Price Discovery Process in the Copper Markets: Is Shanghai Futures Market Relevant?

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Price Discovery Process in the Copper Markets: Is Shanghai Futures Market Relevant?

Abstract: This paper examines the international linkage between the Chinese and other major world copper futures markets in order to study the information spillover process. We find that the copper futures prices of contracts traded on the three major exchanges, Shanghai, London and New York are cointegrated. Using both Gonzalo and Granger (1995) and Hasbrouck (1995) methods, we find that the London market still dominates the price discovery process, contributing over 45%. Though the Shanghai market contributes important information to the price discovery, its share of contribution is still the smallest among the three. The Shanghai Futures Exchange, the second largest copper futures market in the world, contributes about 25%.

Key words: Futures Markets; Cointegration Test; common factor components method, information shares method; China. **JEL Codes**: G13, G15

Introduction

The objective of this paper is to understand the international linkage between the Chinese and other major world copper futures markets in order to study the information spillover process. One important role that futures markets fill for economic agents is price discovery, a process by which information from one market spills over to another. The speed of information spill-over across different markets is an important element for market efficiency. When a commodity is traded on multiple markets where frictionless and continuous information sharing are possible, market participants can choose any market to trade. On the other hand, if market barriers exist due to transaction costs, rules, and regulations, markets may differ in price discovery and participants may choose where to trade to explore information.

This paper investigates the relative importance of price discovery for copper on the London Metal Exchange (LME), the New York Mercantile Exchange (NYMEX), and the Shanghai Futures Exchange (SFE). While the LME and NYMEX have a long history of trading, the Shanghai Futures Exchange only started to trade copper futures contracts in 1992. Though the SFE is a newcomer relative to the LME and NYMEX, its trading volume has been increasing rapidly in recent years. The SFE is now the second largest copper futures market in the world after the LME. It is important to evaluate the roles played by each market, particularly by the SFE, in price discovery process, which we will do in this paper by utilizing both Gonzalo and Granger (1995), and Hasbrouck (1995) methods.

Many studies have sought to understand the relationship between futures prices of the same underlying asset in different markets[2]. There is evidence that each of the markets for which securities are multiply listed contributes to price discovery. Garbade and Silber (1979) empirically test price relationship among dually listed securities that are traded on the NYSE and regional stock exchanges. They find that the satellite markets (regional exchanges) contribute to price discovery in the sense that disclosure of satellite market prices will affect transactions prices in the dominant market (NYSE). Employing the error-correction model of Engle and Granger (1987), Harris, McInish, Shoesmith, and Wood (1995) investigate price discovery for IBM on the NYSE, Midwest, and Pacific exchanges. Ding, Harris, Lau, and McInish (1999) examine the relative price discovery contributed by a stock traded on both Malaysia and Singapore exchanges. They find that exchanges outside the home country can contribute substantially to price discovery. Using both Hasbrouck and Gonzalo-Granger methodologies for extracting the information content held in the Singapore Exchange and Taiwan Futures Exchange, Roope and Zurbruegg (2002) show that strong evidence exists to suggest price discovery primarily originates from the Singapore market for the Taiwan Index Futures. Booth, Brockman, and Tse (1998) have found a cointegration relationship between the prices of wheat futures contracts traded on the Chicago Board of Trade (CBOT) and the Winnipeg Commodities Exchange (WCE) of Canada. They have also found that the Chicago contract prices lead the Winnipeg contract prices with no feedback. Covrig, Ding, and Low (2004) study the information transmission among the Tokyo, Osaka and Singapore exchanges,

[2] There are also a large number of empirical studies on price discovery between futures and underlying spot markets. For example, McMillan, 2005; Pattarin and Ferretti, 2004; Pizzi, Economopoulos, and O'Neill, 1998; Ryoo and Smith, 2004.

using tick instead of daily data. They quantify the contribution of each market and conclude that the Singapore Exchange contributes a share of around 33% in the price discovery process of the Nikkei 225 index despite it being a foreign futures market with a much smaller trading volume. Using daily futures data of gold, platinum, and silver futures contracts, Xu and Fung (2005) examine information transmission across U.S. and Japanese markets. They find that the pricing transmission across both markets is strong, with U.S. information playing a leading role.

