Integration of Chinese Agricultural Commodity Markets: A Cointegration Approach

by

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Abstract

The integration of spatially separated markets was accelerated by intense trade in the last few decades. China started to open its markets since 1978 and now it plays an important role in world trade. However, China's impact is less pronounced on agricultural commodity markets, and its impact varies across different commodities. This study discusses the prices performance of corn, soybean, and wheat in China and the U.S. We examine the integration process of Chinese agricultural commodity markets after China's entry to WTO (i.e. 2004-2012). This study applies the cointegration test with and without a structural change. We detect the cointegration relationship between soybean prices in China and the U.S., but we observe such relationship does not exist in corn and wheat markets within China and the U.S.

Preface

This thesis is original, unpublished, independent work by the author, Zheng, Chen.

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This thesis is dedicated to my parents who firmly stand by me. Their unwavering love always gives me the strength and buoys me up.

Last I would like to thank the rain in Vancouver. It locked me in the study throughout the winter.

Dedication

To my parents

Chapter 1 Introduction

1.1 Background

Spatially separated agricultural commodity markets have become highly integrated because of the globalization of the world economy, lower transportation costs, and the availability of real-time information via the internet. Higher trade is expected to cause spatially-separated markets to integrate into a single market where prices move in tandem and where the law of one price holds in the long run. In the last three decades, developing countries have significantly reduced their trade barriers. Indeed, the world average MFN applied tariff rate[1] was dropped from 26.3% in 1986, to 8.1%, in 2010.[2]

China plays an important role in world trade, and now it is the second largest exporter (Feenstra and Wei, 2009). However, China's impact is less pronounced on world agricultural markets than on other markets such as metals, energy, and so on. Additionally, China's impact on world agricultural markets varies significantly across commodities. Currently, China is the largest importer of soybeans and a leading importer of cotton. However, for other commodities such as corn, rice, and wheat, China rarely interacts with the world markets. In 2012/2013, China imported roughly 18 million 480 lb. Bales of cotton, accounting for about 40% of the total world import volume, and 59 million metric tonnes (mts) soybean, accounting for about 63% of world imports, but it only imported about nine million mts of corn, rice and wheat, accounting for 0.03% of world imports.[3]

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[1] Most Favorable Nations Tariff is the lowest possible tariff a country can assess on another country.

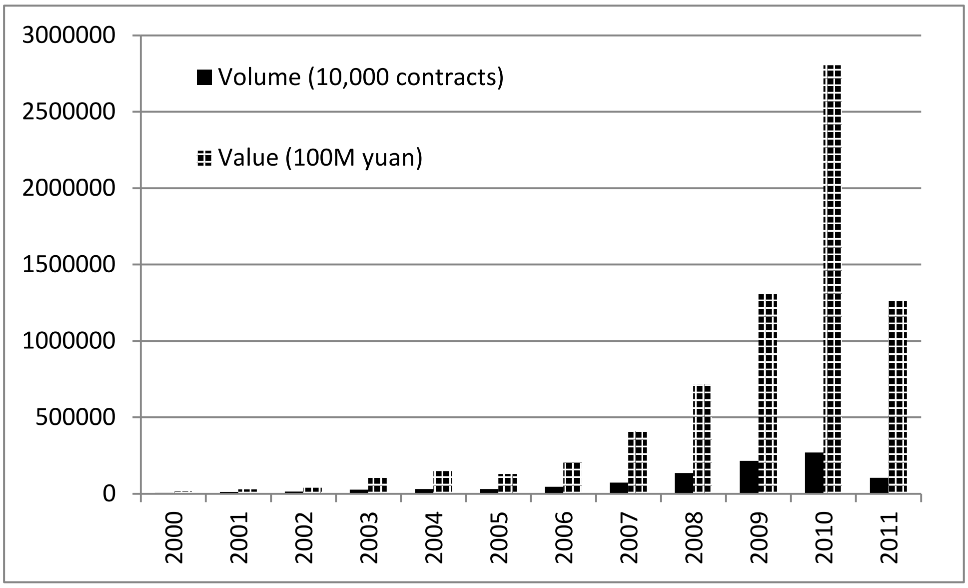
[2] Data estimated by the World Bank.

[3] Data estimated by Foreign Agricultural Service, USDA.

Unlike the economies of western countries, China's economy has been centrally planned and therefore cannot be viewed as a true market economy. After the economic reform in 1978, which introduced the capitalist market principles, China gradually opened its markets to the world but still employed some restrictions and policies in trade. The restrictions were employed for several specific strategic commodities, such as corn, cotton, soybean, wheat and rice. China has aimed for a near self-sufficiency goal for its strategic commodities, and in doing so has obviously reduced the degree of integration with world markets.

In 2001, China was accepted into the World Trade Organization (WTO), which encourages free trade among markets. The shift toward freer trade was expected to result in a higher level of integration of Chinese markets with the world. Consistent with the WTO membership, Chinese derivative markets have become increasingly important in a global context in the last decade. Indeed, since 2007, the volume of traded contracts in the Chinese market has grown rapidly (Figure 1.1). In China, the number of traded contracts in 2007 was about 0.7 billion but it rose to more than 2.7 billion in 2010. In addition, in 2009 China hosted the largest commodities futures market in the world.

Figure 1.1 Contracts traded on China's futures markets (2000-2011)



Data source: Chinese Futures Association, http://www.cfachina.org, accessed 12 August 2012.

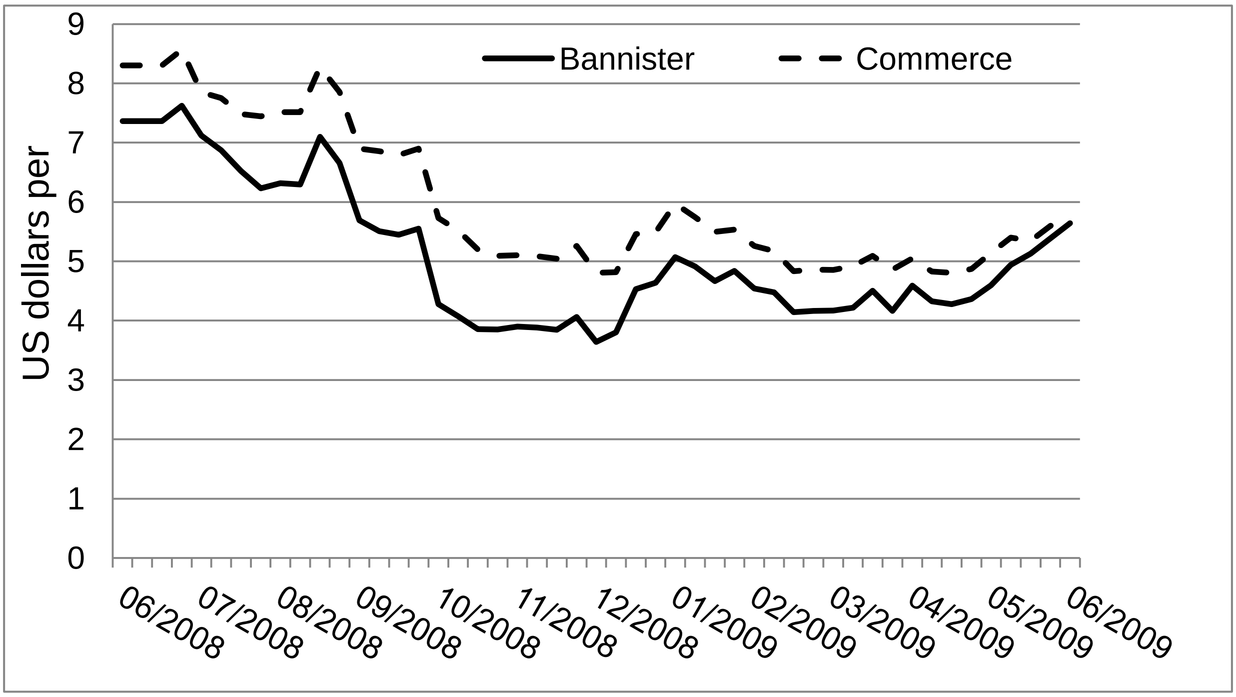
The rapid development of Chinese futures markets in the last 10 years has attracted many researchers in testing the markets linkage between China and the world. Most of the studies involve the cointegration test. Granger (1981) first proposed the idea of cointegration and Engle and Granger (1987) later formally set up the cointegration test. The essence of cointegration within the trade framework is the concept of the Law of one price (LOP), which claims that prices for identical commodities in different regions will be pushed to converge by arbitrage (Isard, 1977).

