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How Informationis Transmitted Across the Nations? An Empirical Investigation of the US and Chinese Commodity Markets

By Zi-Yi Guo

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I. Introduction

The recent financial crisis had witnessed the importance of global coordination for the world economy recovery. Therefore, it would be valuable to study how information is transmitted and shared across the nations. Recently, the term "informationally linked markets" has gained much attention in academia (see Gao and Liu, 2007 and Li and An, 2011). The term refers to markets within which traded assets are fundamentally related to each other. While informationally linked markets are interrelated, they have distinct factors, such as regulations, liquidities, transaction costs, that can affect the price discovery process. Thus, it is important to understand how those informationally linked markets interact with each other through the price discovery process, especially in nowadays when the world economy has never been as integrated. The research in this paper is based on two informationally linked markets: Chinese futures market and U.S. futures market.

Being the world's two major economies, markets in the two countries are, without doubt, interrelated. U.S.-China economic ties have expanded substantially over the past three decades. Total U.S.-China trade rose from $2 billion in 1979 to $579 billion in 2016[1]. China is currently the largest U.S. trading partner, its third-largest export market, and its biggest source of imports. Frequent import and export activities between the two trading partners have significant impact son their spot markets, which, in turn, influence the futures markets. Apart from the international trading connections, there are other reasons that make the futures markets of the two countries interrelated. One is that the futures exchanges in the two countries have more similar than different technological trading system and management arrangement. At the very beginning of China establishing its first futures exchange, it frequently sends expertise to the Chicago Board of Trade and other exchanges to learn both the executive of exchanges and the technology of futures trading from the US. This grants not only the successful establishment of several major futures exchanges in China, but also the two counterparts correlated in many ways. However, there are still significant governmental and legal barriers regarding China's financial market. Studying such a relationship could shed light on the openness of the Chinese commodity markets and on the nature of cross-market information transmission. It could also provide important lessons for various market participants, including commodity traders, hedgers, arbitrageurs, exchanges and regulatory agencies.

II. Literature Review

Without doubt, information spill-over across different markets aroused the interest of researchers in the past few years. Much of the empirical research has focused on the relationship between two countries' equity markets. Garbade and Silber (1979) first conduct the research of short run price behavior of identical assets traded on dominant and satellite markets: NYSE and regional stock exchanges. The results indicate that the regional exchanges are best characterized as satellites, but not pure satellites of the New York Stock Exchange. That is to say, transactions price son regional exchanges do contain information relevant for NYSE traders, but knowledge of the prices of their transactions has effect on the New York market, too. Booth et al. (1996) have studied the relationship among the cross-

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[1] Source: US-China Business Council.

exchange prices of Nikkei 225 Index futures that are traded on the Singapore International Monetary Exchange (SIMEX), London International Financial Futures Exchange (LIFFE) and Chicago International Money Market (IMM). They find that the prices of Nikkei 225 Index futures are cointegrated across all of these exchanges. More recent researches on information transmissions are conducted cross border. Grammig and Hujer (2001) analyze equity price quotes originating in New York and Frankfurt to examine the price discovery process. The evidence suggests that there may be some roles for U.S. market price discovery, but the evidence is strongly supportive of prices largely being determined in the home market. Berument and Ince (2005) use a block recursive vector auto regression (VAR) model to capture the dynamic effect of S&P500 return on the Istanbul stock returns. They find that returns on S&P500 affect returns on ISE100 but not vice versa. By using the same model and two out-of-sample tests, Lin (2008) found that the US stock returns have predictive ability for four Asian emerging equity markets. The estimates from weekly data suggest that returns on S&P positively predict stock returns of emerging markets up to three weeks.

Similar factors that provide unique opportunities for the study of equity markets also apply to futures markets, and the same reasons that make this issue of interest to equity investors also make this issue of interest to hedgers and speculations in the future markets. However, not as many studies have analyzed the relationship between two countries' futures markets. Within this limited research, Booth, Lee and T se (1996) studied the relationship among the cross-exchange prices of Nikkei 225 Index futures that are traded on the Singapore International Monetary Exchange, London International Financial Futures Exchange and Chicago International Money Market. They found that the prices of Nikkei 225 Index futures are con integrated across all of these exchanges. Booth, Brockman and T se(1998) also investigated the price discovery and information transmittal process between US and Canadian wheat market using cointegration analysis and error correction models. The results show that both the US and Canadian wheat futures prices are an integrated series of order one, and that the two series are co-integrated. The evidence shows an equilibrium relationship only in long run, while short run dynamics exhibit no such dependencies. Two previous articles have employed the GARCH-type models to examine the daily volatility spillovers between the S&P 500 Index cash and futures markets. Chan, Chan and Karolyi (1991) use abivariate GARCH model with a sampling interval of five minutes. They find the extent of volatility spillover from the futures to stock market similar to that of the stock to futures market and the futures and stock markets serve important and equal price discovery roles. In another article, Koutmos and Tucker(1996) use daily closing prices from 1984 to 1993 and a bivariate EGARCH model. In contrast to the current article and Chan, Chan, and Karolyi (1991), they report aunivariate directional spillover from futures to index, and conclude that the information from the futures market can be used to predict the volatility in the stock market but not vice versa. Tse (1999) has investigated the minute-by-minute price discovery process and volatility spillovers between the DJIA index and the index futures recently launched by the Chicago Board of Trade (CBOT). By examining the volatility spillovers between the markets based on a bivariate EGARCH model, a significant bidirectional information flow is found. Then, Tse and So (2004) have examined the price discovery and spillovers effects among the Hang Seng Index, Hang Seng Index futures, and the tracker fund markets using the Hasbrouck and Gonzalo and Granger common-factor models and the M-GARCH model. The empirical results show that the three markets have different degrees of information processing abilities, although they have cointegrating relationship between each other.