Though the Chinese futures markets have grown in importance, they are yet to be intensively studied in academic circles. Only in the past few years does there seem to be a growing interest in understanding the role of Chinese futures markets in the information transmission process of the global commodity markets. Wang and Ke (2005) tested the efficiency of the Chinese agricultural commodity futures markets. Hua and Chen (2007) studied the cointegration relationships between the futures prices of several commodities—copper, aluminum, soybean and wheat—traded on the Chinese futures exchanges and their counterparts on the major futures exchanges around the world.

None of the research has studied the role played by the Shanghai Futures Exchange in the information transmission process in global commodity markets. Given the growing eminence of the Shanghai market, it is important to quantify its role in the price discovery process. This paper intends to do this by evaluating the importance in information gathering in copper futures contracts traded on the SFE in relation to other major markets, specifically, the LME and NYMEX. We quantify the contribution of each market and provide evidence of price discovery for the Shanghai Futures Exchanges.

The next section provides a brief description of the Chinese futures markets. We also describe the data in this section. After that, we test whether the futures prices of contracts traded on the Shanghai, London and New York exchanges are cointegrated. In Section IV, we use several different test methods to shed light on the role of one futures exchange in the price discovery process. The final section summarizes and concludes.

Overview of the SFE and the Data

The growing importance of the Shanghai Futures Exchanges in copper futures trading coincides with the growing copper consumption in China. China is now the largest copper consumer in the world, consuming 5.2 million metric tons in 2008, which accounts for more than 27% of the world supply. Over 28% of copper consumed in China is imported. Consequently, the trading volume in terms of tonnage on the SFE has surpassed that on the NYMEX, becoming the second largest exchange next to the LME. In 2008, the copper trading volume on the SFE was 103.9 million tons while it was 52.4 million tons on the NYMEX and 662.7 million ton on the LME. The SFE copper futures price is now an important indicator to copper mining companies around the world.

It is important to point out that there are differences among the LME, NYMEX, and SFE in terms of trading schedules. The SFE only employs a computer auction trading system. It trades from 9:30 to 11:30, and from 13:30 to 15:00. On the other hand, both LME and NYMEX use the traditional open outcry auction trading system as well as computer auction trading system. The trading periods on the LME floor are 12:00 – 12:05, 12:30 – 12:35, 13:15 – 14:45, 15:10 – 15:15, 15:50 – 15:55, and 16:15 – 16:55 in local time. The computer auction system of the LME runs from 1:00 – 19:00 in local time since 2006[3]. The NYMEX floor trades futures contracts from 8:10 to 13:00, while its computer auction trading system trades from 15:15 to 8:00 the next day for weekdays, and from 19:00 to 8:00 from Sunday to Monday. We follow Xu and Fung (2005) to use the transaction data of floor trades on the LME and NYMEX[4]. For the Shanghai Futures Exchange, we use the transaction data based on the computer auction system. Table 1 compares the floor opening and closing time of these three exchanges when all are converted into Beijing time. We notice that there are no overlaps of trading periods between the SFE and LME or NYMEX. The LME or NYMEX starts to trade in a day after the SFE closes trading. There are overlaps in trading periods between the LME and NYMEX, but the NYMEX opens and closes later than the LME.

Table 1 here

In addition, the contract months for copper futures traded on the three exchanges are different. To be consistent, we need to construct the price time series

[3] Before June 1, 2006, the LME electronic trading period was from 7:00 in the morning to 19:00 in the evening.