We illustrate a pair of cointegrated prices series in Figure 1.2.[4] Specifically, Figure 1.2 depicts the prices series of soft white winter wheat during June 2008 to June 2009 in two US delivery stations: Bannister, Missouri and Commerce, Colorado. The wheat prices in two regions tend to move in tandem, because in a free market regime, a shock in one market will have equal impact

[4] In this Chapter, we introduce cointegration very briefly. A more formal introduction will be discussed in Chapter 3.

on prices in both markets. If the wheat price in Bannister increases, traders will earn profits by purchasing the wheat in Commerce, where the price is relatively low, and then transporting the wheat to Bannister. In general, this procedure of making riskless profits is called arbitrage. If there are enough traders doing this arbitrage, price will be driven up in the commodity surplus region (Bannister) and driven down in the commodity deficit region (Commerce). Similarly, a decrease of the price in Bannister will have the opposite effect on the price in Commerce. In this way, supply and demand shocks are distributed across regions, and this distribution will result in a co-movement of prices and build a long term equilibrium between markets, which can be considered a cointegration relationship. In fact, given that two series are cointegrated, we have confidence to predict one series' performance based on its counterpart's, even if we have no access to any other information.

Figure 1.2 Weekly average of spot prices for soft white winter wheat (Bannister, Missouri and Commerce, Coloardo).[5]



[5] This graph is an excerpt from Vercammen (pg. 7, Figure 1.4, 2011) with permission.

Market integration is an important topic in the trade analysis because it gives clues to how price in one market responds to changes in another market (Rapsomanikis et al., 2006). China is the largest agricultural economy in the world. If Chinese agricultural markets are perfectly integrated with the world, then even a small change in China will largely impact other countries. In contrast, if prices in China and the world market are completely independent, then changes in China may not affect the world at all. For example, China is currently the biggest importer for soybean and the U.S. is the largest exporter. If the soybean markets between China and the U.S. are completely integrated, then market force will determine the price and the price changes can be fully transmitted through the markets, which in turn will affect the gain of soybean planters in the U.S. In addition, if the price signals are correctly transmitted, then shocks in Chinese market may further affect the U.S. farmers' long term planting plans by enabling the U.S. farmers to specialize according to their long term advantage (Ghosh, 2011).

Understanding the extent of the integration of Chinese agricultural commodity markets can be useful to policy researchers as well. In 2001, China joined the WTO, which intends to encourage markets integration. The WTO believes that with freer trade regime, the outcome is relatively efficient and the dead-weight loss is relatively small. After more than 10 years of China's membership in the WTO, our study can provide an assessment to scholars who are interested in the efficiency of the WTO agreements, i.e. the dead-weight loss change after China fulfilled its WTO commitments. Additionally, this study may give specific direction to policy makers since it provides some explanations about the relationship between policies and market integration. This information can be a good reference for agricultural policy researchers who focus on developing countries and/or emerging markets.

Recently, the integration of agricultural markets has been controversial. Rapsomanikis et al. (2006) argued that the absence of market integration arising either due to trade barriers and other policies, or due to large transaction cost, will reduce the available price information to economic agents. This reduction will in turn lead to inefficient outcomes. Moreover, Jha and Srinivasan (2000) argued that market integration helps achieve allocative efficiency and long term growth in agricultural production. Ghosh (2011) also favors agricultural markets integration since such integration ensures the regional balance among food-deficit, food-surplus and non-food cash crop-producing regions.

However, an integrated market has its own problem as well. Because agricultural production largely depends on the weather and pests, agricultural commodity markets are usually more volatile and unpredictable than other markets. In China's case, the government relies on large stock piles to keep prices stable. If Chinese agricultural markets are integrated with the world and relies on imports instead of stocks, then China has to face the problem of high volatility, which may worsen Chinese food security problem. The dispute over the integration of Chinese agricultural markets is not our main focus in this thesis. However, our study can certainly provide some evidence and provide a frame of reference for further studies on this dispute.

1.2 Problem statement

Studies about the market integration of Chinese commodity futures markets can be divided into two fields: domestic research and international research. Domestic research mainly focuses on testing the relationship between spot and futures prices. With respect to China, Zhao (2002) found the evidence of the price transmission effect between spot and futures prices for soybeans. Wang and Ke (2005) demonstrated that a long run equilibrium relationship existed between the cash and futures prices in China’s soybean market.

A more important field for this study is the international research, which mainly focuses on testing the linkage between domestic and international prices. Since the early 1990s, when Chinese futures markets were established, several studies have examined the relationship between China’s commodities’ prices and world prices.

Wu (2001) used the Engle-Granger cointegration test to find price relationships of rice, wheat, corn, soybean, peanut oil and hog between China and the U.S. markets using data from 1996 to 1999. Surprisingly, although Chinese markets were considered to be relatively isolated before China’s entry to the WTO, Wu (2001) demonstrated that Chinese and U.S. prices were cointegrated for all of the previously mentioned pairs of prices. Wu argued that those long term equilibrium relationships were largely due to China’s 1978 economic reform. Brotcke (2006) used different kinds of cointegration tests to check futures prices of soybean, soybean meal and wheat in China and the U.S. from 1999 to 2004. She showed that all three commodities had a long-run equilibrium relationship. However, Brotcke noted that the relationship was less pronounced for the case of soybean meal and was likewise weak for wheat. Based on the Johansen test, Hua and Chen (2003) found that between 1998 and 2002, a cointegration relationship existed for soybean futures prices between the Dalian Commodity Exchange (DCE) and the Chicago Board of Trade (CBOT), but there was no such relationship for wheat futures trading on the Zhengzhou Commodity Exchange and the CBOT.

However, the above studies use data back about ten years ago and thus do not reflect the current market situation. China joined the WTO in 2001, and since then China has updated its trade policy for corn, soybean, and wheat multiple times; especially during 2007- 2008 when the world food prices surged up. All these changes in the past ten years can potentially impact the cointegration relationship between China and the U.S. Therefore, it is important to re-examine the cointegration relationship with a newer dataset. Given that China joined the WTO, which encourages free markets regime, we have reason to expect that the cointegration relationship, which was established in the earlier literature, should be strengthened because of China's WTO commitments.[6]

In addition, it is well known that during the food crisis in 2007 – 2008, agricultural commodity prices in world markets surged up; meanwhile, in Chinese markets, food prices were relatively stable. The divergent path of these prices can be considered a relative structural change. The structural change, whether temporary or permanent, clearly affects the pricing relationship across these two markets, which in turn affects the cointegration relationship. One possible scenario is that Chinese and U.S. prices are not cointegrated without allowing for structural change and are cointegrated if structural change is accounted for. This possibility is explored later in this thesis.

1.3 Study objectives

This thesis focuses on examining the market integration between China and the U.S. agricultural commodity markets. Price transmission is central in understanding the market integration process, because it reflects how changes in one market are transmitted to another. We use daily futures price data from 2004 to 2012 in China and the U.S. to test whether prices of corn, wheat and soybeans are cointegrated in China's post-WTO period. Table 1.1 provides specific information about the data which is used to address our study

[6] The detail of China's WTO commitments is discussed in Chapter 2.

objectives.

This study aims to test the extent of market integration between China and the U.S. agricultural commodity markets. As discussed earlier, the cointegration relationship can be used to explain the co-movements of prices in different markets. In fact, the cointegration model has become the standard tool for market integration analysis recently, and it provides useful insights into the issue of market integration (Rapsomanikis et al., 2006). Therefore, in this study we analyze the linkage between China and the U.S. markets by testing the existence of cointegration relationship between three pairs of agricultural commodity prices. Perron (1988, 1989) claimed that the structural change would bias the usual cointegration test. Given the fact that prices in China and the U.S. diverged significantly during 2007 – 2008, our analysis is more complex than previous studies by retest for cointegration allowing for one structural change.

Table 1.1 Summary of commodities and exchanges

Commodity	U.S.	China	Testing Period
Corn	CBOT	DCE	2004/09/22—2012/07/27
Soybean	CBOT	DCE	2004/01/04—2012/07/27
Wheat	CBOT	ZCE	2004/01/04—2012/07/27

1.4 Methodology

This thesis tests the intertemporal relationships of three different pairs of commodities prices in China and the U.S. Each pair of commodity is examined via the cointegration test. Ardeni (1989) argued that traditionally used econometric tests will not be valid if the series is non-stationary. Thus, in order to get a reliable outcome, we first employ a unit root test to determine whether the price series is stationary or not. Various testing methods can be used:

Dickey and Fuller (1979) developed the DF test to test unit roots and later Said and Dickey (1984) improved the DF test to augmented-DF (ADF) test so as to make the test valid under less restrictive conditions. Other methods include the PP test proposed by Phillips and Perron (1988) and ADF-GLS test proposed by Elliot et al. (1996). In this thesis, we adopt the most widely used ADF test. If two prices series are tested to be non-stationary, then we go on to use the Engle-Granger's method (1987) to test for cointegration. If the cointegration relationship is detected, we can say that these two prices series follow a long term equilibrium relationship and those two markets can be considered as integrated markets.