Despite its late introduction into China, Chinese futures markets have grown rapidly and are now playing a significant role in the world commodity markets. Only in the past few years have we seen the emergence of some research. Among those studies, few have focused on the relationship of price discovery among internationally linked markets.

Hua and Chen (2007) studied the relationship between the Chinese and world futures markets of copper, aluminum, soybean and wheat, using Johansen's cointegration test (1988), error correction model, the Granger causality test and impulse response analyses. They discovered that the futures prices in the Shanghai Futures Exchange are cointegrated with the futures prices on the London Metal Exchange (LME) for copper and aluminum. They also find that a cointegration relationship exists for the Dalian Commodity Exchange and CBOT soybean futures prices, but no such relationship for the Zhengzhou Commodity Exchange and CBOT wheat futures prices. Li and Zhang (2009) examined the relationship between the Chinese copper futures market and its London counterparts by constructinga three-regime Markov switching-VECM model. They found that the influence of LME on SFE is bigger than that of SFE on LME. More recently, Hou and Li (2015) used an asymmetric DCC GARCH model to investigate information transmission between U.S. and China index futures markets, and Chen and Weng (2017) applied a VAR-BEKK-Skew-t Model to investigate information flows between the U.S. and China's agricultural commodity futures markets.

In this paper, I use three important futures contracts that are similarly listed on both the U.S. and China markets (copper, soybeans and wheat) to examine the pattern of information flows across the two countries. This study will help us understand more about the role of the U.S. market as a global player in transmitting information flows as the Chinese financial market is becoming an important emerging market in commodity futures trading. With the growth of world trade and globalization of the futures market, we would expect futures prices for the same commodity in different parts of the world to move closely together to reflect the information flows underlying the commodity price.

This paper is different from previous researches in the following ways. First, instead of using market index, as did by most previous research, I choose daily information of individual commodity futures contracts. Market Index is, to some degree, smoothed because it contains different trading products that may be negatively correlated. Individual data can be more volatile than market index. Second, I investigate information transmission not only from developed markets to emerging markets but also the other way around. The financial markets of emerging countries play a more and more crucial role in price discovery process of international markets. China's futures market is steadily expanding, and has become the second largest in the world after the US since 2009.This market presents an interesting case for research.

The remaining part of the paper is structured as follow. Section two provides a brief description of the Chinese futures markets and of the futures contracts that I choose to study. In Section three, I describe the data. Specifically, I select three commodity futures in the Chinese futures exchanges: copper, soybean and wheat. The Chinese copper futures contracts are traded on the Shanghai Futures Exchange (SFE), soybean futures contracts on the Dalian Commodity Exchange (DCE) and wheat futures contracts on the Zhengzhou Commodity Exchange (ZCE). For the corresponding world futures, I use copper, soybean and wheat futures contracts traded on the Chicago Mercantile Exchange (CME). In Section four, I test whether the Chinese and world futures prices are cointegrated. By introducing a Vector-Error-Correlation Model, I study the cointegration of commodity prices in the Chinese futures exchange and its U.S. counterparty. Section five concentrates on volatility spillovers and Section six concludes.

III. Chinese Agricultural Futures Markets and Contracts

a) Chinese agricultural futures exchange

There are three futures exchanges in China: the Zhengzhou Commodity Exchange (ZCE), the Shanghai Futures Exchange (SFE) and the Dalian Commodity Exchange (DCE).

Zhengzhou Commodity Exchange was the first experimental futures market which was approved by the State Council, established on October 12, 1990. ZCE, which started with forward contract trading, launched its first futures contracts on five agricultural products - wheat, corn, soybean, green bean and sesame on May 28, 1993. Wheat futures dominated trading on ZCE. Though China's tariff rate on wheat imports is set at a very low level (1% since 1999), its import quota is highly restrictive. Quota and permits are required to import wheat. All imports have to go through the China National Cereals, Oils and Foodstuffs Import and Export Corp.ZCE now specializes in agricultural and chemical product futures, including hard white wheat, strong gluten wheat, sugar, cotton, rapeseed oil and PTA, a petroleum-based chemical product.