[4] To make sure that our conclusions are not dependent on the choice of data, we also conduct tests using data from electronic trading systems of the LME and NYMEX. Our conclusions are the same.

that are comparable with each other. The LME trades 3, 15, and 27 month continuous contracts. We use three-month daily closing futures prices on the LME. Unlike the LME, both SFE and NYMEX trade contracts that expire within certain period. Thus, we need to construct a continuous futures price series for contracts traded on these two exchanges in the following way. For a given trading month, called M, we collect the daily closing prices for a contract deliverable in M+3 month. On the first day of the next calendar trading month (M+1), we roll over to the next contract deliverable in M+4 month. For example, if the calendar trading month is February, the daily closing price of the contract deliverable in May is collected. On the first day of March, we roll over to the daily closing prices of the contract deliverable in June; the daily closing price of the contract deliverable in June is collected.

Our sample runs from January 2, 1998 to December 31, 2008.[5] We delete non-matching data caused by holidays and non-trading dates in order to make the data of the Chinese and world copper futures prices comparable. In doing so, we obtain our data samples for copper futures prices with a sample size of 2570.

We also consolidate the quotation units for our data. The quotation unit for copper futures contracts traded on the LME is US$ per ton, while the quotation unit on the NYMEX is cents per pound. The Chinese futures contracts are quoted as yuan per ton. For consistency, we converted all the LME and NYMEX quotation unit into yuan per ton.[6]

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[5] Our data samples are collected from Shihua Financial Analysis Databank, which contains futures prices from both Chinese and non-Chinese futures exchanges.

[6] The Chinese currency, RMB, is denominated in Yuan. We used the daily exchange rate to convert dollars into the Chinese currency. One pound is 0.454kg.

Table 2 displays the descriptive statistics of returns on the copper futures continuous contracts traded on the three markets. All the futures returns indicate significant skewness and kurtosis, and do not follow normal distribution. The Q-statistics show that there is a serial correlation in the futures returns of the SFE, LME and NYMEX at 5% confidence level. Finally, $Q^2(24)$ indicates heteroscedasticity in all the futures returns.

Table 2 here

There is a significant amount of overlap in trading periods between the LME and NYMEX. On the other hand, the trading periods of the SFE do not overlap at all with either the LME or NYMEX[7]. Comparing the volatilities of futures returns of these three exchanges may reveal the patterns of information flow among these three markets. The volatilities of these three exchanges in both trading and non-trading period are listed in Table 3. The volatility during the trading period is computed by calculating the variance of $Ln(C_t) - Ln(O_t)$, where O_t and C_t denote the opening price and the closing price, respectively. It measures the variance of price during the trading period of day t. The volatility during the non-trading period is computed by calculating the variance of $Ln(O_t) - Ln(C_{t-1})$, where O_t and C_{t-1} denote the opening price on day t and the closing price on day t-1, respectively. It measures the variance of price from the closing of day t-1 to the opening of day t. Many empirical studies （Fama 1965; French & Roll 1986; Chan & Chan 1993） have shown that the

[7] We refer to the floor trading time.

volatilities during the trading period are larger than the volatilities during the non-trading period. A possible explanation for this phenomenon is that the market information is released during the trading period in general, and there are lots of noise traders in the market. Table 3 suggests that the volatilities of the LME and NYMEX during the trading period are indeed larger than non-trading period. However, the volatility of the SFE shows a different pattern comparing the volatilities of the LME and NYMEX. The SFE price during the non-trading period is much more volatile than the trading period. Further, the volatility of the SFE is much larger than either the LME or NYMEX, irrespective to trading period or non-trading period. We notice that the volatility of the SFE during the non-trading period is more than 600 times of its volatility during the trading period. This is because the opening prices of contracts on the SFE are often affected by information coming from the LME and NYMEX. This leads to the opening prices of the Shanghai market much different from its closing prices of previous days.