As discussed above the divergent path of Chinese and U.S. prices during the 2007 – 2008 food crisis can be viewed as a structural break which biases both the unit root test and the cointegration test (Perron, 1988, 1989). Wang and Tomek (2007) claimed that "once structural breaks were accounted for, most series previously considered integrated of order one turned to be stationary". Boetel and Liu (2008) once again highlighted the difference between non-stationary time series and stationary time series allowing for structural breaks. Therefore, it is necessary to conduct the retest the cointegration relationship allowing for one structural change.

Chow (1960) proposed the Chow test to check a structural change with a known break time. In this study, however, we have no information about the exact date of when structural change happened. Andrews and Ploberger (1994) derived the ExpF and AveF tests to solve this unknown breakpoint problem. We employ the ExpF and AveF tests along with the method proposed by Hansen (1992b) to test the significance of the structural change.

Our procedures for the cointegration test allowing for one structural change are similar to the usual cointegration test, i.e. testing the unit root first and then testing the cointegration. Based on the ADF test, Zivot and Andrews (1992) derived the ZA test to check for unit roots allowing for one structural break. Gregory and Hansen (1996) later derived the GH test for cointegration test allowing for one structural break. In our thesis, in order to be cautious about the effect of a single structural change on the cointegration relationship, we employ the ZA and GH tests in addition to the Engle-Granger's method to examine the linkage between China and the U.S. agricultural commodity markets.

1.5 Outline

The rest of paper is organized as follows: An institution analysis of the U.S. and Chinese futures exchanges is discussed in Chapter 2. Also summarized in Chapter 2 is a description of the production, local consumption, trade, and policy analysis of the three commodities which are used in the analysis (corn, wheat and soybeans). Chapter 3 provides an introduction to the Engle-Granger cointegration test, followed by the introduction to the dataset and the empirical results of the Engle-Granger tests. The last part in Chapter 3 is the discussion of our results and its relation with Chinese agricultural policies. Chapter 4 is devoted to the cointegration test allowing for a structural change. Its structure is similar to the one of Chapter 3. The last Chapter, Chapter 5 concludes the study and provides suggestions for further research.

Chapter 2 The Commodity Futures Markets in China and the U.S.

2.0 Roadmap

This chapter introduces the background information for our analysis. Section 2.1 and 2.2 briefly review the history of the U.S and Chinese commodity futures markets. Section 2.3 compares the two futures markets from the perspective of regulatory structures, trading systems, and etc. Section 2.4 discusses the trade of corn, soybean and wheat between China and the U.S. Section 2.5 reviews China's agricultural policies in four important periods. Section 2.6, the last section, analyzes corn, soybean, and wheat contracts, and briefly introduces their production, consumption, and trade status.

2.1 Brief history of the U.S. commodity futures market

In the 19th century, in the face of rapid growth of agriculture and relatively backward transportation, farmers could not sell all their surplus production within local markets. In 1837, the "village" of Chicago emerged as the center of several local markets. After the Illinois-Michigan Canal opened in 1848, farmers in the hinterlands could ship their product along the Illinois River. As a result, more farmers and merchants could consolidate their activities in Chicago. In the same year, the oldest futures exchange in the world was established, which is called the Chicago Board of Trade.

In 1859, the CBOT was authorized by the state of Illinois to establish rules and to arbitrate over and settle disputes: by inspecting, weighing and certifying grain and grain trades (Lurie, 1979). In particular, corn, wheat, and cotton were the earliest traded commodities. Later in May of 1865, the CBOT transformed forward contracts into futures contracts. The clearinghouse of CBOT was set up in 1884 and “a complete and mandatory clearing system was in place at the CBOT by 1925” (Williams, 1982) In 1919, the Chicago Butter and Egg Board was reorganized and its name was changed to Chicago Mercantile Exchange (CME). In 2007, the CME merged with the CBOT to form the current CME Group. At present, more than 50 options and futures contracts are traded by over 3,600 CBOT members via open outcry and e-Trading, which makes CBOT the largest and most influential futures exchange in the world.

Futures markets have three main purposes (Santos, 2002). Firstly, futures markets enable hedgers to transform price risk into basis risk. The former is the volatilities of prices in spot markets, and the latter is the unpredictable change in the on-going difference between the futures price and the cash price. Generally, basis risk is less than the price risk, so it provides hedgers an ideal method to reduce the risk. Secondly, futures markets can facilitate firms' acquisitions of operating capital. For instance, traders can hold futures contracts instead of holding the inventory, which is usually more costly. In addition, the short selling system enables traders to finance from the futures market in the short term. Thirdly, futures markets inform the public about the expectation of commodities prices. In an efficient market, the pricing of futures commodity considers all the available information on the market. In other words, futures price is a reliable forecast because it is the public's expectation rather than particular individuals or groups.

2.2 Brief history of Chinese commodity futures market[7]

Since 1978, when Chinese economic reform began, the Chinese government gradually deregulated the price and availability of agricultural products; in doing so China employed both markets and planned economic systems to establish prices. However, along with the reform, problems appeared: for

[7] Details in this section referred to the report released by China Securities Regulatory Commission, 2007.

instance, significant variability in the prices of agriculture commodities prices resulted in highly variable supply. Facing all of the problems, the Chinese government decided to establish an agriculture commodity futures market.

In October 1990, with the help of Chicago Board of Trade, China opened its first commodity market, which is called Zhengzhou Grain Wholesale Market. China only had a few investment opportunities at that time. Consequently, people treated the commodity market as a great place to invest or to engage in speculative activities. In order to meet the high demand for speculation, a series of futures exchanges were set up throughout China.

By the end of 1993, over 50 commodity markets and nearly 1,000 futures brokerage agencies were established in China. Since many of these exchanges traded similar commodities, chaos resulted, and over-speculation, market manipulation, and fraud transactions were widely seen in the market. Seeing these problems, the central government began to standardize the futures markets. A set of rules and related laws were successively released and the State Council Securities Committee and China Securities Regulatory Commission were put in charge of all futures exchanges. After standardization was completed in 1994, only 15 exchanges market existed in China. Later in 1999, a second round of standardization of futures market was initiated. Only three of the existing futures exchanges were kept: Zhengzhou Commodity Exchange (ZCE), Dalian Commodity Exchange (DCE), and Shanghai Futures Exchange (SFE). As well, only 12 products were traded instead of 35 products. By 2000, only six products were actively traded in the three Chinese futures markets. At the same time, it became much more costly to establish a futures brokerage agency. Specifically, the minimum level of registered capital was set at 30 Million Yuan (about 3.63 M USD).

From 2000 to 2006, Chinese futures markets experienced a gentle increase but since then they have grown dramatically (Figure 1.1). In 2011, the market shrank back to 2009 level, because the margins requirements and the suspension of trading fee discounts increased. Now, the four exchanges markets in China are: ZCE, DCE, SFE and China Financial Futures Exchange (CFFE); twenty four products are traded in these four markets exchanges. Particularly, wheat is traded in ZCE, and corn and soybean contracts are traded in the DCE. In 2009, the SFE traded 0.434 billon contracts, which is the tenth largest in the world. As well, the DCE traded 0.416 billon contracts (the eleventh largest in the world) and ZCE traded 0.227 billon contracts (the fourteenth largest in the world).[8]

2.3 Comparison between China and the U.S. commodity futures markets

2.3.1 Regulatory structure in China and the U.S.

The regulatory framework in the U.S. has four components:

1) The Commodity Exchange Act (CEA),

2) The Commodity Futures Trading Commission (CFTC),

3) The Exchanges and Clearing Associations,

4) The National Futures Association (NFA) (Anderson, 1986).

The imposed regulations in the U.S. were at first a heavy burden. After experiencing the increased regulatory cost, the futures market in the U.S. moved towards deregulation or self-regulation, which required every component in the framework to establish their own regulations, each serving different purposes. Thus, the structure of these four components of U.S. futures markets is horizontal rather than vertical.

However, the structure of the Chinese futures market regulation is not the same. In November 1993, the Chinese government delegated regulatory

[8] Data source: Chinese Futures Association, http://www.cfachina.org, accessed 15 August 2012.

responsibilities for futures exchanges to the China Securities Regulatory Commission (CSRC). In December 2000, the Chinese Futures Association (CFA) was established. All futures exchanges, including the CFA, are currently under the administration of the CSRC. This vertical structure disables China's futures markets to adjust quickly and flexibly to the changes in the markets.

