean	Std	P5	P25	Median	P75	P95
Return	All	227,256	-1.022	478.345	-433.871	-28.914	0.000	29.422	434.751
($\times 10^6$)	Morning	64,349	-0.159	602.417	-340.599	-31.383	0.000	35.999	343.374
	Afternoon	51,360	1.208	272.847	-343.505	-60.348	0.000	62.691	346.094
	Night	111,547	-2.547	471.736	-580.968	0.000	0.000	0.000	581.564
RV	All	429	0.783	1.24	0.057	0.258	0.513	0.94	2.008
	Morning	429	0.118	0.245	0.014	0.031	0.057	0.119	0.374
	Afternoon	428	0.089	0.165	0.011	0.024	0.044	0.088	0.26
	Night	337	0.733	1.152	0.144	0.282	0.468	0.827	1.824
TSRV	All	429	0.418	0.858	0.025	0.117	0.245	0.446	1.176
	Morning	429	0.065	0.189	0.005	0.012	0.023	0.055	0.196
	Afternoon	428	0.054	0.116	0.005	0.012	0.025	0.051	0.177
	Night	337	0.38	0.789	0.054	0.124	0.23	0.386	0.987
Daily Trades	All	429	1,434	623	683	1,013	1,311	1,677	2,688
	Morning	429	447	228	202	296	395	527	875
	Afternoon	428	461	177	258	351	423	532	796
	Night	337	670	351	275	433	585	795	1,457
Daily Volume	All	429	22,047	11,054	9,992	14,614	19,162	26,400	42,638
	Morning	429	7,910	5,864	2,400	4,220	6,042	9,596	20,664
	Afternoon	428	8,287	4,089	3,778	5,642	7,214	9,815	16,112
	Night	337	7,472	4,790	2,652	4,462	6,434	9,014	15,174

Panel B: Gold Futures									
		N	Mean	Std	P5	P25	Median	P75	P95
Return	All	114,067	-1.934	723.631	-411.070	-124.019	0.000	126.904	422.030
($\times 10^6$)	Morning	57,914	-4.400	932.254	-403.994	-117.089	0.000	117.671	421.569
	Afternoon	38,610	0.251	337.466	-396.227	-119.539	0.000	119.553	396.668
	Night	17,543	1.397	533.887	-533.381	-188.555	0.000	188.661	533.950
RV	All	429	0.344	0.718	0.037	0.069	0.113	0.283	1.39
	Morning	429	0.126	0.211	0.021	0.038	0.064	0.136	0.406
	Afternoon	429	0.102	0.381	0.013	0.025	0.043	0.094	0.319
	Night	53	0.942	1.177	0.22	0.366	0.605	1.076	2.142
TSRV	All	429	0.161	0.279	0.016	0.034	0.064	0.169	0.562
	Morning	429	0.074	0.146	0.007	0.017	0.033	0.07	0.245
	Afternoon	429	0.049	0.099	0.005	0.012	0.023	0.047	0.178
	Night	53	0.311	0.378	0.04	0.127	0.204	0.342	0.692
Daily Trades	All	429	6,327	3,898	3,068	3,991	4,976	6,631	16,015
	Morning	429	2,954	968	1,728	2,255	2,742	3,454	4,785
	Afternoon	429	2,195	700	1,255	1,633	2,111	2,600	3,589
	Night	53	9,537	2,085	6,478	8,187	9,387	10,942	13,941
Daily Volume	All	429	91,540	120,317	23,824	33,420	45,846	74,934	393,672
	Morning	429	40,200	48,363	13,132	19,264	27,858	42,892	94,444
	Afternoon	429	23,483	15,643	9,156	12,916	18,632	27,520	56,412
	Night	53	225,482	89,214	112,292	159,802	211,900	273,234	445,550