Table 3 here

Cointegration

The purpose of this paper is to estimate the contribution to price discovery by each of the three markets. Before estimation methods can be applied, we need to conduct a test for cointegration among the three markets. In order to perform the cointegration test, we first determine the order of integration of each price series. We use the standard Augmented Dickey-Fuller (ADF) test to determine if the unit root exists in each time series[8]. We select the optimal lag length for the equations based on Akaike Information Criterion (AIC)[9]. Table 4 shows the ADF test results for the price series, F_t, as well as for the first difference of the price series, ΔF_t. The results indicate that all the time series of futures prices are non-stationary but that their first differences are stationary. We conclude that all the futures prices follow the I(1) process.

Table 4 here

Since all the futures prices follow I(1), we can test the cointegration relationship among these prices. This is done using the Johansen method (1988) to test the null hypothesis of at most zero, one, or two cointegrating vectors using the trace as well as the maximum eigenvalue statistics. Table 5 shows the Johansen cointegration test results. The null hypotheses of $r = 0$ and $r \leq 1$ cointegrating vectors are successfully rejected by the Johansen trace as well as maximum eigenvalue test. We conclude that the system has two cointegrating vectors and one common stochastic trend. There is a cointegration relationship binding the price series of the futures contracts traded on these three exchanges.

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8 The ADF test for the null hypothesis of unit root tends to have low power against the alternative hypothesis of stationarity. Thus, deciding whether a time series is integrated or not based on the Augmented Dickey-Fuller test may be inadequate. To address this inadequacy, we used a test developed by Kwiatowski, Phillips, Schmidt, and Shin (1992), which complements the ADF test for unit root by testing the null hypothesis of stationarity. The KPSS test confirms our ADF results.

9 Used Schwarz Information Criterion (SIC) does not change our conclusions.

Table 5 here

The cointegration results suggest that the futures prices of the three exchanges move together over the long run. Even though futures prices of copper are non-stationary, implying that they can diverge from each other in the short run, arbitrage activities should prevent them from drifting away from each other for too long[10].

Price Discovery

In this section, we investigate the linkage among the three futures exchanges and evaluate the contributions of each market to the price discovery process. Since the price series of the SFE, LME, and NYMEX are cointegrated, we can apply several test methods to shed light on the role of each futures exchange in the price discovery process. These test methods include the error correction model (ECM), the Hasbrouck (1995) information shares approach, Gonzalo-Granger common factor component method, and Granger causality test.

We first investigate the lead-lag relationship among the three price series using the error correction model. Because the Shanghai market is ahead of London and New York, the lead-lag relationship using the same day price data may reflect the impact of

[10] Though foreign investors are not permitted to trade directly in the Chinese futures exchanges, frequent arbitrage activities still exist to limit price deviation from each market. For example, if the SFE price is lower than the LME closing price substantially (after taking into account all the transaction cost), investors in China can long the copper futures contracts traded on the SFE. They can short the London contracts (Chinese institutional investors are permitted to do so) the next day. Though it is not a riskless arbitrage due to the time difference, this tends to narrow the price difference between the two markets.

Shanghai market on the LME or NYMEX. Though the closing price of the London market or New York market does not impact the same day Shanghai price, it may affect the next day price of the SFE. By taking into consideration of this non-synchronized nature of trading, we use the following error correction model (ECM) to represent the price dynamics of the three exchanges:

$$\Delta SH_t = w_1 + \sum_{i=1}^{q} \alpha_{1i} \Delta SH_{t-i} + \sum_{i=1}^{q} \beta_{1i} \Delta LD_{t-i} + \sum_{i=1}^{q} \gamma_{1i} \Delta NY_{t-i} + \kappa_1 (LD_{t-1} - SH_{t-1}) + \theta_1 (NY_{t-1} - SH_{t-1}) + \varepsilon_{1t} \quad (1)$$

$$\Delta LD_t = w_2 + \sum_{i=1}^{q} \alpha_{2i} \Delta SH_{t+1-i} + \sum_{i=1}^{q} \beta_{2i} \Delta LD_{t-i} + \sum_{i=1}^{q} \gamma_{2i} \Delta NY_{t-i} + \kappa_2 (LD_{t-1} - SH_t) + \theta_2 (NY_{t-1} - LD_{t-1}) + \varepsilon_{2t} \quad (2)$$