2.3.2 Open outcry versus electronic trading

Open outcry is the method of communication between sellers and buyers, which involves physical contacts such as shouting and hand signals. In contrast, electronic trading depends on the electronic trading platform. Electronic trading is used in most of the futures and stocks exchanges of the world because of its apparent lower communication cost.

CBOT now employs both traditional open outcry trading and electronic trading. It is not clear that why CBOT still uses open outcry. Many traders advocate for the open outcry system because the physical contacts allow traders to speculate buyer/sellers' motives or intentions and to adjust their positions accordingly. (Charnani, 2009, pp. 76). Unlike the dual trading system in CBOT, only the electronic trading system is employed in China. China's futures exchanges are unified by one trading system, which can greatly reduce the transaction costs, improve liquidity, competition and transparency, and implement the price/time priority principle. (Jain, 2005)

2.3.3 Others

The U.S. has very few restrictions for trading futures contracts. In comparison, China has more restrictions. For instance, although some enterprises with foreign capital are active in Chinese futures markets, foreigners are generally not allowed to trade Chinese futures contracts. Similarly, except for some selected firms that have international offices, most Chinese trading companies or traders are not allowed to trade in the international exchanges. Obviously, this restriction places Chinese traders at a competitive disadvantage because it prohibits Chinese traders from using international contracts to reduce risk. In addition, this policy has somewhat diminished the integration of two countries' futures markets.

2.4 Bilateral trading between China and the U.S.

After the economic reform in 1978, China engaged in trading commodities in the world markets. During the transition from a planned economy to a market economy, the Chinese government began to loosen its restrictions on imports and exports. In December 2001, China joined the WTO. Since then, in order to fulfill its WTO agreements, China relaxed even more trade barriers. However, for political and historical reasons, the Chinese government still actively controls the key agricultural commodities—such as corn and wheat—which have strategic value to the country. Like the other WTO members, China employs tariff-rate-quotas (TRQs)[9] in the corn and wheat markets. We can be see the detail in Table 2.1

However, China does not control the non-strategic agricultural commodities, such as soybeans. Therefore, the free soybean market is greatly influenced by the international forces of supply and demand. In contrast, the wheat and corn markets are much more restricted by Chinese policies.

[9] In the TRQ system, the tariff rate is dependent on the volume of trade. A lower tariff is charged if the volume is below the set quota and a higher tariff is charged otherwise.

Table 2.1 China's utilisation of TRQs for corn and wheat

Commodities		In Quota				Out Quota	
		Tariff Rate (%)	Total Quota Amount (1,000mts)			Tariff Rate (%)	
			2002[10]	2003	2004	2002	2004[11]
Corn	Seed	1				32	20
	Other	1				74	65
	Flour	9	5,850 (68%)[12]	6,325 (64%)	7,200 (60%)	64	40
	Groats and meal	9				74	65
	Cereal grains otherwise worked	10				74	65
Wheat	Durum wheat	1				74	65
	Seed	1				74	65
	Other	1				74	65
	Wheat or muslin flour	6	8,468 (90%)	8,652 (90%)	9,636 (90%)	74	65
	Groats and meal	9				74	65
	Pellets	10				74	65

Source: Zhou and Kang (2009); Huang and Rozelle (2008).

Since China and the U.S. began to actively trade in the late 1980s, China has grown to be one of the most important agricultural commodities trade partners for the U.S. In 2011, bilateral agriculture trade consisted of U.S. $18.9 billion in U.S. exports to China and U.S. $4.0 billion in imports from China.[13] Table 2.2 shows the China-U.S. trade figures for corn, soybeans, and wheat from 2009 to 2011. Note that the Chinese soybean market is much more active as compared with the other two commodities, which is consistent with the above discussion.

[10] Effective as of 1 January.

[11] 2002-2004 is the three-year transition period allowed by the WTO.

[12] Percentage of quota allocated to State Trading Enterprises.

[13] Data source: Economic Research Service, USDA. http://www.ers.usda.gov/topics/international-markets-trade/countries-regions/china/trade.aspx, accessed 15 August 2012.

Table 2.2 Bilateral trade between China and the U.S. (selected commodities)

		Quantity (mt)			Value (US $)		
		2009	2010	2011	2009	2010	2011
U.S. imports from China	Corn	47	140	121	67,798	220,346	272,024
	Soybean	NA	NA	NA	45,915,304	12,877,756	13,956,941
	Wheat	NA	NA	NA	34,622	11,817	22,892
U.S. exports to China	Corn	148,251	1,454,887	2,727,730	48,054,805	278,123,040	842,769,724
	Soybeans	22,817,676	24,203,314	20,603,151	9,193,670,635	10,816,585,573	10,451,439,286
	Wheat	412,713	201,826	478,926	86,892,644	40,535,645	160,193,846

Data source: Economic Research Service, USDA, http://www.ers.usda.gov/topics/international-markets-trade/countries-regions/china/trade.aspx, accessed 15 August 2012.

2.5 Brief review of China's agricultural policies

2.5.1 Great Chinese famine

When the People's Republic of China was established in 1949, the country was still an agricultural economy. During the 1950s, Mao and his followers believed that industrialization was the most important tool for China's economic development. The countries' resources were largely allocated to urban and industrial development as a result of "heavy-industry-oriented development strategy" (Lin, 2003). Agricultural product prices were set extremely low to subsidize industrial development. Influenced by the Soviet Union strategies, China organized hundreds of millions farmers into a collective agriculture hierarchy. Although the cash crop production quantities are limited, all agricultural production decisions were made by local leaders who in turn followed the plan made by higher leaders. All those local leaders had to deliver their quota of agricultural production to local stations run by governmental marketing bureaus. Those bureaus were in charge of setting government procurement prices, and transferring agricultural products to deficit areas (Lomar et al., 2009).

However, Mao's government did very poorly in pursuing their goal. The Great

Famine (1958-1961) caused 15 million deaths. The policies and the “Great Leap Forward Movement” discouraged farmers from producing and millions of them switched to industrial jobs. The root cause of the famine was this switch which greatly decreased agricultural production. During 1960-1961, the drop in grain output was more than 25% (Ashston, et al., 1984). Moreover, the UN embargo and the Sino-Soviet Split in 1960 closed China’s access to the international grain markets.

After the famine, China abandoned the “Great Leap Forward Movement”, but the reform was not carried out until 1978. The disaster impacted several generations of Chinese people, and immensely influenced Chinese policy makers’ decisions. The subsequent governments in China emphasize the importance of food security and the “Self-Sufficiency Strategy”.

2.5.2 Self-sufficiency strategy

The 1950s UN embargo forced China to make “self-sufficiency” the cornerstone of its trade policy. The Great Famine in 1958-1961 further convinced the Chinese government that this strategy should be the key principle in agricultural policy making. The Chinese government considers grains, oilseeds, and cotton to be the strategic crops. For decades, during both the collective and the reform period, the Chinese government attempted to increase production of the strategic crops. As the reform allowed China start to integrate with the world, the “self-sufficiency” strategy was gradually relaxed. In 1995, China started to open its soybean market for two reasons: first, to allocate more lands to plant other grains, and second, to allow the international markets to supply Chinese excessive demand. In 2003, the National Development and Reform Commission increased the over-quota cotton imports to unprecedented levels in order to meet the rising demand of China’s rapidly growing textile and clothing industry. However, for rice, wheat, and corn, China still maintains a near-self-sufficiency strategy (95 percent). Note that in the past two years, China's net import for corn has significantly increased (Table 2.5). However, the Chinese government emphasized that the 95% self-sufficiency goal for corns must be achieved.[14]

In recent years, China's self-sufficiency strategy has become controversial. On the one hand, Chinese policy making is still influenced by the famine disaster. In addition, the self-sufficiency strategy stabilizes the prices in China, which was clearly demonstrated during the 2007/2008 food crisis. On the other hand, from the case of soybeans and cotton, we can learn that China is willing to give up its self-sufficiency strategy, when the production cost is high, the demand cannot be met domestically, and/or when the crops are no longer "too-strategic".

In addition, Chinese farmers would not produce the strategic crops without the government's intervention because the strategic crops are less profitable than other crops. Similar to the subsidy programs in developed countries such as the Farm Bill in the U.S., the Rice Farming Income Stabilization Program in Japan and the Common Agricultural Program in the E.U. (Solot, 2006), subsidy programs in China have been very costly. Their costs are even higher, when subsidies work against farmers' comparative advantage. Moreover, recent research based on China's agricultural policies in 2008 suggests that Chinese interventions in 2008 generated very little increase in farm income, which is probably the most important goal for the Chinese government (Yu and Jensen, 2012). They argued that liberalizing and integrating Chinese markets with world markets will free the Chinese market of costly distortions, let China fully use its comparative advantage, and save the government large amounts of money.

