

PRICE DISCOVERY FUNCTION OF CORN FUTURES MARKET:

A COMPARATIVE STUDY OF U.S. AND CHINA

by

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(Under the direction of Cesar Escalante)

ABSTRACT

Price discovery is the process whereby the futures market formulates an asking price by gathering and interpreting information on supply and demand. It is one of the most important functions of futures market, especially for agricultural commodities. Much research has been done on price discovery in a variety of markets, but most of them were restricted in one area. This study compares the effectiveness of the price discovery function for corn futures markets in the U.S. and China. Monthly spot prices data is collected, and the closing prices of the nearest contracts one-month and two-months lagged behind the spot prices are selected to construct two futures prices series. EG two-step cointegration test shows that there is a cointegration relationship between each pair of spot and futures prices. Error Correction Models are then constructed to analyze the impacts of futures prices on spot prices in the short-term when deviation from the equilibrium happens. The empirical results show that the effectiveness of price discovery in the Chinese corn futures market is close to that in the U.S. market.

INDEX WORDS: Price discovery, Cointegration test, Error correction model

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CHAPTER 1

INTRODUCTION

1.1 Futures Market

Globally, futures market has become an important and integral component of many economic and risk management decisions. The futures market has evolved immensely since the first modern futures exchange was set up in Chicago in 1848. Now there are about 50 futures exchanges all around the world, mostly in America and Europe. Futures varieties have also developed from single commodity futures to financial futures, interest rate futures, foreign exchange rate futures, and precious metal futures.

Futures contract is an agreement between buyer and seller to deliver an asset (specified quantity and grade) at a certain time in the future for a price agreed to when the contract is first entered. In contrast, a spot contract involves an agreement to buy or sell the asset immediately or within a very short period of time. To close out a position in the futures market, one needs to take an offsetting trade. Most futures contracts are closed out before maturity. If not, the underlying assets should be delivered to the long position party by the short position party. Those contracts on financials, for example stock indices and Eurodollars, will be settled in cash.

The two most basic functions of futures market are hedging and price discovery.

Hedging is a risk management tool to reduce the potential losses from price fluctuations. By simultaneously buying and selling the same or highly related commodities in two different markets, future price change in one market may be offset partly or entirely by the opposite change in the other market. The nature of hedging is that hedgers can share the risk of price with speculators to arrive at an acceptable risk level.

Consider a hog feeder that plans to buy 5,000 bushels of corn 3 months later. He is satisfied with the corn price at this time, but worries about a potential price raise in 3 months. To lock the price, he can take a long position (which means buy) in one corn futures contract that has a maturity date nearest and early to his purchase date. Each futures contract of corn contains a standardized quantity of 5,000 bushels, so the feeder will be fully hedged. When the maturity approaches, if the price raise did happen in the spot market, theoretically, the related futures price should have increased as well. Now the hog feeder has two choices: either settle or close out the contract. Settling means he will finally receive the 5,000 bushels of corn at the predetermined price. More commonly, he will choose to close out, selling the contract at a higher price. Thus, the profit in the futures market would compensate the loss in the spot market. This is a simple example of hedging.

Notice that only when the futures price and spot price move in the same direction can market participants use hedging. Actually, how well the prices in futures and spot markets are correlated has a critical influence on the effectiveness of hedging. The relationship between futures price and spot price relates to the other fundamental function of futures market: price discovery.

1.2 Price Discovery

Futures price is the equilibrium price at which market participants agree to buy or sell this particular contract. It reflects the market expected spot price of the underlying asset in the future. Supply and demand in the spot market determine the futures price, but not perfectly. Other factors, such as storage cost, transaction cost, opportunity cost, and market expectations, also impact futures price. That is why futures price and spot price generally move in one direction, but the variations are not exactly the same. The difference between spot price and futures price is called “basis”.

Basis fluctuates throughout the futures contract period and this uncertainty is known as “basis risk”. As the futures contract approaches maturity, futures price will converge to the spot price, which means that basis will finally turn to zero. In general, basis fluctuation is more stable than the fluctuation of futures price or spot price. In other words, basis risk is usually lower than price risk. From the previous introduction of hedging, it's easy to realize that hedging is just to replace the higher price risk with the relatively lower basis risk. In this sense, a stable basis is the premise of successful hedging.

To better understand basis and hedging, we now dig further into futures price and spot price. As a financial derivative market, futures market is based on the underlying spot market, so the futures price is definitely influenced by the spot price. However, futures price can also influence the spot price to some degree through the process of price discovery.

Price discovery is the process that futures market formulates an authoritative and expected price by continuously gathering and interpreting information on supply and demand. This process reflects the futures market's dynamic adjustments to new information as it becomes available over time.

Futures market has two advantages in the price formulation process compared with spot market. First, in the futures market, transactions are centralized in the futures exchange, while in the spot market, market participants are dispersed in several separate locations and transactions happen privately. Second, futures price represents the price in a specific spot and at a specific time in the future. A large number of traders make transactions at their respective expected prices, and the result is the futures price, which represents the overall opinion of the entire market.

These advantages make futures market more able to perform the price discovery function. When price discovery works well, the price discovered by the futures market will influence the spot market, which means that the information gathered by the futures market will be transmitted to the spot market. Besides, it is reasonable to assume that as price discovery becomes more effective, the information of the spot market can also be received by the futures market. Effective price discovery should depend on several conditions: for instance, numerous traders, traders' familiarity with the market, and transparency of transactions.

Now we return to our previous discussion of basis risk. Through price discovery, information will be transmitted between spot and futures market, and there should be a linkage between the two prices. A stable relationship between them means a stable basis, and a stable basis means a lower risk. This is the reason why basis risk is lower than the underlying price risk. In this sense, price discovery is the foundation of hedging.

On the other hand, successful hedging will foster the functioning of price discovery. Working (1962) analyzed the onion transaction data in U.S. from 1931-1958, and the result showed that a big number of hedging transactions clearly reduced the price fluctuations in the last month of the storage season. When market participants use hedging actively, prices are more predictable and are easier to be discovered.