$$\Delta NY_t = w_3 + \sum_{i=1}^{q} \alpha_{3i} \Delta SH_{t+1-i} + \sum_{i=1}^{q} \beta_{3i} \Delta LD_{t-i} + \sum_{i=1}^{q} \gamma_{3i} \Delta NY_{t-i} + \kappa_3 (NY_{t-1} - LD_{t-1}) + \theta_3 (NY_{t-1} - SH_t) + \varepsilon_{3t} \quad (3)$$

where Δ is the first difference. SH_t, LD_t, and NY_t are the closing prices of contracts on the Shanghai, London and New York markets, respectively. $\alpha_{ji}, \beta_{ji}, \gamma_{ji}$, j = 1, 2, 3, are the short term adjustment coefficients. q is the lag length, determined according to AIC. ε_{1t}, ε_{2t} and ε_{3t} are white noises, following a joint normal distribution. κ_i and θ_i (i=1,2,3) are the coefficients for the error correction terms. These coefficients have two interpretations. They first indicate the adjustment speed and direction if prices deviate from each other. They also provide information on the Granger causal direction among the three prices. Notice that in equation (2) and (3), time t price in Shanghai is used to calculate its deviation from t-1 price in either London or New York, due to the time difference of the Shanghai market and the other two.

Table 6 here

Table 6 shows the error correction model and Granger causality test results. Equation (1) contains information regarding the impact of the LME and NYMEX prices on the SFE prices. By estimating equation (2) and (3), we can interpret the impact of the SFE prices on the LME and NYMEX futures prices, because the SFE futures contracts trade ahead of the LME and NYMEX. We find that all coefficients are significant at 5 percent level of significance, except α_2 in equation (1), γ_2 in equation (2) and β_2 in equation (3), indicating that each market is influenced by price changes of the other two markets.

To further understand the price discovery process, we need to quantify the contribution of each market. We achieve this objective by using the common factor components approach of Gonzalo and Granger (1995) as well as the information share approach of Hasbrouck (1995).

The Gonzalo and Granger (1995) approach is based on a vector error correction model. It uses the error term to distinguish the permanent factor component of the prices from the transitory component due to noises. According to this approach, if the prices of the three markets are cointegrated, a vector error correction model to estimate the contribution of one market to the revelation of the innovations can be specified as:

$$\Delta p_{i,t} = c_i + \sum_{j \neq i}^{2} \alpha_{i,j} (p_{i,t-1} - p_{j,t-1}) + \sum_{i=1}^{3} \sum_{q=1}^{Q} \gamma_{i,t-q} \Delta p_{i,t-q} + \varepsilon_{i,t} \qquad (4)$$

where indices 1, 2, and 3 correspond to the SFE, LME, and NYMEX. $\Delta p_{i,t}$ is the change of prices in market i (i = 1, 2, 3) at time t. $\alpha_{i,j}$ measures the price adjustment speed between market i and j. $\gamma_{i,t-q}$ is the lag q autoregression coefficient for market i. Q is the optimal lag length. $\varepsilon_{i,t}$ is the error term.

According to Gonzalo and Granger (1995), we can decompose the price into a permanent and a temporary component:

$$p_t = f_t i_n + \varepsilon_t \tag{5}$$

Where $p_t = (p_{1,t}, p_{2,t}, p_{3,t})'$ is the price vector, f_t is a vector consisting the common factors, i_n is the unit row vector. $f_t i_n$ reflects the common factor components of the market information, while ε_t shows the temporary components.

We can further represent the common factor f_t as a linear combination of prices of these three markets, $f_t = \eta p_t$, where $\eta = (\eta_1, \eta_2, \eta_3)$ is a vector coefficient for common factors. If we standardize η so that $\sum_{i=1}^{3} \eta_i = 1$, each η_i can be interpreted as the contribution of market i to price discovery.