[14] On May 26, 2012, Han Changfu, the Ministry of Agriculture Minister, wrote an article on People's Daily and stated that China's corn demand should not depend on international trade.

2.5.3 China’s WTO commitments

China was accepted into the World Trade Organization (WTO) in December 2001. China’s WTO commitments in the agricultural sector can be categorized into three components: market access, domestic support, and export subsidies (Huang and Rozelle, 2008).

i) Market access

China agreed to lower tariffs and to remove quantitative restrictions for all agricultural commodities apart from some selected strategic commodities. For the strategic commodities, China implements tariff rate quotas (TRQs). The average agricultural import tariff was scheduled to be reduced from 21% in 2001 to 17% in 2004. In anticipation of China’s WTO entry, the import tariff for soybeans was 114% prior to 2000 and was reduced to 3% in early 2000. Since 2000, the tariff rate for soybeans has not changed and previous import quotas have been phased out. Table 2.1 shows the tariff change patterns for corn and wheat.

ii) Domestic support

Generally, the WTO allows a 5% *de minimis* support of the total value of agricultural production for developed countries and a 10% support for developing countries. However, China is allowed an 8.5% support for its agricultural sector. Wu (2006) estimated that China’s support level for its agricultural sector in 2006 was only 0.6%. Considering this, the 8.5% limit for China is not binding. To raise its products’ competitiveness, China can increase its domestic support level by a substantial amount and still not violate its WTO commitment.

China mainly employs three measures of domestic supports (Zhou and Kang, 2009). First, China abolished its agricultural tax and taxes on agricultural products in 2006. Unlike developed countries where agricultural production is usually subsidized, China has historically taxed its agricultural production. Indeed, it is the first time that China has chosen to abolish all agricultural taxes (Yao, 2006). Second, China subsidized the agricultural development through three kinds of subsidies: subsidies for grain production, subsidies for promoting the adoption of improved seeds, and subsidies for helping farmers acquire farm machinery. The total value of agricultural subsidies, which amounted to 0.1 billion yuan in 2002 has increased to over 50 billion yuan in 2007 (Zhou and Kang, 2009). The last form of support is the continuation of grain procurement. China initialized a minimum support price (MSP) program in the early 1990s. This program enables farmers to sell their production to the government at a price floor that is set by state-owned enterprises when the market price falls below the price floor. In 2005, this program was extended to wheat for the first time.

iii) Export subsidies

China agreed to abolish all export subsidies and pledged not to introduce any export subsidies for agricultural commodities after its entry to WTO. To increase the competitiveness of Chinese agricultural products, the Chinese government introduced two new programs which are allowed by the WTO. First program involves tax rebates on grain exports. Since January 1, 2002, in China, zero value-add tax (VAT) on wheat and corn exports was approved. Moreover, any sales tax imposed on them would be fully refunded. In 2003, China increased the rate of rebates for processed wheat and corn from 5% to 13% (Ministry of Finance and State Taxation Bureau, 2002, 2003). The second support program involves an exemption of railway construction levies for grain transportation. Since April 1, 2002, China exempted railway construction levies for paddy and rice, wheat and wheat flour, corn, and soybeans (State

Development and Planning Commission[15], 2002). As was estimated by Wu (2006), the railway construction levies accounts for 30%-40% of the total transportation cost of grains transported in China. This exemption was scheduled to end at the end of 2005 but it is still employed right now (Zhou and Kang, 2009).

2.5.4 China's agricultural policy in 2007 – 2008

During 2007-2008, the prices of agricultural commodities in world markets increased dramatically. In order to stabilize its domestic prices, the Chinese government adopted a series of policies to protect its domestic markets from the world prices volatility. These active interventions included: removing VAT export rebates on grains, soybeans and ethanol; stopping the construction of new grain-based bio-fuel processing plants; imposing export duties on fertilizer sales; reducing import tariffs; increasing budgetary support for agricultural production; increasing the supply of grains from government stocks; increasing the minimum purchase price for wheat and rice; and announcing prices controls for several commodities. (OECD, 2009a). China's most important short term policies for corn, soybeans, and wheat are illustrated in the following table.

[15] State Development and Planning Commission was renamed as National Development and Reform Commission in 2003.

Table 2.3 China's short term policies in 2007/2008

Commodities	Interventions
Corn	Abolish export VAT rebate (previously at 13%).
Soybean	Decrease import tariff from 3% to 1%. Abolish export VAT rebate (previously at 13%). Apply 5% tax on export.
Wheat	Abolish export VAT rebate (previously at 13%). Apply 20% tax on export. Increase the minimum procurement price by 4%-7%.

Source: OECD, (2009a; 2011).

Although food prices in world markets declined to normal levels after the crisis, the suppression of Chinese VAT rebates was still in place until March 2011. Moreover, the minimum procurement price for wheat continually increased throughout the 2008-2010 period. In contrast, for soybeans, China abolished all the temporary changes in the export tax at the end of June 2009 and returned the 3% import tariff in March 2008 (OECD, 2009a; 2011). Additionally, the Chinese government increased subsidies for purchasing farm machinery and farm inputs, and increased direct payments to grain producers to strengthen domestic supplies. The total amount of support in 2006-2008 was estimated to be 93.00, 140.87 and 184.51 billion RMB, respectively. After 2008, the Chinese government continued to increase the level of support for its agricultural sector (OECD, 2009a; 2011).

The above temporary policies successfully insulated China's markets from the world markets. China clearly achieved some desirable outcomes, such as increased domestic supply and decreased exports, via these policies. The outcome was especially notable for corn and wheat markets, which maintained the 95% self-sufficiency target. However, these policies might discourage the needed expansion of Chinese agricultural production in the long term (Yu and Jensen, 2012).

2.6 Analysis of commodities – corn, soybean and wheat

2.6.1 Contracts details for corn, soybean and wheat in China and the U.S.[16]

Table 2.4 lists the contract details for corn, soybean, and wheat in both Chinese and U.S. futures markets. Note that commodities of one particular kind in the two markets are not exactly the same. Indeed, in the U.S. market, the corn contract is for No.2 Yellow, the soybean contract is for No.2 Yellow, and the wheat contract is for No.1 & No.2 Hard Red Winter. In China, the corn contact is the first and the second grade corn, the soybean contract is No.3 yellow or No.1, No.2, No.4 and the wheat contract is the 2nd grade strong gluten.

Table 2.4 Comparison of selected contracts details

Commodity	Exchange	Trading Unit	Unit Price in	Trading time	Trading System
China					
corn	DCE	10 tons	yuan/ton	9:00-11:30am & 1:30-3:00pm	electronic trading
soybean	DCE	10 tons	yuan/ton		
wheat	ZCE	10 tons	yuan/ton		
the U.S.					
corn	CBOT	5000 bushels	dollar/bushel	9:30am-1:15pm[17]	open outcry
soybean	CBOT	5000 bushels	dollar/bushel		
wheat	CBOT	5000 bushels	dollar/bushel		

Source: Chicago Board of Trade, http://www.cmegroup.com/company/cbot.html;
Dalian Commodity Exchange, http://www.dce.com.cn/portal/template/index.html;
Zhengzhou Commodity Exchange, http://www.czce.com.cn/portal/index.html;
All accessed 15 August 2012.

In addition, the maturity months for the respective pairs of contracts are not the same. In China, contracts for corn, soybean and wheat trade in January,

[16] Contract information in this subsection referred to contracts details in CME Group, DCE and ZCE.

[17] Beginning May 13, 2012 for trade date May 14, 2012, customers will have access to CME Globex from 6 p.m. to 4 p.m. (Central Time) Monday to Friday and from 5 p.m. to 4 p.m. Sunday to Monday. In our paper, for simplicity, we do not discuss the e-trading via the new platform but the traditional open outcry at the CBOT trading floor.

March, May, July, September, and November. In the U.S., contracts for corn and wheat futures trade in just in five months – September, December, March, May, and July. Moreover, soybean futures trade in seven months – September, November, January, March, May, July, and August. Note that the maximum horizon for trading Chinese contracts is 18 months. Conversely, in the U.S. some contracts continued to trade (albeit thinly) two or three years.