The application of price discovery is not limited to hedging. Producers, investors, and financial agencies can use the prices discovered by the futures market in making production, management, and investment strategies. From a macro point of view, futures market depends on price discovery to optimize resource allocation, reduce spot price fluctuations, and adjust market demand and supply.

The effective functioning of hedging and price discovery is especially important to agricultural commodities. Efficient commodity futures markets contribute to macroeconomic issues like food market system, food production stability, and national food security. Governments also refer to the information from the futures markets when making and implementing agricultural policies.

In this study, we emphasize on the price discovery function of futures market. As the foundation of futures market, price discovery deserves to be better explored. We choose the corn market as our research objective.

1.3 Corn

There are three reasons why we choose the corn market in our analysis of price discovery.

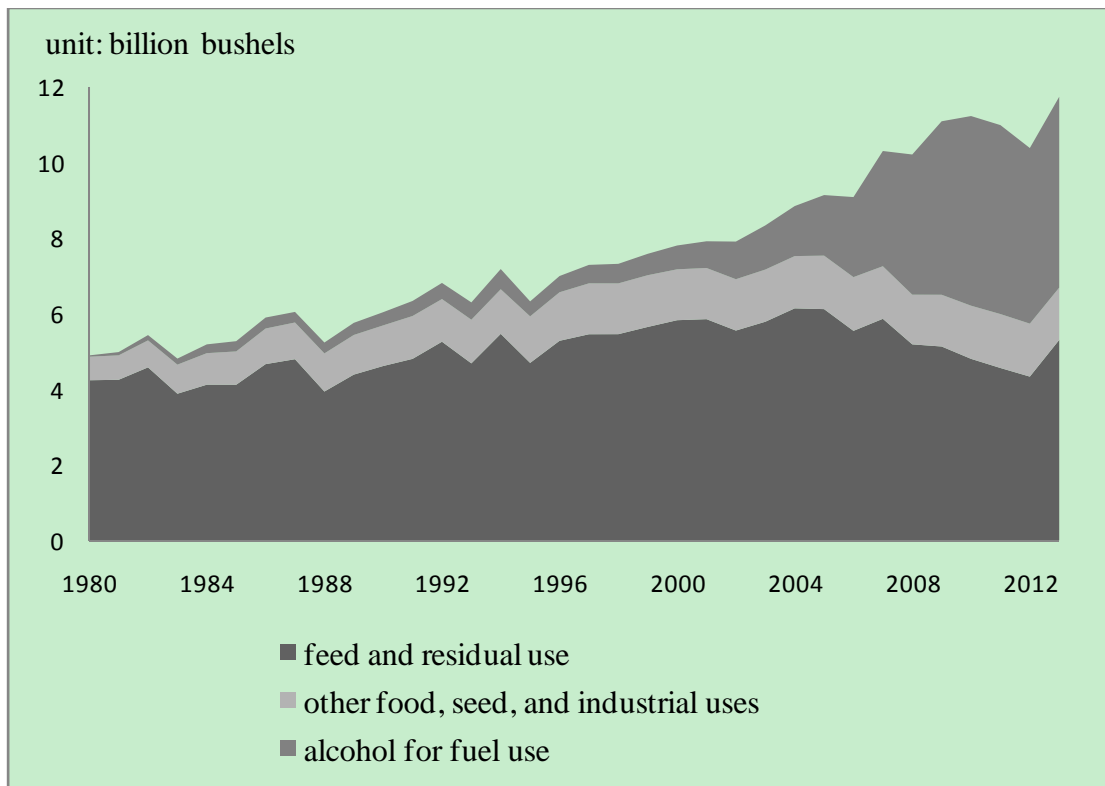
First, corn is a very important grain product in many countries. Corn is one of the most widely propagated and consumed food crops in the world. According to the United States Department of Agriculture (USDA), corn is the primary U.S. feed grain, accounting for more than 90% of total feed grain production and use. Corn is mostly used as the main energy ingredient in livestock feed, but it is also processed into a variety of food and industry products, like sweeteners, corn oil, industry alcohol, and fuel ethanol. In general, there are 3 main uses of corn: feed and residual use; other food, seed, and industrial uses; and alcohol for fuel use. The large increase in demand for bioenergy in recent years has resulted in a higher demand for corn,

making this crop a more prominent traded commodity in the world market. Figure 1 shows the quantity of corn consumed for the three uses respectively in U.S. from 1980 to 2013. The demand for fuel use has increased rapidly since 2000. The demand for feed use dropped around 2007 to 2011, while the demand for food and industry use was quite stable over time.

U.S. is the world's largest corn producer with approximately 20% of corn production exported to other countries. Among all the agricultural commodities, corn exports make the largest net contribution to the U.S. agricultural trade balance, indicating the importance of corn exports to the U.S. economy.

Figure 1. U.S. Domestic Corn Use 1980-2013

(Data Source: USDA Economic Research Service)



Meanwhile, the Chinese corn trade situation has significantly changed in the last decade, as the country transformed from a net exporter to a net importer in 2010. One reason that might

explain this change is the imposition of government policy on export subsidies and tax rebates that discouraged exports. Now China is the second largest corn consumer in the world, with most of the corn imports coming from the U.S. The uncertainty of corn trade has boosted the development of Chinese corn futures market.

The second reason why we choose corn market for our study is that the futures contracts of corn have been well developed in U.S. With a long history of almost 150 years, corn futures contract was the first futures contract in the world. In 1865, the first standardized futures contract for corn began to be traded in the Chicago Board of Trade (CBOT). Later in 1985, corn options came into the CBOT market, which was also the first option contract.

Before mid-1970s, corn futures had the largest volume among all the futures contracts. But later, as the development of financial futures contracts, commodity futures contracts no longer dominated the futures market. Even so, corn futures contracts are still very important and active. According to the survey of Futures Industry Association (FIA) in 2013, CBOT corn futures ranked 7th among all agricultural futures and options contracts worldwide, which was the most heavily traded corn futures contract.

The third reason is that we are interested in the relationship between the effectiveness of price discovery and the development of futures market. Futures market in U.S. has been developed for a long time. We have a good reason to believe that CBOT corn futures can display a quite efficient price discovery function. But how well does price discovery work in a developing futures market?