While the Gonzalo and Granger (1995) approach constructs a permanent component that is a simple combination of the data ($f_t = \eta p_t$) where the coefficient η_i measures the contribution of innovation from market i, Hasbrouck (1995)'s information shares approach tries to find the amount of variation in prices and to explain how much of that is explained by price changes on market i. Though De

Jong (2002) believes that Hasbrouck (1995)'s information shares approach provides a more proper measure of the amount of information generated by each market, both approaches have their own merits. In fact, the results obtained from the two approaches are similar so long as the residual correlations in the vector error correction model are relatively small. On the other hand, if the residuals between the markets are correlated, these two approaches provide different results. To make our results robust, we also quantify the contribution of each market to the price discovery process using the Hasbrouck information shares approach.

The Hasbrouck (1995) approach starts from the following vector moving average:

$$\Delta P_t = \Psi(L)\varepsilon_t \tag{6}$$

Where $P_t = (SH_t, LD_t, NY_t)'$ is a 3×1 vector, $\Psi(L)$ is a matrix polynomial in the lag operator. $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3,t})'$ is a zero-mean vector of serially uncorrelated disturbances with covariance matrix Π. $\Psi(1)$ is the sum of the moving average coefficients. $\Psi(1)\varepsilon_t$ constitutes the long-run impact of a disturbance on each of the prices. Let ψ denote the common row vector in $\Psi(1)$, and it can be shown that the elements of ψ sum to unity.

According to Hasbrouck (1995), $\psi\varepsilon_t$ is the permanent component of the futures price changes due to the arrival of new information. The variance of this term is $\sigma_f^2 = \psi\Pi\psi'$. If the covariance matrix Π is diagonal, then the information share of i^{th} market is given by $S_i = \psi_i^2\sigma_i^2 / \sigma_f^2$, where ψ_i is i^{th} element of ψ, and σ_i^2 is the i^{th} element in the diagonal of Π. If the covariance matrix Π is not diagonal, then S_i is not uniquely defined. Under this circumstance, Hasbrouck (1995) suggests a procedure to establish upper and lower bounds by using the Cholesky factorization of the covariance matrix. This is achieved by decomposing the covariance matrix Π into a lower triangular matrix F such that $\Pi = FF'$. The proportion of the new information contributed by each market i can be determined by $S_i = ([\psi F]_i)^2 / \sigma_f^2$, where $[\psi F]_i$ is the i^{th} element of the row matrix ψF. An upper (lower) bound for a market's information share can be obtained by permuting ψ and Π to place that market's price first (last).

Using both Gonzalo and Granger (1995) and Hasbrouck (1995) methods, we estimate the proportion of the new information attributable to each market in Table 7. Because the Shanghai market closes before London or New York market opens, we need to mitigate the problem caused by the non-synchronized data. We achieve this goal by averaging two price series, (SH_t, LD_t, NY_t) and (SH_{t+1}, LD_t, NY_t)[11].

Table 7 here

From Table 7, we find using the Gonzalo-Granger (1995) common factor approach that the SFE contributes about 25% of the price discovery and the NYMEX a little higher at about 29%, while the LME contributes about 47%. The LME still dominates in price discovery in the copper futures market. Though the information share attributable to the Shanghai futures market is the least of the three, it is not

[11] Using non-synchronized data can be a problem. To deal with this issue, we have created two data sets of time series, depending on the opening sequence of the exchanges. We average these two time series when applying Hasbrouck method to mitigate the non-synchronized data problem. Figuerola-Ferretti and Gilbert (2005) also has the non-synchronized data when studying price discovery in the COMEX and Sydney aluminum markets using Hasbrouck method. They try to mitigate the non-synchronized data issue by averaging daily data.

much different from the NYMEX. The relatively younger Shanghai Futures Exchange has grown into a significant market in recent years, and its information content should not be ignored by the participants in the world copper market[12]. Table 7 also contains the information shares estimated using the Hasbrouck (1995) model[13]. The average information shares attributed to the SFE, LME, and NYMEX are, respectively, 24%, 49%, and 27%[14]. The estimations are quite consistent with the numbers from the Gonzalo-Granger model. However, the upper and lower bounds of each market's information share are quite large, indicating that cross-market errors are probably highly correlated.