2.6.2 Production, local consumption and international trade[18]

i) Corn

Table 2.5 summarizes the situation of supply, demand, and trade of corn in China and the U.S. During 2006-2011, China, after the U.S., was the second largest corn producer in the world. Meanwhile, the U.S. and China ranked as the largest two consumers of corn in the world. The U.S is also the leading exporter in the world, and because of its sizeable domestic production, the U.S. rarely imports substantial volumes of corn. In contrast, China is not an active corn trader in the world market. Corn is considered one of the most important and strategic agricultural products by the Chinese government. The Chinese government has set a higher than average TRQs on corn, and China rarely exports corn. Thus, China's corn market does not well interact with the world and most of the production is consumed within the country. As a result, in 2013 China owned the highest ending stocks of corns amongst all corn producing countries, at 60,135,000 mts.[19]

In China, corn is mostly grown in the northeast of the country. Major growing areas include the province of Heilongjiang, Jilin, Liaongning, Hebei, Shansi and Shandong, among which Jilin and Shandong are the two largest producers of corn, and account for nearly one quarter of the total production in

[18] The detail about production for corn, soybean and wheat in China and the U.S. referred to Foreign Agricultural Service, USDA and Economic Research Service, USDA, respectively.

[19] Foreign Agricultural Service, Official USDA Estimates.

China. Chinese corn contracts are trade on the Dalian Commodities Exchange (DCE) in Shangdong province, which has easy access to Jilin province via shipments. In the U.S., corn is grown throughout the Midwest and is mainly concentrated in the states of Iowa and Illinois. The U.S. corn contracts trade on the Chicago Board of Trade (CBOT), which is located in the heart of the state of Illinois.

Table 2.5 Production, consumption and trade of corn in China and the U.S.

Commodity	Attribute	Country	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012
Corn	Production (1000 mts)	China	151,600	152,300	165,914	163,974	177,245	192,780
		United States	267,503	331,177	307,142	332,549	316,165	313,918
	MY Imports (1000 mts)	China	16	41	47	1,296	979	5,000
		United States	304	509	344	212	703	635
	MY Exports (1000 mts)	China	5,269	549	172	151	111	100
		United States	53,987	61,913	46,965	50,295	46,590	39,372
	Total Consumption (1000 mts)	China	145,000	150,000	153,000	165,000	180,000	188,000
		United States	230,674	261,632	259,272	281,590	285,014	277,889

Data source: Foreign Agricultural Service, Official USDA Estimates. http://www.fas.usda.gov/psdonline/psdquery.aspx, accessed 20 August 2012.

ii) Soybean

Table 2.6 summarizes the situation of supply, demand, and trade of soybean in China and the U.S. The supply and demand gap for soybeans in China is huge, so China is highly dependent on international trade. In 2011, China was the world's largest consumer of soybeans, but it produced less than one fifth of its overall demand. Obviously, the only way that China can meet this large demand is to outsource soybeans from overseas. Unlike the Chinese corn and wheat markets, the Chinese soybean market is almost free with only a 3% tariff rate. The U.S., however, is the largest exporter of soybeans in the world market. Moreover, most of the U.S. soybean exports end up in China. In addition, the U.S. is also the largest producer of soybeans. Therefore, the Chinese soybean market interacts well with the U.S. market.

Table 2.6 Production, consumption and trade of soybean in China and the U.S.

Commodity	Attribute	Country	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012
Soybean	Production (1000 mts)	China	15,074	13,400	15,540	14,980	15,100	13,500
		United States	87,001	72,859	80,749	91,417	90,605	83,172
	MY Imports (1000 mts)	China	28,726	37,816	41,098	50,338	52,339	57,500
		United States	246	269	361	397	393	408
	MY Exports (1000 mts)	China	446	453	400	184	190	250
		United States	30,386	31,538	34,817	40,798	40,849	36,741
	Total Consumption (1000 mts)	China	46,120	49,818	51,435	59,430	65,950	70,800
		United States	53,473	51,627	48,112	50,671	48,403	48,753

Data source: Same as Table 2.5.

The major soybean growing regions within China is the northeast provinces. Heilongjiang province alone accounts for one third of Chinese soybean production. Two soybean contracts are traded in DCE: No.1 Soybean and No.2 Soybean. We only analyze No.1 Soybean, because No.2 Soybean is traded at a very small volume. In the U.S., more than 80 percent of the soybean acreage is concentrated in the upper Midwest, which has easy access to the CBOT in Chicago.

iii) Wheat

Table 2.7 summarizes the situation of supply, demand, and trade of wheat in China and the U.S. In 2011, the EU-27 as a whole was the largest wheat producer in the world, producing 137,395,000 mts. China followed the EU-27 as the second largest producer, and the U.S. ranked the fifth. However, because of China's big population, Chinese domestic consumption is also very large. Note that in 2011, China's production was less than its consumption, so China had to depend on trade or its own stockpile. Similar to corn, wheat is considered a strategic commodity. In 2012, even though the production falls short of consumption, China's wheat stock was 55,746,000 mts, ranking the first in the world.[20] In the U.S., although its wheat production is the fifth largest, its export ranks the first in the world. Reasons for the U.S. export dominance in the wheat market may include: its relatively small population, and various kinds of substitutes for wheat.

Unlike corn, wheat has several different varieties. In China, wheat is divided into spring and winter varieties. Spring wheat is planted in March and April, and is harvested in July and August; while winter wheat is planted in September and October, and is harvested in May and June. Spring wheat is mainly planted in Heilongjiang and Inner Mongolia, and the main growing area of winter wheat is in Shangdong and Henan.

In the U.S., the main variety of wheat is hard red winter--which is planted in September and October--and is harvested from May to August, depending on the specific location. The major growing area for hard red winter wheat is the

[20] Foreign Agricultural Service, Official USDA Estimates.

state of Kansas. Other kinds of wheat include soft red winter wheat, planted in the east of the Mississippi; soft white winter wheat, planted in the Pacific Northwest; durum and dark spring wheat, planted in the state of both North Dakota and South Dakota. In the CBOT, the traded wheat is the hard red winter wheat.

Table 2.7 Production, consumption and trade of wheat in China and the U.S.

Commodity	Attribute	Country	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012
Wheat	Production (1000 mts)	China	108,466	109,298	112,464	115,120	115,180	117,920
		United States	49,217	55,821	68,016	60,366	60,062	54,413
	MY Imports (1000 mts)	China	388	49	481	1,394	927	2,933
		United States	3,317	3,065	3,456	3,227	2,638	3,050
	MY Exports (1000 mts)	China	2,783	2,835	723	892	941	978
		United States	24,725	34,363	27,635	23,930	35,076	28,563
	Total Consumption (1000 mts)	China	102,000	106,000	105,500	107,000	110,500	120,500
		United States	30,940	28,614	34,293	30,978	30,710	32,153

Data source: Same as Table 2.5.

Chapter 3 Cointegration and Research Findings

3.0 Roadmap

In this study, we adopt the cointegration model to examine the integration of Chinese and U.S. corn, soybean, and wheat markets. This Chapter discusses the cointegration tests and the corresponding empirical results in detail. Section 3.1 reviews the relationship between LOP and cointegration. Section 3.2 explains the unit root and cointegration test in detail. Section 3.3 and 3.4 introduce the dataset employed and provide specific descriptive statistics. Section 3.5 summarizes the empirical results and Section 3.6 discusses the policy implication.

3.1 Law of one price, integration and cointegration

In general, in the absence of transaction costs and trade restrictions, prices for identical commodities will be pushed to converge by arbitrage, and this is called the Law of One Price (LOP) (Isard, 1977). Note that even transaction costs and trade restrictions exist, the LOP may continue to work. Vercammen (2011) discussed the LOP from many perspectives: by allowing the existence of transportation costs, storage costs, and other costs in a traditional partial equilibrium model of supply and demand. He pointed out that the LOP ensures that prices in different markets share a similar pattern over time. In other words, the LOP ensures that prices series in different markets are related by a long term equilibrium. Markets with this characteristic are referred to as integrated markets. In financial markets, the no-arbitrage condition refers to a situation where all assets are priced properly and there is no arbitrage opportunity left. The no-arbitrage condition generally takes a longer time in commodity markets than in financial markets, because the transportation time is longer and more subject to cost uncertainties. Although it takes a longer time to establish the no-arbitrage condition in commodity markets, prices are generally considered to be free of sizeable arbitrage opportunities. The lack of arbitrage opportunities is another way of stating that prices have a long term equilibrium relationship.

Testing market integration is an important problem in trade/price analysis. If we can conclude that two markets are integrated, we can then easily infer one market's behavior from the other market. Testing the performance of prices series is central in testing for market integration. According to the LOP, if prices in different markets follow a steady state pattern in the long term, then we will claim these markets are integrated. Isard (1977) used an AR(1)--autoregressive with one lag--model to test for the markets integration between the U.S. and Germany. The AR(1) model considers the current price to be linearly dependent to its price in the previous period. However, the AR model should only be applied to stationary series, of which the mean, variance, and autocovariance function do not change over the time. Violating this principle results in what is known as spurious regression (Granger and Newbold, 1974). Unfortunately, commodity prices are usually tested to be non-stationary. Before 1980s, most researchers used a first-differencing method to eliminate the non-stationary problem. This method is an improvement but it still has a number of important drawbacks (Plosser and Schwert, 1978).