To undertake a comparative analysis, we use CBOT corn as a benchmark. Corn futures contract in Dalian Commodity Exchange (DCE) in China is selected as a representative of relatively new futures contracts. More details about CBOT and DCE will be introduced in the next two sections.

Although U.S. and Chinese futures markets are in different stages of development, the spot markets of corn in the two countries are both very important in the world trade, as we have mentioned earlier. Hence, studying the markets of U.S. and China is meaningful to our understanding of the world corn market.

1.4 U.S. Corn Futures Market

U.S. was the first country to create futures trading, and corn was the first futures variety. By now there are three futures exchanges that trade corn futures and options in the U.S., and CBOT corn is the most famous corn contract all over the world. We will use the prices of CBOT corn and the spot prices of corn around Chicago in our study.

Established in 1848, CBOT was the first futures and options exchange in the world. In 2007, CBOT merged with Chicago Mercantile Exchange (CME) to form the CME Group, the world's largest and most diverse derivatives marketplace. According to the report of CME Group, on average, the company handles 3 billion contracts worth approximately \$1 quadrillion annually. Commodity products in CME Group help in the establishment of benchmark prices and play important roles in risk management for farmers and producers. As a subsidiary exchange of CME Group, CBOT contributed 34.31% of volume and 17.03% of open interest to the company in 2013. The volume of CBOT corn futures in 2013 was about 64 million, 6% of the total products in CBOT.

CBOT corn futures price is a widely accepted pricing benchmark in the global trade. Many international corn contracts use CBOT futures price plus a premium to decide a bargain price. Besides, it is a common practice among U.S. corn merchants to hedge when engaging in international block transactions. In this way, CBOT corn futures contract has certain impact on global corn production and trade.

1.5 Chinese Corn Futures Market

In contrast to the U.S. futures market, Chinese futures market is a much younger market with a history of only 24 years. However, Chinese futures market has been growing extremely rapidly in recent years. On a combined basis, there were 1.87 billion contracts traded in Chinese commodity futures market in 2013, which was 38.9% higher than the previous year. The single most active contract in China was the steel rebar futures, which was also the world's leading futures on steel. Commodity futures market in China has become a key barometer for economic growth.

The first futures exchange in China was set up in Zhengzhou in 1990, featuring grain and oil contracts. Now there are four futures exchanges in total: one is specialized in financial derivatives, and the others are more famous in commodity futures and options. Among these exchanges, Dalian Commodity Exchange (DCE) is the largest commodity futures exchange in China, and is also the only futures exchange in Chinese northeastern area.

According to the Futures Industry Annual Volume Survey of Futures Industry Association (FIA) in 2013, DCE ranked 11th globally by number of contracts traded and/or cleared. Compared with the previous year, volume of contracts traded in DCE increased by 10.7% and open interest increased by an even higher rate of 39.23%. Soymeal futures, soyoil futures, palm oil futures, corn futures, No.1 soybean futures in DCE are all among the top 20 traded agricultural futures and options contracts globally.

China first launched corn futures contract in 1993, but in 1995, a serious crisis in corn futures market was caused by illegal operations of futures exchanges and lack of regulating experience of the government. Then, corn futures contracts were forced to cease. Until 2004, DCE re-launched the corn futures contract and it was a great success. In 2006, DCE changed the details of the corn contract once again. DCE corn was the world's second largest futures market for corn in 2013, just after the CBOT corn. However, there was still a big gap between them: the volume of DCE corn futures is only about 21% of that of CBOT.

The revived DCE corn futures market is now in its tenth year. Looking into its price discovery function will be helpful to assess the efficiency of Chinese futures market after the government reorganized the whole market.

1.6 Research Objective

This study will use the price discovery function paradigm to deduce trends of relative market efficiencies of two futures markets that are at different levels of maturity. We will focus solely on the corn futures contract. There are two steps in our analysis for price discovery. First, we need to verify the validity of price discovery in both markets by testing for the existence of a long-term equilibrium relationship between spot price and futures price. Then, in the event that price discovery does take effect, we will try to explore how the two prices impact each other in

the short-term. We need to measure the effectiveness of transmission of information between spot and futures markets. The results from our empirical study might be helpful to farmers, feeders, and investors who participate in corn markets.

1.7 Thesis Organization

This chapter describes the definition and importance of price discovery, and introduces the background of corn futures markets in U.S. and China. In the next chapter, we review the literature on economic theories that explain the relationship between spot price and futures price. We also summarize the tests and models that have been used to capture this relationship in empirical research. Chapter 3 describes the data and methodology of this study, and Chapter 4 presents and interprets the results of our tests and models. The final chapter discusses the conclusions and implications of this study.

CHAPTER 2

LITERATURE REVIEW

Economic research on price discovery dates back to the 1930s. Several theories have been advanced to explain the internal relationship between spot price and futures price, and many econometric tests and models have been developed to analyze how the two prices influence each other.

2.1 Theoretical Research

In an efficient market, price is determined by supply and demand. Futures market evaluates prices in a future period, so the prices in the futures market reflect the prices that make supply and demand equal in the future. Research has been done on how futures prices are discovered and determined. The two most representative and influential theories are the theory of storage and the stochastic model of price.

2.1.1 The Theory of Storage

The earliest research on the relationship between futures price and spot price was conducted by the famous economist Keynes (1930). According to his observations, if the spot price was higher than the futures price, the excess part (cash premium) should be the amount that buyers were willing to pay to avoid the possible price fluctuations during the production period. If the futures price was higher than the spot price, the excess part (futures premium) should include storage cost, depreciation cost, and interest cost.

Kaldor (1939) and Working (1948, 1949) then summarized and developed the theory of storage to explain the relationship between spot and futures prices. The spread between spot and

futures prices was determined by fundamental supply and demand conditions and was related to storage costs, inventory levels, and convenience yields. The equation of this relationship is:

$$F = S + CR \quad (1)$$

where F is the futures price, S is the spot price, and CR is the carrying costs that include storage cost, interest cost, risk premium, and depreciation cost.