SFE was formed from amalgamation of the Shanghai Metal Exchange, the Shanghai Foodstuffs Commodity Exchange, and the Shanghai Commodity Exchange in December 1999. At present, futures contracts underlying commodities, i.e., gold, copper, aluminum, lead, steel rebar, steel wire rod, natural rubber, fuel oil and zinc, are listed for trading. These commodities are regarded by the Chinese government as strategically important industrial inputs and are thus subject to no import quotas or duties. Export of these commodities is still restricted, though export duties have been reduced significantly since 1999.

DCE trades futures contracts underlined by a variety of agricultural and industrial products on a national scale. So far, futures contracts on agricultural products including soybean, soybean oil, corn, palm oil, and soy meal, petroleum-based products including LLDPE and PVC, and energy product coking coal are traded on the Dalian bourse. Soybean futures dominate trading volume son DCE.

All three exchanges use electronic trading systems. Each exchange also maintainsa trading floor. Trades are cleared by each exchange's clearing department. The trading systems all utilize high-capacity optical cables, dedicated datelines and two-way satellite to ensure real time, security and reliability of order processing. I choose representative contracts from each of the three exchanges for studying cointegration of the Chinese futures market and the U.S. futures market.

b) Chinese agricultural futures underlying products

i. *Copper*

During the last 10 years, the Chinese copper consumption has grown at about 2.4 times the world average. China is now the largest copper consumer in the world. Consequently, the trading volume in terms of tonnage on the SFE has grown to a level that almost rivals that of the NYMEX, the second largest copper futures exchange next to the LME. In 2010, the ratio of trading volume in the three exchanges is 0.5: 1: 2.9. Prices of copper futures traded on SFE, together with the prices on LME and NYMEX, are now important indicators to copper mining companies around the world.

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ii. *Soybean*

China abolished its import quota on soybeans in 1996, but its export quota still exists. China is now the world's largest soybean importing country, while the USA is the largest soybean producer and exporter. Conditions in the USA soybean market, combined with USA agricultural trade policy, can presumably have a significant impact on soybean prices in the Chinese market. The Dalian Commodity Exchange is the largest futures exchange for non genetically modified (non GM) soybeans in the world. In 2002, the trading volume of soybean futures on DCE was over$250 billion, about 25% of the CBOT soybean futures volume but seven times that of the third largest market, the Tokyo Grains Exchange. In 2010, however, DCE exceeds the Chicago Mercantile Exchange (CME) in terms of soybean (both GM and non GM) futures trading volume. Therefore, it is reasonable to hypothesize that US soybean futures prices can also influence Chinese soybean futures prices in a significant way.

iii. *Wheat*

China produces approximately 108,712 TMT[2] (thousand metric tons) of wheat annually. This makes China the world's largest wheat producer. At the same time, China is the world's seventh largest importer of wheat, importing an average of 4,247 TMT of wheat. This is because China has a population of over 1.3 billion people, and domestic consumption in China may surpass its production. Another reason is that variability in production and quality issues also compel China to import a certain quantity of wheat.

Winter wheat is the kind that China imports from the U.S. The United States is the third largest producer of wheat in the world. On average, the United States produces 62,550 TMT of wheat. United States imports, on average, 2,584 TMT and it exports 28,547 TMT, making the U.S. the largest wheat-exporting nation in the world.

The futures market of wheat indicates the demand and supply in the spot market. The futures prices are even more sensitive to import. For example, on December 20th, 2001,a U.S. exporter claimed to have sold 200TMT soft red winter wheat to China. The price of soft wheat futures traded in CBOT soured and reached a historical high level. The characteristics of the wheat markets in China and U.S. represent a possible interactive relationship between the two markets.

Government policy affects patterns of information flows. The commodities copper, soybean and wheat are subject to different levels of government regulation in China. Table 1 displays the import duty and value added tax for copper, soybean and wheat imports to China. Agricultural products such as soybean and wheat evidence stronger protection from government compared with copper. Moreover, different from soybean and copper, wheat has an import quota that has been set at 9.64 million tonnes. The import duty that excess quota is 65%.

Table1: Import duty and value added tax of copper, soybean and wheat in China.

Commodity	Import duty			
	most favored nation		Regular	Valued added
	within quota	excess quota		
copper	No quota	0%	0%	17%
soybean	No quota	3%	180%	13%
wheat	1%	65%	180%	13%

IV. Data and Summary Statistics

a) Data

I chose copper, soybean and wheat futures contract traded on SFE, DCE and ZCE respectively and all three contracts traded on CME. The three contracts are all among the first futures contracts listed in the futures exchanges and they have been very actively traded since then. Table 2 summarized the characteristic of futures contracts traded in different exchanges.