The non-stationary problem was not solved until the concept of cointegration was introduced in the early 1980s. Granger (1981) proposed that even if a pair of time series is individually non-stationary, a linear combination of the two series might be stationary. If this is the case, then the two series are said to be cointegrated. The idea of cointegration enables researchers to examine the long term relationship between two non-stationary series. Ardeni (1989) argued that when testing the LOP of commodity prices, which are usually non-stationary, we should use cointegration test rather than the traditional correlation test. Hamilton (1994) described cointegration as "[…], there is some long-run equilibrium relation tying the individual components together, represented by the linear combination […]" (pp. 572). Thus we can conclude that if the prices series in China and the U.S. are cointegrated, then there is a long term equilibrium relationship between these two sets of data, in which the two markets are integrated. Testing for cointegration is therefore equivalent to testing the integration between Chinese and U.S. markets, which is our goal in this thesis.

3.2 Engle-Granger cointegration test

A more vivid idea of cointegration can be illustrated as a tale of the drunk and her dog (Murray, 1994). Suppose we see a drunk and her dog wandering in the park. The paths of both the drunk and the dog are unpredictable random walks, but because the dog is on a leash, the distance between the drunk and her dog is predictable. We call the drunk and her dog one cointegrating pair. In the context of agricultural commodity prices, suppose we observe two prices series move through the time, each following a random walk, if their connection is tested to be statistically significant, we will conclude these two prices series are cointegrated.

The formal definition of cointegration is as follows: "the vector of x_t are said to be cointegrated of order d, b, denoted x_t ~ CI(d,b), if (i) all components of x_t are I(d); (ii) there exists a vector α $(\neq 0)$ so that $z_t = \alpha' x_t$ ~ I(d-b), b>0. The vector α is called the cointegrating vector" (Engle and Granger, 1987). In the above definition I(d) means that a non-stationary series which will be stationary if the series is differenced d times. An I(0) series refers to a stationary series. Thus, according to the previous definition, if individual series are I(1) and if their linear combination is I(0), then the pair of series are said to be cointegrated. The parameters of the linear combination which are contained in the α vector, constitute the cointegrating vector.

From the definition, we can see that the cointegration test consists of two steps. First, we test to which order the series are integrated, i.e. we find the d in I(d). Second, we test the cointegration relationship.

3.2.1 Unit root test

We employ the unit root test to determine if a particular series is I(0), I(1) or I(d), d>1. Specifically, we adopt the augmented Dickey-Fuller (ADF) test, which can be described as follows:

Consider an AR(1) model,

$$y_t = \pi y_{t-1} + \sigma\varepsilon_t \qquad (3.1)$$

where y_t is the testing variable and ε_t is a white noise error term with variance 1. When $|\pi| < 1$, this process is stationary and when $|\pi| \geq 1$, the shocks will accumulate over time. Specifically, if π=1, then we can conclude that this series contains a unit root and that y_t is an I(1) process. If π>1, then the values of y_t will oscillate with larger and larger cycles and eventually explode in value. Obviously, future prices series cannot be boundless, so we must exclude the last case.

Next we subtract y_{t-1} from both sides of equation (3.1) and rearrange it to obtain:

$$\Delta y_t = y_t - y_{t-1} = (\pi - 1)y_{t-1} + \sigma\varepsilon_t \qquad (3.2)$$

In order to test for a unit root, we can set up the null hypothesis H_0: π^*=0 against H_1: π^*< 0, where $\pi^* = (\pi - 1)$. Then we use the OLS to estimate π^*

and its standard deviation from equation (3.2) and get the statistic τ. If we fail to reject H_0 in favor of H_1, then we should conclude that this process has a unit root. Otherwise, this process would be trend stationary. Note that the τ statistic is not a simple t-statistic because its distribution is not the same as that of an ordinary t statistic (Davidson and MacKinnon, 2004). Therefore, we should compare the τ statistic with the critical values provide by MacKinnon (2010).

If y_t is either an I(0) or I(1)[21]process (in most cases this is true) we just need to do the DF test once. Specifically, we test the hypothesis as we showed above. Because this is a one-tail test, if the estimated value π^* is less than the DF critical value, we can then reject the null hypothesis and conclude y_t is stationary. Otherwise, we would fail to reject the null hypothesis and conclude y_t ~ I(1).

However, the DF test does not take any longer lag periods into account (i.e., only y_{t-1} is included in the regression equation). This restriction may lead to serially correlated error terms. So an augmented Dickey-Fuller test is introduced in order to allow for a higher order AR process. The ADF was originally introduced by Dickey and Fuller (1979) and developed by Said and Dickey (1984).

Assume we represent the DF regressions (Davidson and MacKinnon, 2004) as:

$$\Delta y_t = \boldsymbol{X_t}\gamma + (\pi - 1)y_{t-1} + e_t \tag{3.3}$$

and $$\Delta \mathrm{y}_{\mathrm{t}-1} = \boldsymbol{X_{t-1}}\gamma^{\circ} + (\pi - 1)\mathrm{y}_{\mathrm{t}-1} + \mathrm{e}_{\mathrm{t}-1} \tag{3.4}$$

Given an AR(1) process $u_t = \rho_1 e_{t-1} + u_t$, subtract $\rho_1 \Delta y_{t-1}$ from Δy_t, and

[21] To be accurate, in our following tests we would check if the series would be integrated at higher order.

rearrange it, we can get

$$\Delta y_t = \boldsymbol{X_t}\gamma + (\pi - 1)(1 - \rho_1)y_{t-1} + \pi\rho_1\Delta y_{t-1} + u_t \tag{3.5}$$

So in general the ADF test extends the DF test (3.2) as follows:

$$\Delta y_t = \boldsymbol{X_t}\gamma + \pi^* y_{t-1} + \sum_{j=1}^{p} \delta_j \Delta y_{t-j} + u_t \tag{3.6}$$

Within the equation (3.6), $\boldsymbol{X_t}$ is a row vector of deterministic regressors, π^* and δ_j are parameters which need to be tested; *p* determines the lag number in this AR model. The specific value of π^* will indicate if the data series is stationary. Note that $\pi^* = \pi - 1$ is equivalent to $\pi^* = (\pi - 1)(1 - \rho_1)$. Consequently, the hypothesis that $\pi^* = 0$ is always the same as the hypothesis that $\pi = 1$. Determining the specific value of *p* (i.e., number of lags) is a practical problem when employing the ADF test. Common methods include Akaike's Information Criterion (AIC), the Schwarz's Bayesian Information Criterion (BIC), and Hall's General-to-Specific rule. In our paper, we use the AIC to choose the optimal number of lags.

In our thesis, we implement the ADF test at least three times to examine each price series (Pfaff, 2011).

First, we test the model with both trend and drift.

$$\Delta y_t = \beta_1 + \beta_2 t + \pi^* y_{t-1} + \sum_{j=1}^{p} \delta_j \Delta y_{t-j} + u_t \tag{3.7}$$

We start by testing the null hypothesis $\pi^* = 0$. If the null is rejected, we would conclude that the data series is stationary and no further tests are needed.

If the null is not rejected, then we test the model with drift alone.

$$\Delta y_t = \beta_3 + \pi^* y_{t-1} + \sum_{j=1}^{p} \delta_j \Delta y_{t-j} + u_t \tag{3.8}$$

Again we used the same null hypothesis as above. If the null is rejected, the series is stationary otherwise it must be integrated.[22]

If the series is indeed integrated then we must determine if the series is I(1) or integrated at a higher order. Practically, we can apply ADF to

$$\Delta\Delta y_t = \pi^* \Delta y_t + u_t \tag{3.9}$$

If $\pi^* = 0$ is rejected, then we can conclude that Δy_t ~ I(0) and y_t ~ I(1). Otherwise, we need to further test if y_t ~ I(2) or an even higher order using a similar method.

3.2.2 Cointegration test

Let $P_{c,c}$ and $P_{u,c}$ denote the pair of futures prices for corn in China and the U.S., respectively. After testing for stationary using the above ADF procedures, these two prices series may have one of the following two outcomes:

1. $P_{c,c}$ and $P_{u,c}$ are integrated at different orders, i.e. $P_{c,c}\sim$ I(d) and $P_{u,c}\sim$ I(b), in which d≠b. In this case, these two series cannot be cointegrated. (Engle and Granger, 1987)
2. $P_{c,c}$ and $P_{u,c}$ are integrated at the same order, i.e. $P_{c,c}\sim$ I(d) and $P_{u,c}\sim$ I(d). a) If d=0, then both series are said to be stationary, which means their means and variances do not change over time. Therefore, these two series must be cointegrated.

   b) If d≥ 1, then these two series may or may not be cointegrated (Engle and Granger, 1987).