In Chapter 1, we mentioned that the futures market can restrain price fluctuations to some extent. According to the theory of storage, this function is based on the return of storage. When the return of storage is positive (futures price is higher than spot price), the market is called a “contango market”, and the total inventory levels will be high in the economy. However, when the return of storage is negative (spot price is higher than futures price), the market is called an “inverted market”. This situation happens mainly because of the shortage of supply in the spot market. In this situation, more inventories will be put into the spot market to alleviate the supply insufficiency. Through the return of storage, futures market adjusts the allocations of supply and demand in different time periods.

Aside from these three economists, other researchers, like Telser (1958), Bresnahan and Suslow (1985), Bresnahan and Spiller (1986), Williams (1986), Williams and Wright (1989, 1991), Brennan (1991), Deaton and Laroque (1992), all made significant contributions to the construction of the theory of storage. This theory has not only promoted the research of price discovery, but also has provided the empirical evidence on inventory and basis.

2.1.2 The Stochastic Model of Price

Samuelson (1965) considered the futures market as a perfect competition market, and he fully affirmed the function of speculation in the futures market. Speculation can decrease price risk and the volatility of commodity demand. The participation of various speculators increases the liquidity of futures market, which is the basic requirement of successful hedging.

According to Samuelson's model, in theory, futures price equals the conditional expectation of the spot price on the maturity date of the futures contract. The generalized model is:

$$F(T, t+T) = E[S_{t+T} | S_t, S_{t-1}, \dots] \quad (2)$$

where $F(t, t+T)$ is the futures price at time t for a contract that will expire at time $t+T$, and S_{t+T} is the spot price when the contract expires. Samuelson also pointed out that the volatility of the spot prices was higher than the futures prices, which is called the Samuelson Effect. The conclusion is that in an information-efficient market, price changes cannot be predicted if they fully incorporate expectations and information of all market participants.

Based on Samuelson's theory, later researchers have developed more practical models to be used in empirical research. The essence of these kinds of models is that the futures price is an unbiased estimator of the spot price at the maturity date of the contract.

2.2 Empirical Research

Empirical methods used to analyze price discovery has developed from simple OLS models to a variety of complicated time series models. This study reviews several influential models appeared in literature.

2.2.1 Efficient Market Model

Bigman, Goldfarb and Schechtman (1983) tested the efficient market hypothesis that futures prices were unbiased estimates of spot prices at the delivery date. Price discovery was described

as the process by which new information that has been accumulated with the passage of time contributed to the predictive power of the estimates of futures price. The model was evolved from Samuelson's theory, and the regression equation was:

$$S_T = \alpha_i + \beta_i F_{T-i} + \mu_{T-i}, i = 1, \dots, T-1 \quad (3)$$

where T was the delivery date, S_T was the spot price at time T, and F_{T-i} was the futures price quoted at time T-i. The efficiency hypothesis implied that, for all i:

$$\alpha_i = 0, \beta_i = 1 \quad (4)$$

They used the weekly data of wheat, soybean and corn in the empirical study. All observations of futures prices were divided into groups according to their time distance from delivery date, and the regression analysis was conducted for each group separately. The results showed that for futures contracts 6 weeks before delivery or less, the market could generally be characterized as efficient, indicating the function of price discovery. However, for longer-term futures contracts, futures prices were strongly influenced by spot prices at that time, and a great deal of their predictive power was spurious.

This study was influential among early empirical researches on price discovery, but it was criticized by several researchers later. Maberly (1985) disagreed with the conclusion that $\hat{\alpha} > 0$ and $\hat{\beta} < 1$ implied that futures pricing was inefficient. He argued that the misleading conclusion was the result of applying OLS to censored data by using a simulation analysis. Elam and Dixon (1988) disagreed with Maberly. They argued that the reason should be attributed to using OLS on a model with a lagged dependent variable. The bias was caused by the existence of unit root in spot price.

Shen and Wang (1990) agreed that random walk of spot price was the main source of rejection, but it was wrong for Elam and Dixon to use F statistics. They thought that the

cointegration technique suggested by Engle and Granger (1987) might be an alternative to test market efficiency, which we will introduce later in this chapter.

2.2.2 GS Model

Garbade and Silber (1983) developed a famous model to describe the interrelationship between cash market prices and futures prices of storable commodities. The model suggests that over short intervals of time, the correlation of price changes is the function of elasticity of arbitrage between the physical commodity and its counterpart futures contract. The essence of price discovery function of futures markets hinges on whether new information is reflected first in changed futures prices or in changed cash prices. The model is:

$$\begin{pmatrix} P_t \\ F_t \end{pmatrix} = \begin{pmatrix} \alpha_p \\ \alpha_f \end{pmatrix} + \begin{pmatrix} 1 - \beta_p & \beta_p \\ \beta_f & 1 - \beta_f \end{pmatrix} \begin{pmatrix} P_{t-1} \\ F_{t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{p,t} \\ \varepsilon_{f,t} \end{pmatrix} \quad (5)$$

P_t is the spot price at time t , and F_t is the futures price at time t . α_p , β_p , α_f , and β_f are parameters. $\varepsilon_{p,t}$ and $\varepsilon_{f,t}$ are random error terms. β_p shows the effect of last period's futures price on the current spot price, and β_f shows the effect of last period's spot price on current futures price. α_p and α_f reflect the trends of price movements. We use $\beta_p/(\beta_p + \beta_f)$ to measure the extent of the role that spot or futures price plays in price discovery. If $\beta_p/(\beta_p + \beta_f) > 0.5$, then the influence of futures price is greater than spot price, which means that futures market leads the process of price discovery. If $\beta_p/(\beta_p + \beta_f) < 0.5$, then the influence of spot price is greater than futures price, which means that spot market leads the process of price discovery.

Garbade and Silber applied this model on seven storable commodities. They used daily closing prices of agricultural commodities and daily opening prices of metals in the futures price data. The result showed that, in general, futures market dominated cash market in price discovery. This model is still widely used in recent study on price discovery.

2.2.3 Cointegration Analysis and ECM

We have mentioned that the result of efficient market model is misleading, and some researchers suggested that cointegration test might be a good alternative. Two kinds of cointegration tests have been most widely used: EG two-step method and Johansen cointegration test.