Table 4
Stationarity and Cointegration Tests

Panel A presents Augmented Dickey-Fuller stationarity (ADF) test on the natural logarithm of price level and its first difference (return). The null hypothesis is presence of unit root in the data. Values in the parenthesis are the Ljung-Box (1999) p-values. Panel B presents the results from Johansen (1991) test for number of unique cointegrating relationships where r represents the number of cointegrating vectors on the Chinese gold spot market and gold future market price series. The Johansen (1991) test requires the testing hypotheses of at most zero or one cointegrating vectors using trace or maximum eigenvalue tests. Values in the parenthesis are the MavKinnon-Haug-Michelis (1999) p-values. The tests are conducted using full day trading or divided the full day into three trading sessions (morning, afternoon, and night). The Sample period is January 2012 – October 2013.

Panel A: Augmented Dickey-Fuller Stationary Test

	All	Morning	Afternoon	Night
Variable	ADF	ADF	ADF	ADF
Spot (log prices)	-2.285	-2.0948	-2.1535	-2.199
	(0.44)	(0.55)	(0.52)	(0.21)
Spot (returns)	-338.144	-239.2877	-195.7217	-135.104
	(0.00)	(0.00)	(0.00)	(0.00)
Futures (log prices)	-2.226	-2.0676	-2.1571	-2.2234
	(0.47)	(0.56)	(0.52)	(0.20)
Futures (returns)	-346.910	-244.8502	-196.7	-135.1544
	(0.00)	(0.00)	(0.00)	(0.00)

Panel B: Cointegration Analysis

	All		Morning		Afternoon		Night	
Rank	Trace	Max. Eigen	Trace	Max. Eigen	Trace	Max. Eigen	Trace	Max. Eigen
H_0: r = 0	42.131	41.803	33.901	33.717	23.852	23.750	15.495	14.265
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.15)	(0.46)
H_0: r = 1	0.329	0.329	0.184	0.184	0.102	0.102	3.841	3.841
	(0.57)	(0.57)	(0.67)	(0.67)	(0.75)	(0.75)	(0.03)	((0.03)

Table 5
Price Discovery of Chines Gold Market

This table presents the result of price discovery on Chinese gold markets using three price discovery measures. The three price discovery metrics are Information Share (IS), Component Share (CS), and Information Leadership Share (ILS). The estimates are in percentage term and are calculated from a vector error-correction model containing only one common factor and estimated using the minute-by-minute prices of the spot and futures markets. The price discovery is estimated for each and every trading day, and the mean, median, and standard deviation of the price discovery measures are reported. Proportion is the proportion of day that the price discovery occurs more in that specific market. Panel B, C, and D provide similar analyses using data from different trading sessions within a day. Sample period is January 2012 – October 2013.

Panel A: Price Discovery in All Overlapping Trading Periods

	Information share		Components share		IL share	
	Spot	Futures	Spot	Futures	Spot	Futures
Mean	44.47%	55.53%	51.64%	48.36%	38.30%	61.70%
Median	40.35%	59.65%	52.70%	47.30%	35.98%	64.02%
Std.	30.28%	30.28%	27.69%	27.69%	27.82%	27.82%
Proportion	43.39%	56.61%	55.03%	44.97%	33.07%	66.67%

Panel B: Price Discovery in Morning Trading Session

	Information share		Components share		IL share	
	Spot	Futures	Spot	Futures	Spot	Futures
Mean	44.09%	55.91%	49.53%	50.47%	39.26%	60.74%
Median	38.78%	61.22%	49.76%	50.24%	35.64%	64.36%
Std.	31.74%	31.74%	27.63%	27.63%	29.64%	29.64%
Proportion	42.55%	57.45%	49.73%	50.27%	32.71%	66.76%

Panel C: Price Discovery in Afternoon Trading Session

	Information share		Components share		IL share	
	Spot	Futures	Spot	Futures	Spot	Futures
Mean	45.50%	54.50%	52.77%	47.23%	37.98%	62.02%
Median	40.65%	59.35%	54.84%	45.16%	33.25%	66.75%
Std.	32.15%	32.15%	27.30%	27.30%	31.26%	31.26%
Proportion	44.25%	55.75%	54.57%	45.43%	35.50%	64.50%