Apart from the long-run relationship among the futures prices of the three markets and their contribution to the common implicit efficient price, we can also examine the short-run price dynamics by using Granger causality tests. Table 8 lists the Granger causality tests of the bilateral combination of the three markets.

Table 8 here

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[12] Though foreign investors are not allowed to trade directly futures contracts on the SFE, copper futures prices of the Shanghai market are closely watched by traders around the world as China is the largest copper consumer and importer. The SFE futures prices partly reflect the demand and supply conditions in China and thus may contain information important to investors in other markets.

[13] High contemporaneous correlations are expected as a result of using daily data, which makes Hasbrouck method ineffective (See Baillie et. al., 2002). On the other hand, Baillie et. al. (2002) argues for using the mean of the bounds in Hasbrouck method to resolve the interpretational ambiguities. Many other papers applying Hasbrouck method to study price discovery use daily or even higher frequency data. For example, Ates and Wang (2005) uses daily data. Covrig, Ding and Low (2004) uses tick data. Roope and Zurbruegg (2002) uses 5-min series.

[14] We have also estimated the information contribution by each market using the electronic trading data from June 1, 2006 to December 31, 2008. We find that the information shares attributed to the SFE, LME and NYMEX are 22.9%, 52.8%, and 24.2%, respectively.

The statistics in Table 8 reject the null hypothesis that past prices of one market do not affect the current prices of another market. We conclude that there is a two-way Granger causality for every pair of prices. But the F-statistics seem to suggest that the London market or New York market has a stronger impact on the Shanghai market than the Shanghai market has on London or New York. These conclusions are consistent with the finds when we evaluate the information contribution by each market using the Gonzalo and Granger approach or the Hasbrouck approach.

Conclusion

This paper investigates the price discovery process of the copper futures contracts traded on the three largest copper futures markets: the London Metal Exchange, the Shanghai Futures Exchange, and the New York Mercantile Exchange. Using both Gonzalo and Granger (1995) and Hasbrouck (1995) methods, we find that London still dominates in the price discovery process. The information attributable to London copper futures market is over 45%. Though a newcomer, the Shanghai Futures Exchange has grown to such an importance that it is no longer an irrelevant player in the world copper market. Given that the Shanghai Futures Exchange has already surpassed the New York Mercantile Exchange to become the second largest copper futures market, this result is largely expected. On the other hand, its information share in the price discovery process is still smaller than the New York market. While the information attributable to the New York market is close to 30%, the Shanghai market only contributes less than one quarter of the price discovery.

The information content of the SFE seems to be inconsistent to the role that China plays in the copper consumption market as well as in the copper trading volume. One possible reason is that the Chinese futures market is still not completely open to the outside. Foreign investors are not allowed to participate in futures trading directly in China. Another reason is the lack of institutional investors in the Chinese futures market. By the end of 2007, there were only total 4280 institutional accounts, or only 2.18 percent of the total accounts. These suggest that there is still room for improvement in efficiency in the Chinese futures market. Opening the Chinese futures market to global institutional investors probably will enhance its price discovery role in the world copper market.

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Table 1 Floor Trading Time of Copper Futures Contracts

Exchanges	Opening	Closing	Contract Months
SFE	9：00	15：00	1-12 months
LME	20：00	0：55*	3, 15, 27 months
NYMEX	21：10	2：00*	1-12 months

Note：All have been converted into Beijing time.

*represents the time in the next day.