Gulen (1998) calculated the simple average of daily data as the monthly crude oil futures prices for one-month-, three-month- and six-month-ahead contracts from NYMEX. Monthly spot prices data was also collected. He applied the Dickey-Fuller test that includes dummy variables to account for the crash in 1986, and the result showed that each series was integrated of order one. He then applied the EG two-step method to test whether the futures prices and spot prices are cointegrated. He concluded that the futures price was an unbiased predictor of the spot price as they were found to be cointegrated. The cointegrating relationship was stronger the shorter the term of the futures contract. This paper received considerable attention in the literature using cointegration analysis.

Crowder and Hamed (1993) used the monthly data from NYMEX to test the market efficiency of oil futures market. The futures price is defined as the closing price of a futures contract 30 days prior to the last trading day on that contract. The futures spot price is the cash price on the last trading day of the corresponding futures contract. The next futures price observation then begins on the next trading day using the same data matching method for all spot

and futures prices combinations. All variables are transformed into natural logarithms.

After testing for the unit root, Crowder and Hamed then used the Johansen cointegration test. The result implied that the futures price is an unbiased predictor of the corresponding future spot price. They argued that the casual relationship between spot and futures prices can be made by analyzing the error correction coefficients. The error correction model was:

$$\Delta X_t = \mu + \Pi X_{t-1} + \sum_{j=1}^{k-1} \Gamma_j X_{t-j} + \varepsilon_t \quad (6)$$

where X_t is a $p \times 1$ vector of $I(1)$ variables and Π is $p \times p$ matrix that has reduced rank when the variables in X_t are cointegrated. Crowder and Hamed set the $X_t = [S_t, F_{t-1}, R_t]'$ to test an arbitrage equilibrium hypothesis.

2.2.4 Common Factor Models

Hasbrouck (1995) suggested an econometric approach based on an implicit unobservable efficient price common to all markets. The common factor was the implicit efficient price of the security, which was the random-walk component of the prices. The innovation variance in this random walk was a measure of the information intensity of the price discovery process. This method is called information share method, and Hasbrouck applied it on Dow stocks traded on NYSE. The result showed that price discovery appeared to be concentrated: the median information share was 92.7%. In other words, most of the price discovery took place at the futures market.

Gonzalo and Granger (1995) proposed a new way of estimating common long-memory components of a cointegrated system. They obtained common factors in every subsystem by and then analyzed cointegration among them. They suggested that common factors were linear combinations of the original variables and that the error correction terms do not cause the common factors at low frequencies. Estimation was done from a fully specified error-correction

model, which made it possible to test hypotheses on the common factors using standard chi-squared tests.

Hasbrouck's information share model and Gonzalo and Granger's permanent – transitory decomposition model are the two most widely used common factor models to analyze price discovery. Baillie (2002) examined the two kinds of models, and suggested that they complement each other and provide different views of the price discovery process. The Hasbrouck model considered each market's contribution to the variance of the innovations to the common factor, while the Gonzalo and Granger model focused on the components of the common factor and the error correction process. They were directly related and provided similar results if the residuals were uncorrelated between markets. However, if substantive correlation existed, they typically provided different results.

2.2.5 VAR Model

Traditional structural regression models are generally constructed on the basis of economic theories and hypothesis, and then analyze how the changes of parameters impact the related variables. However, some models are difficult to construct or are far from the reality because of too relaxed assumptions. Besides, sometimes it's hard to distinguish between endogenous and exogenous variables. Vector Autoregression model (VAR) and Vector Error Correction Model (VECM) have been used to deal with these problems.

VAR is used to capture the linear interdependences among multiple time series. All variables in a VAR model are treated symmetrically in a structural sense and each variable has an equation explaining its evolution based on its own lags and the lags of other variables. VECM adds error correction features to a VAR model. VAR and VECM modeling do not require as much knowledge about the forces influencing a variable as structural models, and the only prior

knowledge required is a list of variables which can be hypothesized to affect each other.

Booth (1995) examined the intraday price discovery process among stock index, index futures and index options in Germany. He constructed pseudo-price series for futures and options prices and applied VECM to model the interactions among the prices. The statistical evidence suggested that stock index futures contract was the driving force of the price discovery process.

Steeley (2012) studied price discovery for Chinese shares cross-listed in multiple markets. He used the impulse response functions and the variance decompositions from a VAR process. The combination of these methods helped to explain the price discovery process from more aspects.

2.2.6 Volatility Spillover Models

GARCH model, which is short for Generalized Autoregressive Conditional Heteroskedasticity model, is one of the most widely used models to analyze volatility spillover. The model is characterized by their ability to capture volatility clustering in time series data.

Chan (1991) applied bivariate GARCH model on the S&P 500 stock index and index futures prices, and then used impulse response analysis to illustrate the dynamics of the bivariate GARCH system. The results indicated a strong intermarket dependence in the volatility of the cash and futures returns. Price innovations that originated in either market could predict the future volatility in the other market.

Tse (1999) examined the minute-by-minute price discovery process and volatility spillover between the DJIA index and the index futures launched by CBOT. By constructing a bivariate EGARCH model, a significant bidirectional information flow was found. Innovations in one market could predict the future volatility in another market, but the volatility spillover in futures market was higher.

2.3 Research Effort in China

Chinese futures market has functioned for only two decades and the degree of research relatively lags behind. Research on price discovery of futures market has centralized in financial futures contracts. This paper reviews several studies about price discovery in Chinese commodity futures markets.

Li (2011) researched the relationship between cotton futures price and cotton spot price in different regions based on EG two-step cointegration test and Granger causality test. The results showed that there was a cointegration relationship between spot and futures prices, and the cotton futures price played unidirectional role in guiding spot price.

He and Xie (2012) analyzed the sugar spot and futures markets in China in the cointegration framework, and found that Chinese sugar spot market had the pricing power, even though futures market led the price discovery. The reasons of this separation might be the irrational speculation in futures market, oligopoly and local government politics, and the operational efficiency of the wholesale spot market.

He and Zhang (2013) described the dynamic relationship between futures and spot cotton market in China. Price discovery and volatility spillovers were examined through VEC models, Granger causality test, impulse response analysis and BEKK model. The results suggested a long-term relationship and short-term bidirectional Granger causality between spot and futures prices.