Using daily settlement prices, similar as in Guo (2016) I constructed a nearby futures price series. Futures' series are different from equity's because futures are of different contracts and equity is a continuous time series itself. The method is as following: first, identify the nearby futures contract, which is the nearest actively traded contract to spot month. Then use the settlement prices of the nearby contract until it reaches the first day of delivery month. At this point, we use the contract of the next nearby month. The reason to use nearby contracts is that they are the most actively traded and liquid contracts.

[2] (source: http://www.fao.org/statistics/en/)

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Table 2: Structures of the futures contracts of copper, aluminum, soybean and wheat traded in CME, SFE, DCE, and ZCE

Commodit	Copper		Soybean		Wheat	
Exchange	CME	SFE	CME	DCE	CME	ZCE
Trading Unit	25,000 pounds	5 tons	5,000 bushels	10 tons	5,000 bushels	10 tons
Pricing Unit	U.S. Cents/pound	Yuan/ton	U.S. Cents/pound	Yuan/ton	U.S. Cents/pound	Yuan/ton
Tick Value	0.05 Cents/pound	10 Yuan/ton	0.025 Cents/pound	1 Yuan/ton	0.025 Cents/pound	1 Yuan/ton
Daily Price limit	N/A	< 3% of previous settlement price	N/A	< 4% of previous settlement price	N/A	< 4% of previous settlement price
Contract Month	January-December	January-December	January, March, May, July, August, September, November	January, March, May, July, August, September, November	March, May, July, September, December	January, March, May, July, August, September, November
Termination of Trading	3rd last business day of the trading month	15th of the trading month	15th of the trading month	10th of the trading month	15th of the trading month	last 7th trading day of the trading month
Delivery Period	Any business day beginning on the first day of delivery month	16th to 22th of the trading month	2nd business day folling the last trading day of the delivery month	7th day after the last trading day of the trading month	2nd business day following the last trading day of the delivery month	1st to last trading day of the trading month
Settlement Type	Physical delivergy	Physical delivergy	Physical delivergy	Physical delivergy	Physical delivergy	Physical delivergy
Trading Hours	CME Globex:		CME Globex:		CME Globex:	
	Sunday-Friday, 6:00pm-5:15pm (5:pm-4:15pm Central Time) with a 45-minute break each day beginning at 5:15pm (4:15 CT)	Monday-Friday, 9:00am-11:30am, 1:30pm-3pm	Sunday-Friday, 6:00pm-7:15pm, 9:30am-1:15pm	Monday-Friday, 9:00am-11:30am, 1:30pm-3pm	Sunday-Friday, 6:00pm-7:15pm, 9:30am-1:15pm	Monday-Friday, 9:00am-11:30am, 1:30pm-3pm
	CME ClearPort:		Open Outcry:		Open Outcry:	
	Sunday-Friday, 6:00pm-5:15pm (5:pm-4:15pm Central Time) with a 45-minute break each day beginning at 5:15pm (4:15 CT)		Monday-Friday, 9:30am-1:15pm Central Time		Monday-Friday, 9:30am-1:15pm Central Time	
	Open Outcry:					
	Monday-Friday, 8:10am-1:00pm (7:10am-12:00pm Central Time)					

Because of the availability of data, the time periods I chose for the three contracts are not the same. Data of copper futures used by this paper are the daily settlement prices from 2 January 2008 to 15September 2011 obtained from the website of the Shanghai Futures Exchange and Wiki posit. Data of soybean futures are the daily settlement prices from 4 January 2006 to 30December 2011 obtained from the website of the Dalian Commodity Exchange and Wiki posit. As of wheat futures, I used the daily settlement prices from 4 January 2006 to 30 October 2009 obtained from the website of the Zhengzhou Commodity Exchange and Wiki posit.

In order to make the data comparable, I deleted non matching data caused by different holidays and consolidated the quotation units of the data. Quotation unit for copper futures contracts traded on CME is US cents/pound and quotation units for soybean and wheat on CME are US cents/bushel. All Chinese futures contracts are quoted as Yuan/ton. I converted the quotations for copper to US dollar/pound and quotations for soybean and wheat to US dollar/ton. I use daily exchange rate to convert Chinese Yuan to US dollar. The historical exchange rate data is obtained from Wiki posits.