Panel D: Price Discovery in Night Trading Session

	Information share		Components share		IL share	
	Spot	Futures	Spot	Futures	Spot	Futures
Mean	35.81%	64.19%	39.45%	60.55%	42.01%	57.99%
Median	32.81%	67.19%	37.68%	62.32%	46.66%	53.34%
Std.	27.88%	27.88%	23.61%	23.61%	23.81%	23.81%
Proportion	28.85%	71.15%	32.69%	67.31%	42.31%	57.69%

Table 6

Spot Market Price Discovery and Market Efficiency in Different Trading Sessions

This table presents the price discovery and compares the market efficiency in three different trading sessions for the gold spot market. There are three non-overlapping trading sessions in a trading day: Morning, Afternoon, and Night. The ratio TSRV/RV is used as a measure of market efficiency. TSRV or two-scale realized variance is a measure of information flow; RV or realized variance is a measure price volatility that is contributed by both information and microstructure noise. Information share is the measure of price discovery. TSRV/RV and Information share are obtained daily, the reported number are the average figures across all trading days. Statistical tests are conducted to examine the differences of TSRV/RV or Information share between different trading sessions. WPC or weighted price contribution is an alternated measure of price discovery across non-overlapping trading sessions. The WPC is calculated for the full sample. In Panel B, the Friday data is removed from the analysis because there is no night trading session on Friday. Sample period is January 2012 – October 2013.

Panel A: Price Discovery in Different Trading Session (All Trading Days)

	TSRV/RV	Information share	WPC
Morning	0.52	20%	20%
Afternoon	0.64	21%	20%
Night	0.53	59%	60%
Night > Morning (t-stat)	0.26	20.80	
Night > Afternoon (t-stat)	-5.38	19.80	
Afternoon > Morning (t-stat)	5.45	0.69	

Panel B: Price Discovery in Different Trading Session (Exclude Friday)

	TSRV/RV	Information share	WPC
Morning	0.52	13%	16%
Afternoon	0.63	13%	16%
Night	0.53	74%	68%
Night > Morning (t-stat)	0.23	51.40	
Night > Afternoon (t-stat)	-4.65	52.50	
Afternoon > Morning (t-stat)	4.88	-0.73	

Table 7

Futures Market Price Discovery and Market Efficiency in Different Trading Sessions

This table presents the price discovery and compares the market efficiency in three different trading sessions for the gold futures market. There are three non-overlapping trading sessions in a trading day: Morning, Afternoon, and Night. The ratio TSRV/RV is used as a measure of market efficiency. TSRV or two-scale realized variance is a measure of information flow; RV or realized variance is a measure price volatility that is contributed by both information and microstructure noise. Information share is the measure of price discovery. TSRV/RV and Information share are obtained daily, the reported number are the average figures across all trading days. Statistical tests are conducted to examine the differences of TSRV/RV or Information share between different trading sessions. WPC or weighted price contribution is an alternated measure of price discovery across non-overlapping trading sessions. The WPC is calculated for the full sample. In Panel B, the Friday data is removed from the analysis because there is no night trading session on Friday. Sample period is July 2013 – October 2013.

Panel A: Price Discovery in Different Trading Session (All Trading Days)

	TSRV/RV	Information share	WPC
Morning	0.49	30%	45%
Afternoon	0.46	26%	35%
Night	0.40	45%	20%
Night > Morning	-1.87	3.17	
Night > Afternoon	-1.30	4.07	
Afternoon > Morning	-0.66	-1.15	

Panel B: Price Discovery in Different Trading Session (Exclude Friday)

	TSRV/RV	Information share	WPC
Morning	0.50	26%	42%
Afternoon	0.45	19%	34%
Night	0.40	55%	25%
Night > Morning (t-stat)	-2.01	7.05	
Night > Afternoon (t-stat)	-1.04	9.45	
Afternoon > Morning (t-stat)	-1.20	-2.35	