2.4 Summary of Literature Review

Researchers have agreed that price discovery should come from some relation between spot price and futures price. Economic theories set up equations for spot and futures prices, and early empirical research tried to test these equations directly. However, the strict assumptions under

the theories and the unit roots in price series made the results of the empirical research unreliable. Later researchers introduced more complicated econometric methods to deal with time series data. Now price discovery can be studied not only from the relationship between spot price and futures price, but also from the relationship between their volatilities. Several empirical methods are usually combined in one study to analyze price discovery from different aspects.

Research on price discovery in the U.S. has received much effort, but the effort in China is not desirable. The empirical results of some studies are conflicting, and the research processes are not stated in very detail. The quality of data in Chinese market is a major concern. Generally, there are two problems with the data used in price discovery studies in China. One is quality of spot price. Several agencies collect spot prices data, but many of them are discontinuous or not volatile, making them not appropriate to be used in econometric models. The other one is the method of constructing a continuous futures price series. The method used in research on mature futures markets is not suitable to the Chinese futures market. This problem will be further discussed in the next Chapter.

CHAPTER 3

DATA AND METHODOLOGY

3.1 Data Collection

Since DCE changed the specifications of the corn contract in 2006, the time period of the data used in this study starts from 2006. Each year, CBOT launches 5 new corn contracts, which start in March, May, July, September, and December separately, and will expire after one year. DCE launches 6 new corn contracts, which start in January, March, May, July, September, and November separately. The last trading day of each contract is the business day prior to the 15th calendar day of the contract month.

We collect the average prices of country elevator bids to producers of No.2 yellow corn in Illinois and take average of the daily data to construct a monthly price series for the U.S. corn market. This second-hand data was obtained from The Wall Street Journal market data center. The average spot prices data of No. 2 yellow corn near Dalian area was collected from the SunSirs Commodity Data Group. We take natural logarithms of the spot price series, and they are denoted as LS_t .

We are interested in whether futures prices can be used to predict spot prices in advance, which is an important function of price discovery. To test this in our study, we can use the closing prices some particular time earlier than the spot prices to construct a futures price series. The smallest time span between two corn contracts is 2 months, so the time span should be no longer than 2 months. Otherwise, the overlapped information may cause auto regression problems (Hansen and Hodrick, 1980). In this study, we select the closing prices of the contract nearest to

delivery when they are one-month and two-months earlier than the spot prices we have collected. For instance, the futures prices correspond to the spot price in March 2006 are the closing prices of the March 06 contract on February 28th and January 31st. We take natural logarithms of the futures prices, and the two series are denoted as $LF_{t-1,t}$ and $LF_{t-2,t}$.

In this study, we construct futures and spot prices data from March 2006 to March 2015. Figure 2 and Figure 3 display the price series in the U.S. and Chinese corn market separately. There seems no trend in the U.S. market, but the Chinese market show an upward trend.

.Figure 2. 2006.03-2015.03 Spot and Futures Prices in the U.S. Market (unit: dollar)

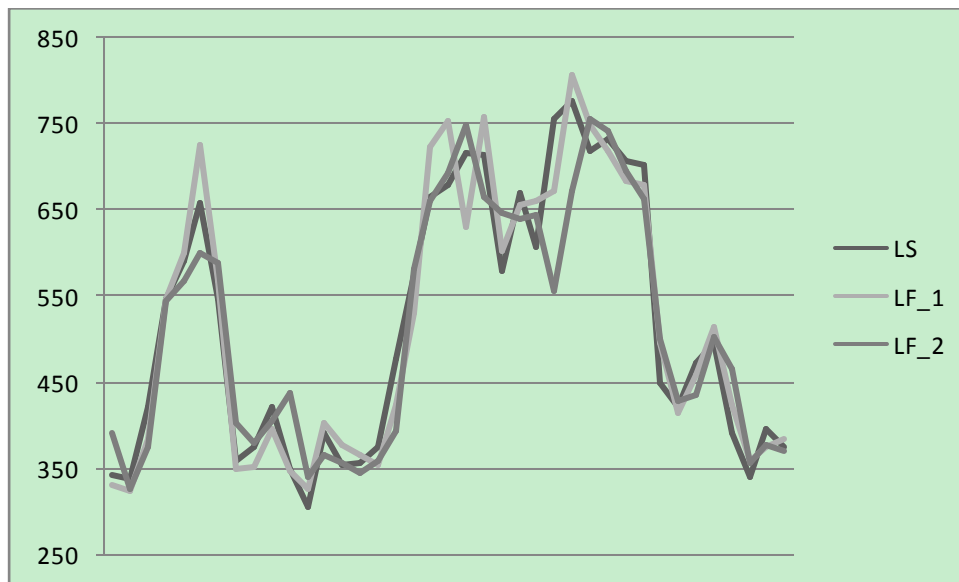
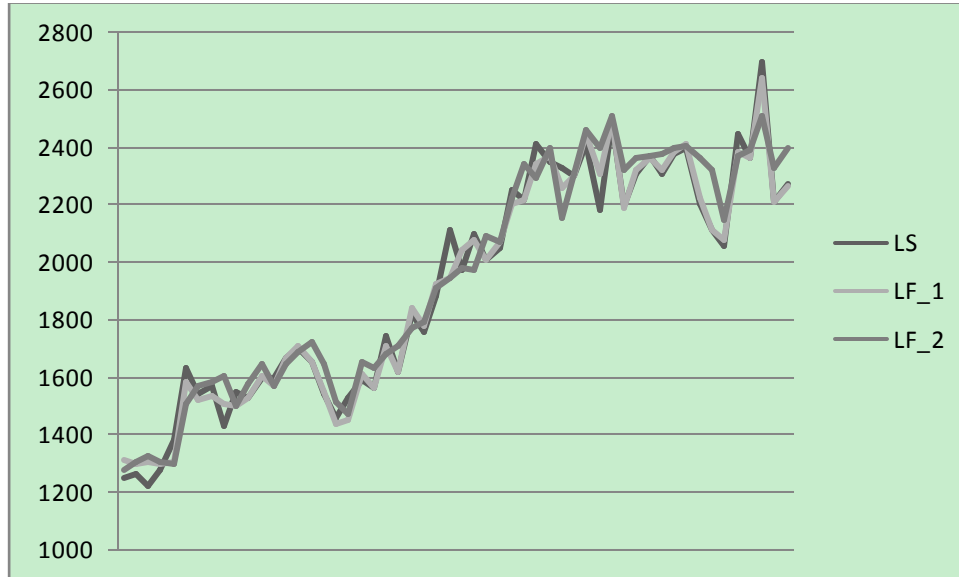


Figure 3. 2006.03-2015.03 Spot and Futures Prices in the Chinese Market (unit: yuan)



3.2 Methodology

3.2.1 Cointegration Test

In this study, EG two-step method will be employed to test the cointegration relationship between spot prices and futures prices. According to Engle and Granger (1987), cointegration means that the spot and futures prices should be integrated of the same order, and there is a long-term equilibrium relationship between the variables.