Table 3: Symbols

CCU	Copper futures traded on Chicago Mercantile Exchange (CME)
SCU	Copper futures traded on Shanghai Futures Exchange (SFE)
CSS	Soybean futures traded on Chicago Mercantile Exchange (CME)
DSS	Soybean futures traded on Dalian Commodity Exchange (DCE)
CWT	Wheat futures traded on Chicago Mercantile Exchange (CME)
ZWT	Wheat futures traded on Zhengzhou Commodity Exchange (ZCE)

b) Summery Statistics

Table 4 presents the descriptive statistics of copper, soybean and wheat contracts traded in China and the US. We notice that the prices are not normally distributed. Rather, copper and soybean prices are negatively skewed and wheat prices are positively skewed. All the excess kurtosis of the six time series is negative, which is at odds with conventional wisdom of heavy-tailed distribution for financial data, such as in Babbs and Guo (2016). Copper and soybean futures in China and US are significantly positively correlated.

Table 4: Descriptive statistics

Commodity	Copper		Soybean		Wheat	
Location	US	China	US	China	US	China
Mean	3.6739	3.2288	372.2443	536.2280	218.8540	223.6881
Standard Error	0.0308	0.0289	2.6595	3.5463	2.4161	1.2557
Standard Deviation	0.8928	0.8367	99.7564	133.0219	72.3209	37.5869
Kurtosis	-0.5095	-0.5798	-0.9677	-0.5761	-0.0007	-1.3925
Skewness	-0.5681	-0.5784	-0.0458	-0.2057	0.8735	0.1238
Correlation	0.99057285		0.938801729		0.3734	

Figure 1 to Figure 3 plot the price moving trend of copper, soybean and wheat futures. From the trend above, we can see similar moving patterns for copper and soybean futures, which indicate a long run relationship. However, there seems to be no such pattern in wheat futures.