Table 2 Descriptive Statistics of Futures Returns

	SFE	LME	NYMEX
Mean	0.000129	0.000154	0.000157
Median	0.00	1.21E-05	0.00
Standard deviation	0.0149	0.0176	0.0185
Skewness	-0.2113	-0.6658	-0.7640
Kurtosis	5.36	13.99	13.02
JB	616.55 [0]	13114.65 [0]	1106.73 [0]
$Q(24)$	83.89 [0]	89.22 [0]	82.68 [0]
$Q^2(24)$	4158.30 [0]	1326.90[0]	957.67 [0]

Note: the yield changes equal $\ln(C_t)-\ln(C_{t-1})$, where C_t denotes the closing price on day t. JB denotes Jarque-Bera statistics. Q(24) denotes the 24 lag Ljung-Box Q-statistics for serial correlation. Values in square brackets are corresponding probabilities.

Table 3 Comparison of Volatilities in Trading and Non-trading Period

	SFE	LME	NYMEX
Volatility during the trading period	1.71E-04	1.44E-04	1.53E-04
Volatility during the non-trading period	683.39E-04	1.30E-04	1.42E-04

Table 4 ADF Unit Root Tests

	SFE	LME	NYMEX
F_t	-0.99	-0.98	-0.95
ΔF_t	-19.90	-21.84	-21.99

Note: the critical value for 5% level of significance is -2.86 with no trend.

Table 5 Cointegration Test of the Price Series (SH_t, LD_t, NY_t)

Null Hypothesis	λ_{trace}	5% Critical Value	1% Critical Value	λ_{Max}	5% Critical Value	1% Critical Value
$r \leq 0$	173.75	29.68	35.65	129.18	20.97	25.52
$r \leq 1$	44.57	15.41	20.04	43.60	14.07	18.63
$r \leq 2$	0.97	3.76	6.65	0.97	3.76	6.65

Note: λ_{trace} *and* λ_{Max} *are the statistics for the trace test and maximum eigenvalue test, respectively. We use Akaike Information Criterion (AIC) to select the lag length.*

Table 6 Error Correction Model, Based on Equations (1) – (3)

Explanatory Variables						
	（1） ΔSH_t		（2） ΔLD_t		（3） ΔNY_t	
参数	Coefficient	t -stat	Coefficient	t -stat	Coefficient	t -stat
μ	0.0041	3.89	-0.0061	-4.32	-0.0061	-4.02
$\alpha_{.1}$	-0.2978	-14.44	0.4892	18.07	0.4918	16.92
$\alpha_{.2}$	-0.0109	-0.64	0.2500	8.94	0.3015	10.04
$\beta_{.1}$	0.2500	6.68	-0.4654	-9.23	-0.1053	-2.49
$\beta_{.2}$	0.1072	3.21	-0.2215	-5.03	-0.0387	-0.82
$\gamma_{.1}$	0.2604	7.17	0.1294	2.63	-0.3263	-6.19
$\gamma_{.2}$	0.0853	2.65	0.0636	1.47	-0.1504	-3.24
κ	-0.0704	-2.37	-0.0323	-3.90	-0.0436	-2.99
θ	0.1065	3.58	0.1732	4.19	-0.0393	-4.42

Table 7 Contribution of Each Market to Price Discovery（%）

	SFE	LME	NYMEX
Common Factor Weight	24.69	46.75	28.56
Information Shares Approach			
Upper bound	81.26	99.30	83.51
Lower bound	0.77	8.61	0.85
Mean Information Share	23.72	49.13	27.15

Note: Common factor weights are calculated based on the Gonzalo-Granger approach. Information shares are estimated using the Hasbrouck model.

Table 8 Granger Causality Tests

Null Hypothesis	F-stat	P value
SFE does not cause LME	8.82	0
SFE does not cause NYMEX	11.36	0
LME does not cause SFE	331.34	0
NYMEX does not cause SFE	354.33	0
LME does not cause NYMEX	30.68	0
NYMEX does not cause LME	8.48	0