Most asset prices series are I(1) series. If LS_t , $LF_{t-1,t}$ and $LF_{t-2,t}$ are all integrated of order one, we can construct the cointegration model:

$$LS_t = \beta_0 + \beta_1 LF_{t-i,t} + \mu_t, i = 1, 2 \quad (7)$$

where LS_t is the spot price at time t , $LF_{t-i,t}$ is the futures price at time $t-i$ of the contract nearest to delivery at time t , β_0 and β_1 are cointegration parameters, and μ_t is the residual.

We will first run the regression of this cointegration model, and obtain the residuals. If we reject the hypothesis that the residuals has a unit root, LS_t and $LF_{t-i,t}$ are cointegrated. This cointegration relationship is a necessary condition for the market efficiency hypothesis.

The augmented Dickey-Fuller unit root test will be employed to test whether the series is stationary. For a time series X_t , the model for the ADF test is:

$$\Delta X_t = \beta X_{t-1} + \sum_{i=1}^k \theta_i \Delta X_{t-i} + v_t \quad (8)$$

A constant term or a trend can also be added to this model. Akaike information criterion will be applied to decide the lag order k . The AIC value will be calculated as:

$$AIC = 2k - 2\ln(L) \quad (9)$$

where L is the maximized value of the likelihood function for the model. The preferred k is the one that makes the minimum AIC value.

For the equation 8, we need to test the hypothesis that $H_0: \beta = 0$. If we fail to reject the null hypothesis, it means that X_t has a unit root. In other words, it is nonstationary. Then we should take first difference of X_t and take the ADF test once again. If the first difference of X_t is stationary, we say that X_t is an I(1) series.

3.2.2 Error Correction Model

If the spot and futures prices are cointegrated, an error correction model can be constructed. Cointegration relationship is the long-term equilibrium relationship. If prices deviate from the equilibrium in the short-term, the deviations will be corrected because of the existence of cointegration.

The ECM equation is:

$$\Delta LS_t = \delta_0 + \delta_1 \Delta LF_{t-i,t} + \rho \mu_{t-1} + v_t \quad (10)$$

where $\Delta LS_t = LS_t - LS_{t-1}$, $\Delta LF_{t-i,t} = LF_{t-i,t} - LF_{t-i,t-1}$, $\mu_{t-1} = LS_{t-1} - \alpha LF_{t-i,t-1}$, α is the cointegration parameter, δ_0 is the constant term, δ_1 measures the direction and degree of the impact of ΔLF_{t-i} on ΔLS_t , ρ is the speed of correction.

CHAPTER 4
EMPIRICAL RESULTS

4.1 ADF Test

Using the Akaike information criterion, we found the preferred lag order for each price series. The result is shown in Table 1. In the ADF tests for each series, the preferred lag order will be used.

Table 1. The Preferred Lag Order for Each Price Series

Lag Order	U.S. Market			Chinese Market		
	LS _t	LF _{t-1,t}	LF _{t-2,t}	LS _t	LF _{t-1,t}	LF _{t-2,t}
Original Series	1	1	2	5	5	2
First Difference Series	0	0	0	4	4	1

Three kinds of ADF tests have been tried: (1) the ADF test without trend but with constant; (2) the ADF test without trend and constant; (3) the ADF test with trend and constant. Among them, the test statistics generated by the first kind of method is the largest. Thus, we use the ADF test with constant but without trend.

Table 1 shows the test statistics and p-values of the price series in the ADF tests. P-values are showed in parentheses. The results indicate that all the price series are non-stationary at 5% significance level. We take first difference of all the variables, and apply the ADF test once again. This time, all the variables are stationary even at 1% significance level. It means that all the price series are I(1) series. Since all the variables are integrated at the same order, we are able to take the cointegration test in the next step.

Table 2. Test Statistics and P-values of the ADF Tests

Series	Market	Spot Price	Futures Price	
			one-month	two-months
Original	CBOT	-2.253 (0.1877)	-2.565 (0.1004)	-1.974 (0.2980)
	DCE	-1.225 (0.6629)	-1.224 (0.6633)	-1.562 (0.5024)
First Difference	CBOT	-5.273** (0.0000)	-4.923** (0.0000)	-4.972** (0.0000)
	DCE	-4.573** (0.0001)	-4.112** (0.0009)	-5.729** (0.0000)

4.2 Cointegration Test

According to the EG two-step method, the first step is to run the OLS regression of the two variables (Equation 7) and obtain the residuals $\hat{\mu}$. The next step is to test whether the residuals is stationary. If it is stationary, there is a cointegration relationship between the two variables.

The results of the OLS regressions and ADF tests of residuals are showed in Table 3. The numbers in the parentheses in the OLS Regression column are t statistics. From Table 3, we can see that R^2 and F statistics of the OLS regressions are very large, and all the estimated parameters of LF_{t-i} are very significant. From the results of the ADF tests, all the residuals of the OLS regressions are stationary at 1% significance level.

Thus, for the CBOT corn contract, the spot price (LS_t) is cointegrated with both the futures prices one-month and two-months before the last trading day ($LF_{t-1,t}$, $LF_{t-2,t}$), and the cointegration coefficients are 0.951 and 1.013 separately. For the DCE corn contract, the spot price is also cointegrated with the futures prices one-month and two-months before the last trading day, and the cointegration coefficients are 1.005 and 0.990 separately. We fail to reject the hypothesis that β_0 is different from 0 in each regression.