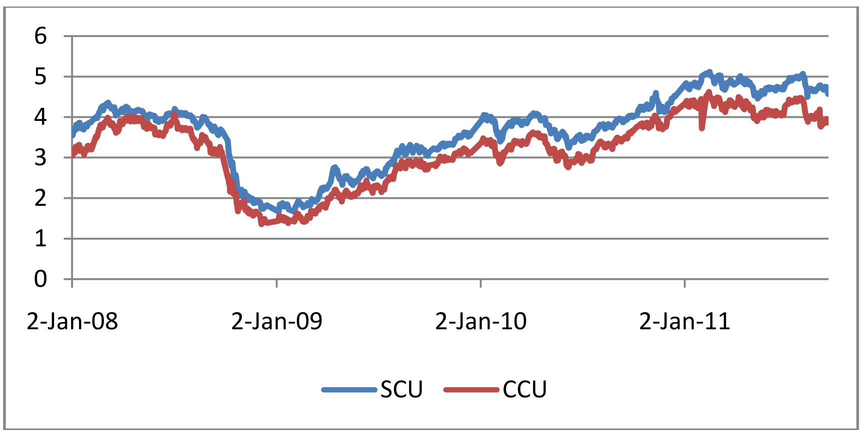

Figure1: Price dynamics of copper futures

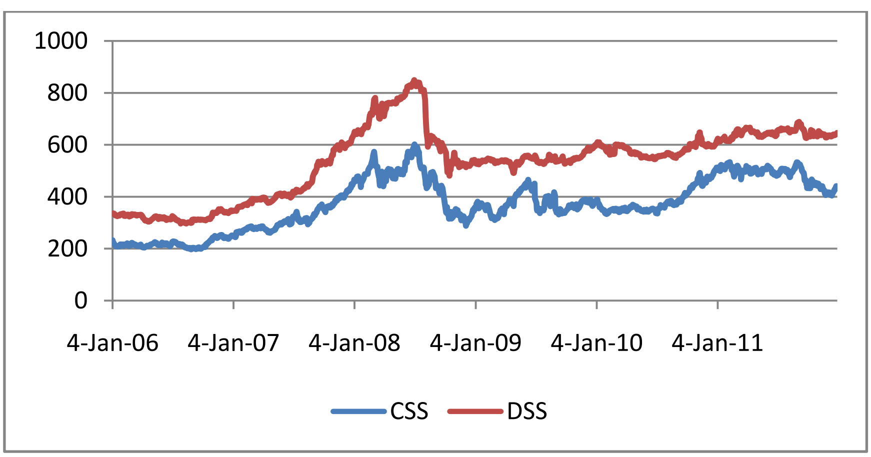

Figure 2: Price dynamics of soybean futures

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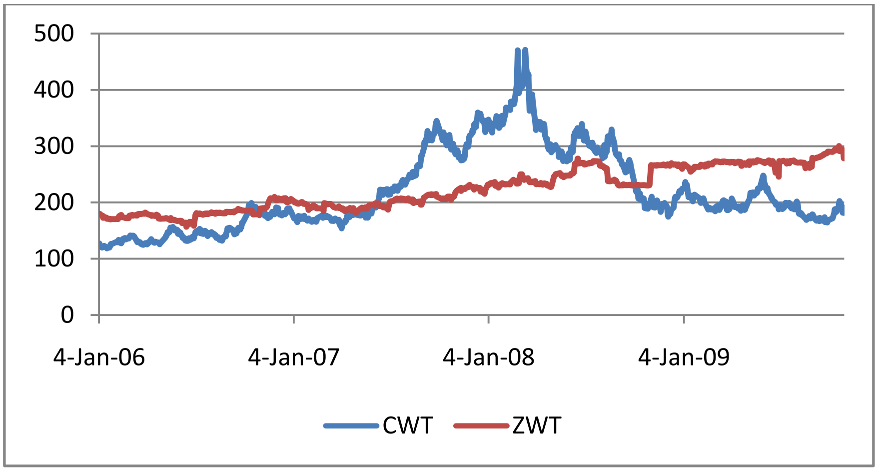

Figure 3: Price dynamics of wheat futures

IV. Methodology

a) *Cointegration Test*

Before testing for cointegration, each individual price series should be examined for I(1) first. The commonly used methods to test for the presence of unit roots are the Augmented Dickey-Fuller (ADF) unit root tests (1981). ADF test correlation by assuming that the series follow an AR(p) process and adding lagged difference terms of the dependent variables. Unit root can be tested by the ADF model, which is primarily concerned with the estimate ofθ. In the following equation, wetest the null hypothesis of $\theta = 0$ against the alternative hypothesis of$\theta < 0$:

$$\Delta y_t = \mu + \delta t + \theta y_{t-1} + \sum_{i=1}^{k} \rho_i \, \Delta y_{t-1} + \varphi_t,$$

Where Δ denotes the first difference, $y_t$is the time series being tested, *t* is the time trend variable, and *k* is the number of lags which are added to the model to ensure that the residuals, φ_t are white noise. The result of not rejecting the null hypothesis implies that the series is non-stationary; whereas rejection of the null indicates the time series is stationary. If the series is non-stationary and the first difference of the series is stationary, the series contains a unit root.

If the futures prices are integrated of the same order, in this case, I (1), Johansen's cointegration tests can then be conducted.

$$\Delta Y_t = c + \exists Y_{t-1} + \sum_{i=1}^{k-1} \cup_i \, \Delta Y_{t-i} + \delta_t,$$

Where Δ is a symbol of difference operator. $\delta_t$is a 2*1 vector of residuals. The VECM has information about the short-and long-run adjustment to changes in Y_t via the estimated parameters $\exists$and $\cup_i$. Here, the expression $\exists Y_{t-1}$ is the error correction term and $\exists$ can be factored into two separate matrices$\alpha$and β, such as $\exists = \alpha\beta'$ where β' denote the vector of cointegrating parameters while α is the vector of error correction coefficients measuring the speed of convergence to the long run steady state.

Johansen suggested two test statistics to test the null hypothesis that there are at most *r*cointegration vectors. The null hypothesis is the rank of the coefficient matrix: $\exists$, is at most r, for r = 0, 1, L … n -1 . The cointegration test is done by applying the methodology proposed by Johansen (1988) based on the trace and maximal eigen value statistics.

$$\tau_{trace} = -T \sum_{i=r+1}^{n} \ln(1 - \tau_i)$$

$$\tau_{max-eigen} = -T ln(1 - \tau_{r+1})$$

where$\tau_1 \ldots \tau_r$ are *r* largest squared correlations between the residuals obtained by regressing ΔY_t andΔY_{t-1}on $\Delta Y_{t-1}, \Delta Y_{t-2}, \ldots \Delta Y_{t-k-1}$ and 1. In this case, the null hypothesis should be tested for r≤0 and r≤1. If r≤0 cannot be rejected, we will conclude that there is no co integration. If r≤0 is rejected and r≤1 is not rejected, it says that there is a co integration relationship.

b) *Vector Error Correction Model*

This section presents the Vector Error Correction model (Engle and Granger, 1987) to analyze price transmission between markets in the two countries. If futures contracts traded in China and US are co integrated, they can be represented by the following model:

$$\Delta UF_t = a_1 + b_1 Z_{t-1} + \sum_{i=1}^{p} c_{1,i} \, \Delta UF_{t-i} + \sum_{i=1}^{q} d_{1,i} \Delta CF_{t-1} + \epsilon_{1,t} \quad (1)$$

$$\Delta CF_t = a_2 + b_2 Z_{t-1} + \sum_{i=1}^{p} c_{2,i} \, \Delta CF_{t-i} + \sum_{i=1}^{q} d_{2,i} \Delta UF_{t-1} + \epsilon_{2,t}. \quad (2)$$

UF and CF represent the daily prices of futures traded in Chinese and US futures markets respectively. $Z_{t-1} = UF_{t-1} - \vartheta CF_{t-1}$, is the error correction term and $\epsilon_{1,t}$ and $\epsilon_{2,t}$ are white noise.