Table 3. The Results of the Cointegration Tests

Market	Series	OLS Regression	ADF Test
CBOT	one-month	$LS_t = 0.302 + 0.951 LF_{t-1,t}$ <p>(1.43) (27.94)</p> $R^2=0.955, F=780.41$	<p>-5.867**</p> <p>(0.0000)</p>
	two-months	$LS_t = -0.075 + 1.013 LF_{t-2,t}$ <p>(-0.20) (17.12)</p> $R^2=0.888, F=293.23$	<p>-5.802**</p> <p>(0.0000)</p>
DCE	one-month	$LS_t = -0.035 + 1.005 LF_{t-1,t}$ <p>(-0.27) (59.47)</p> $R^2=0.986, F=3536.30$	<p>-5.190**</p> <p>(0.0000)</p>
	two-months	$LS_t = 0.063 + 0.990 LF_{t-2,t}$ <p>(0.28) (33.00)</p> $R^2=0.954, F=1088.70$	<p>-7.277**</p> <p>(0.0000)</p>

4.3 ECM Model

According to Equation 10, we construct an ECM model for each pair of spot and futures prices. The results are shown in Table 4. The coefficients of δ_0 and ρ are all significant at 1% significance level. Besides, the R^2 of all the models are very large, indicating that the models are effective and meaningful.

Table 4. ECM: Futures Prices Correct Spot Prices

	Series	μ_{t-1}	ECM
U.S. Market	one-month	$\mu_{t-1} = LS_{t-1} - 0.951LF_{t-1,t-1}$	$\Delta LS_t = -0.001 + 1.012\Delta LF_{t-1,t} - 1.066\mu_{t-1}$ (-0.06) (14.71) (-5.54) $R^2 = 0.863, F = 110.06$
	two-months	$\mu_{t-1} = LS_{t-1} - 1.013LF_{t-2,t-1}$	$\Delta LS_t = 0.004 + 1.188\Delta LF_{t-2,t} - 1.124\mu_{t-1}$ (0.24) (8.70) (-5.24) $R^2 = 0.685, F = 38.13$
Chinese Market	one-month	$\mu_{t-1} = LS_{t-1} - 1.005LF_{t-1,t-1}$	$\Delta LS_t = 0.000 + 1.058\Delta LF_{t-1,t} - 1.086\mu_{t-1}$ (0.10) (19.48) (-7.94) $R^2 = 0.890, F = 201.59$
	two-months	$\mu_{t-1} = LS_{t-1} - 0.990LF_{t-2,t-1}$	$\Delta LS_t = -0.002 + 1.159\Delta LF_{t-2,t} - 1.099\mu_{t-1}$ (-0.25) (8.23) (-7.18) $R^2 = 0.631, F = 42.81$

The coefficient of $\Delta LF_{t-i,t}$ measures the impact of futures price changes on future spot price changes. Since all the estimated coefficients are greater than 1, futures prices can strongly influence the spot prices. Both the U.S. and Chinese corn futures markets show the function of price discovery.

μ_{t-1} is the average deviation of S_t from the equilibrium in the short-term. The coefficient of μ_{t-1} measures the speed of correction when deviation from the equilibrium happens. We find that all the correction speeds are greater than 1, which means that the deviation from equilibrium happened last month will have a magnified effect on the spot price this month. The negative sign of the coefficient means that if spot prices are larger than the equilibrium futures prices last month, spot prices will decrease this month.

4.4 Summary and Comparison

In this study, we analyze the relationship between monthly spot prices and the futures prices one-month and two-months prior than the spot prices in the U.S. and Chinese corn markets. All the price series are integrated of order one, that is, $I(1)$. There are strong correlations between spot and futures prices, and we come to the conclusion that futures prices are cointegrated with future spot prices in both markets. The leading functions of the one-month and two-month lagged futures are similar. Thus, the futures prices of corn can be used to predict the spot prices even two months in advance.

The cointegration coefficients are greater than 1, meaning that futures prices have magnified effects on spot prices. The changes in futures prices will cause more volatile fluctuations in spot prices later. The correction speeds are also greater than 1, meaning that once spot prices deviate from the equilibrium level, the futures prices will lead the spot prices back to equilibrium very fast.

We summarized the results of our empirical studies in Table 5. Among all the pairs of price series, the correlation between the spot prices and futures prices 2 months prior is the strongest. Both the U.S. and Chinese corn futures markets show clear evidence of price discovery. Corn futures prices can be applied to predict the spot prices 2 months in advance.

Table 5. Summary of the Empirical Studies

	U.S. Market		Chinese Market	
LS_t	LF_{t-1}	LF_{t-2}	LF_{t-1}	LF_{t-2}
Cointegration	yes	yes	yes	yes
Long-term Relationship	$LS_t = 0.951 LF_{t-1,t}$	$LS_t = 1.013 LF_{t-2,t}$	$LS_t = 1.005 LF_{t-1,t}$	$LS_t = 0.990 LF_{t-2,t}$
Short-term Coefficient	1.012	1.188	1.058	1.159
Correction Speed	1.066	1.124	1.086	1.099

CHAPTER 5

CONCLUSIONS

Although Chinese corn futures market is much younger than the U.S. corn futures market, for the time period of March 2006 to March 2015, the average performance of price discovery in DCE corn has caught up with that in the CBOT corn. This conclusion is a little amazing at first glance, but we can find some clues from the current situation of the development of commodity futures contracts globally.

On the one hand, for the last few years, China's commodity futures markets have been growing extremely rapidly. China's commodity exchanges are among the fastest growing exchanges in the world. DCE corn has already been the second most traded corn futures contract in the world. On the other hand, compared with other futures contracts, the percentage of agricultural commodity futures contracts continues to decrease. Financial futures contracts, such as individual equity, equity index, interest rate, and currency, has replaced the agriculture category to be the most popular categories. In 2013, the volume of the agriculture category was only 5.6% of the total volume of futures trading. Since corn futures has becoming less and less important in the overall futures market, this may imply that there is little room for CBOT corn futures to improve the price discovery function. As the explosive growth in Chinese futures market, the market efficiency of DCE corn futures market is already very close to the market efficiency of CBOT corn futures market.

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