This approach is widely used in the literature to describe price interactions among various informationally linked markets (see Booth et al., 1999), as it captures both short and long term effects of information flow across markets. In particular, short term effects are captured by cross market lagged returns in the equations and long term effects are reflected long term equilibrium error correction terms, defined as the difference in the last period's price between the two markets. One important thing is to understand that price discovery refers to the impounding of new information into the price. When one market is considered leading the other in information transmission, it means information disseminates first in this market. However, it does not necessarily imply that this market is the original source of information.

c) Volatility spillovers

Volatility is another important source of information. An examination of volatility spillover can help us further in understanding information transmission process across markets. Considering a multivariate GARCH (1,1) model:

$$\sigma_{1,t}^2 = \omega_1 + \alpha_1 \sigma_{1,t-1}^2 + \beta_1 \varepsilon_{1,t-1}^2 + \gamma_1 \varepsilon_{2,t-1}^2 \quad (3)$$

$$\sigma_{2,t}^2 = \omega_2 + \alpha_2 \sigma_{2,t-1}^2 + \beta_2 \varepsilon_{2,t-1}^2 + \gamma_2 \varepsilon_{1,t-1}^2. \quad (4)$$

The terms ε_1 and ε_2 in the above equations are residuals from equation (1) and (2). In equation (3) and (4), the conditional volatility is influenced not only by past residual shocks from its own market, but also by those from the other market. Volatility spillover are measured by coefficients γ_1 and γ_2.

V. Empirical Results

Cointegration analysis is conducted to detect long-run and short-run relationship before examining the price discovery process and volatility spillover. Based on the AIC criterion, I find the model has lowest AIC at two lags. ADF unit root tests are done before the cointegration tests.

Table 5 presents the result of ADF unit root tests. It indicates the existence of unit root in each of the log futures price series. Further, test result shows that all the series are stationary after the first order difference, which indicates that all the time series follow *I*(1) process.

Table 5: The Augmented Dickey-Fuller (ADF) unit root tests

	copper		soybean		wheat			critical values		
no trend	CCU	SCU	CSS	DSS	CWT	ZWT		1% level	5% level	10% level
log prices	0.0418	0.3050	0.8052	1.2143	0.3601	1.207		-2.567	-1.941	-1.617
First difference	-33.5057	-27.6224	-36.7441	-17.9937	-29.815	-34.238				
with trend	CCU	SCU	CSS	DSS	CWT	ZWT		critical values		
log prices	-1.4007	-1.2911	-1.7931	-1.3637	-1.1956	-3.938		-3.965	-3.413	-3.129
First difference	-33.4824	-27.6187	-36.7486	-17.0552	-29.860	-34.252				

Since all the time series of futures prices follow I (1), I can test the cointegration relationship across markets. The results of cointegration test for the copper, soybean and wheat futures price data series are presented in table 6. For copper futures, both the trace and maximal eigen value tests significantly reject the null hypothesis of none cointegration vectors, whereas the test fails to reject the null hypothesis of one cointegration. For soybean futures, there is one cointegration equation at 5% significant level according to the trace test, but no cointegration relationship has been detected based on the maximal eigen value test There is no cointegration relationship for Wheat futures.

Table 6: The Johansen con integration test

	Null Hypothesis	Statistics		5% critical value	
		trace	max-eigen	trace	max-eigen
copper	r≤0	28.56144*	27.57577*	15.4947	14.2646
	r≤1	0.985674	0.985674	3.8415	3.8415
soybean	r≤0	16.09256*	13.9663	15.4947	14.2646
	r≤1	2.126257	2.126257	3.8415	3.8415
wheat	r≤0	4.651628	3.57155	15.4947	14.2646
	r≤1	1.080078	1.080078	3.8415	3.8415

This result is consistent with results from previous research. Hua and Chen (2007) examine the co integration relationship using data ranging from January 1998 to 31 December 2002 and January 1998 to 31 December 2004. They both receive that result of no cointegration of wheat futures between China and US. Since wheat is the staple food in China and the government has more control over it than other commodity products, it is not hard to understand the non-cointegration relationship.

Estimation result from the VECM model for copper futures series are reported in Table 7. A number of observations can be derived from the estimation results. First of all, at a 5% significant level, only the coefficient of error correction term in SCU equation is significant. This implies that the error correlation term is important in explaining the price discovery process for Chinese copper futures market. This demonstrates the leading role of US copper futures market in processing information. In equation (2), the coefficients of both lags of US copper futures market are significant at 1%. We can interpret from this result that US market has an impact on the price discovery process of Chinese copper futures market. In equation (1), the coefficient of first lag of SCU is significant at 1% and the coefficient of second lag is not. This implies that Chinese copper futures market has a shorter term lagged impact US copper futures market than US to China. Another interesting finding is the impact that the past information has to its own country is negative whereas the impact to the other country is always positive.

Table 7: VECM estimation results for copper futures; ** refers to 5% level of significance.

Dependent Variables	Explanatory variables			
	ΔCCU		ΔSCU	
	Coefficient	t-stat	Coefficient	t-stat
Z_{t-1}	-0.032	-1.190	0.069**	3.879
ΔCCU_{t-1}	-0.207**	-4.727	0.360**	12.476
ΔCCU_{t-2}	-0.085	-1.912	0.170**	5.797
ΔSCU_{t-1}	0.159**	2.745	-0.218**	-5.725
ΔSCU_{t-2}	0.072	1.480	-0.008	-0.250
c	0.001	0.308	0.001	0.465

Table 8 presents the VECM result of soybean futures market. At a 5% significant level, coefficients of error correction term in both equations are significant, -0.012 (t-value = -1.981) and 0.008 (t-value = 2.516). This indicates a bidirectional error correction process between the two futures markets. In both equations, only coefficients of first lag across market impact are significant. The impact from U.S. soybean market to Chinese soybean market is bigger than the other way round.

Table 8: VECM estimation results for soybean futures; ** refers to 5% level of significance.

Dependent Variables	Explanatory variables			
	ΔCSS		ΔDSS	
	Coefficient	t-stat	Coefficient	t-stat
Z_{t-1}	-0.012	-1.981**	0.008**	2.515
ΔCSS_{t-1}	0.048	1.699	0.213**	14.503
ΔCSS_{t-2}	0.007	0.218	0.026	1.663
ΔDSS_{t-1}	-0.124**	-2.366	-0.633**	-2.292
ΔDSS_{t-2}	0.090	1.836	0.053**	2.071
c	0.0005	0.916	0.0004	1.326

The overall results of VECM in both copper and soybean futures markets show that the U.S. and Chinese markets are informationally linked on daily price basis. There is a bidirectional relationship between the two markets and the relationship is asymmetric. US copper and soybean futures market has a stronger impact to Chinese soybean and copper futures market than Chinese market to U.S. market.

Table 9: GARC Hestimation results for copper futures; **refers to 5% level of significance.

copper			
Variable	Coefficient	z-Statistic	Prob.
ω_1	0.000114**	6.864283	0.00000
β_1	0.134492**	3.090528	0.00200
α_1	0.420052**	7.938181	0.00000
γ_1	0.699133**	8.77136	0.00000
ω_2	-0.0000012	-0.736315	0.46150
β_2	0.023959	1.448998	0.14730
α_2	0.739359**	35.63051	0.00000
γ_2	0.105589**	8.721536	0.00000

The coefficients of importance in the bivariate GARCH (1, 1) model are γ_1 and γ_2. They capture the volatility spillover from one market to the other. In Table 9, the corresponding volatility-spillover coefficients are all significant at 5% significance level. This result implies strong interactions between the two countries' copper futures markets. Table 10 represents the volatility spillover for the soybean markets. Different from copper futures, we can see that there is no significant feedback effect between the two markets for soybean futures.

Table10: GARCH estimation results for soybean futures; **refers to 5% level of significance.

soybean			
Variable	Coefficient	z-Statistic	Prob.
ω_1	0.000132**	5.057478	0.00000
β_1	0.737435**	7.579515	0.00000
α_1	0.259663**	5.343434	0.00000
γ_1	0.000136	0.255335	0.79850
ω_2	0.000127**	5.184467	0.00000
β_2	0.791866**	7.241912	0.00000
α_2	0.213742**	3.485253	0.00050
γ_2	0.001048	0.804272	0.4212

VI. Conclusion

Given the rapid development of the Chinese futures market and the competition and cooperation among futures exchanges, it is important to understand the international linkage between the Chinese futures market and other international futures markets. This paper examines the price discovery process and volatility spillover in the Chinese futures market and the U.S. futures market. In particular, I investigate the lead-lag relationships using the VECM model and the GARCH (1,1) models. By choosing one representative futures contract, I find a consistent result with previous research about the information transmission process. It shows that the price series of copper futures and soybean futures are cointegrated across markets. For copper futures, there is a bidirectional relationship between the two markets and the relationship is asymmetric. The US copper futures market has a stronger impact on the Chinese copper futures market than the other way around. As for the soybean futures, there is a one-lag price transmission across markets. However, no volatility spillover has been found for soybean futures markets. Wheat futures traded in the two countries are not cointegrated. The Chinese wheat futures prices are more likely to be determined by domestic demand and supply condition. This is consistent with the observation that imports and exports of wheat are highly restricted with high tariff rates and quotas in China.

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