[22] The model without either drift or trend is actually the case when β_3=0, which can be tested using the F-test for (3.8) with null hypothesis $\beta_3 = \pi^* = 0$. However, in our analysis, it is more important to know whether the series has unit roots or not, rather than knowing which model fits better. So we do not conduct the proposed F-test in our paper.

Note that only in the last case i.e. 2b), we need the cointegration test to conclude if two prices series are cointegrated. The cointegration test can be described as follows:

Consider a simple regression model which has only one variable,

$$y_t = \mu + \alpha x_t + e_t \tag{3.10}$$

in which x_t and y_t are both I(1). According to Engle and Granger's definition, x_t and y_t are said to be cointegrated if there exists a vector (μ, α)' which ensures a linear combination $z_t = y_t - \mu - \alpha x_t \sim$ I(0). If we let $z_t = e_t$, then the cointegration problem can be translated into determining if e_t is I(0), i.e. run ADF test on this error term. Again take the test on corn markets as an example, if both $P_{c,c}$ and $P_{u,c}$ are I(1), we need to derive the ordinary least squares residual in (3.10) and then adopt ADF test to find out whether the residual is I(0). If the residual is I(0), then the prices are cointegrated. Otherwise, they are not cointegrated.

Equation (3.10) also intuitively interprets the idea of cointegration: x_t and y_t have a long term equilibrium relationship as (3.10) shows, but e_t may cause a short term deviation from this equilibrium. An analysis of e_t informs us about the speed of adjustment (SOA) in the time series variables; this analysis is the focus of the error correction model (Engle and Granger, 1987) but is not the focus of this thesis.

In sum, the complete procedure for the cointegration test involves two steps. The first step is to run the ADF test on the individual price series to determine the order of integration. If both prices series have the same order of integration, then it is appropriate to move on the second step. The second step involves two parts (suppose all series are I(1), which is the most likely case; take the price of corn as an example):

a) Run the regression on $P_{c,c} = \mu + \alpha P_{u,c} + e_t$ and collect the error term series.
b) Use the ADF test described above to test if e_t ~ I(0). If so, then we can conclude that $P_{c,c}$ and $P_{u,c}$ are cointegrated. Otherwise, they are not cointegrated.

3.3 Data description

In general, each commodity has six variables which are reported at the end of each day: the opening price, settle price, high price, low price, volume, and open interest. We follow the standard procedure by conducting the cointegration test using the settle price series for each of the three commodities—corn, soybean, and wheat—in both the Chinese and U.S. futures markets. The data period for corn is from 2004/09/22 to 2012/07/27. For soybean and wheat the data period is from 2004/01/02 to 2012/07/27.

Because contracts in China and U.S, have different maturity months, we will use rolling settle price data in our analysis. Rolling data is simply the settle price for the next nearest delivered contract. For instance, on Oct.24, 2005, the settle price for Chinese corn is based on the Chinese November, 2005 contract, and the settle price for U.S. corn in based on the U.S. December, 2005 contract. On Nov.20, 2005, the settle price for Chinese corn is based on the Chinese January, 2006 contract, but the settle price for U.S. corn is still based on the U.S. December, 2005 contract. This occurs because November 20th is beyond the pre-defined delivery date and so the settle price rolls over to the next nearest contract. This rolling settle price approach solves the problem of comparing prices for the same commodity in markets with different maturity months.

All of the data used in the analysis are converted to U.S. dollars based on the prevailing daily exchange rate, which was downloaded from the website of the Board of Governors of the Federal Reserve System. Converted settle prices of the same day are then used in the regression analysis. Lastly, we adjust the data by removing data for the dates in which either one or both markets were closed for a national holiday.

Chinese data was downloaded from the Wind and Bloomberg database.[23] U.S. data are extracted from the CRB Infotech CD, which was purchased in the spring of 2012.

3.4 Data analysis

3.4.1 Corn

Corn contracts trade on both the CBOT and the DCE. At CBOT, corn contract trades five times per year with maturity dates spanning roughly four years; however, at DCE corn contract trades six times per year with maturity dates spanning just one year. Table 3.1 shows the descriptive statistics for the corn contracts in both markets. All prices are reported as dollars per metric tonne ($/mts).

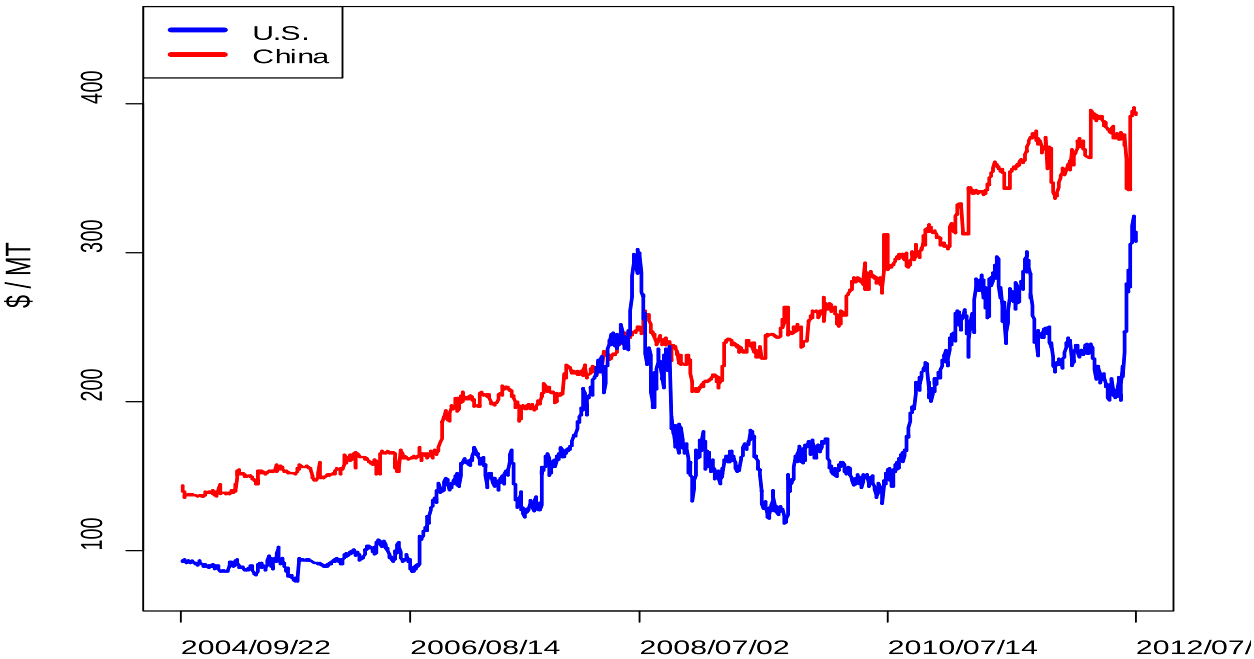
Figure 3.1 displays the corn price series for both markets. Note that the Chinese corn price is generally higher than the U.S. corn price during the testing period. In addition, as compared with the U.S. corn price, the Chinese corn price has generally trend up over time with relatively low levels of volatility. During the 2007- 2008 food crisis, U.S. corn prices rose above the Chinese corn prices. Even though both prices shared a similar pattern during the crisis, the increase/decrease percentage in China price pattern is much smaller than the U.S.

[23] Data provided by acquaintance XU, zhou and his working company Shanghai East Asia Futures Co., Ltd.

Table 3.1 Descriptive statistics of corn contracts in China and the U.S.

	China	U.S.
Mean	239.88	167.07
Standard Error	1.75	1.41
Median	230.70	159.06
Mode	138.95	93.41
Standard Deviation	74.54	60.39
Sample Variance	5556.44	3647.09
Kurtosis	-0.89	-0.89
Skewness	0.47	0.38
Range	261.10	245.28
Minimum	136.05	79.33
Maximum	397.14	324.61
Sum	442823.72	308416.3
Count	1846	1846

Figure 3.1 Daily settle prices for nearby corn contracts in China and the U.S.



3.4.2 Soybean

Soybean contracts trade on both the CBOT and the DCE. In China both Soybean No.1 and Soybean No.2 contracts are traded each day. The Soybean No.2 contract is for genetically modified soybeans and the trade amount is very low.[24] Consequently, in the analysis below, we focus on DCE's Soybean No.1 contract. DCE soybean contracts trade six times per year or a period spanning roughly one and half years. In contrast, CBOT soybean contracts trade seven times per year for a period spanning about three years and eight months. Table 3.2 shows the descriptive statistics for the soybean contracts in both markets. All prices are reported as dollars per metric tonne ($/mts).

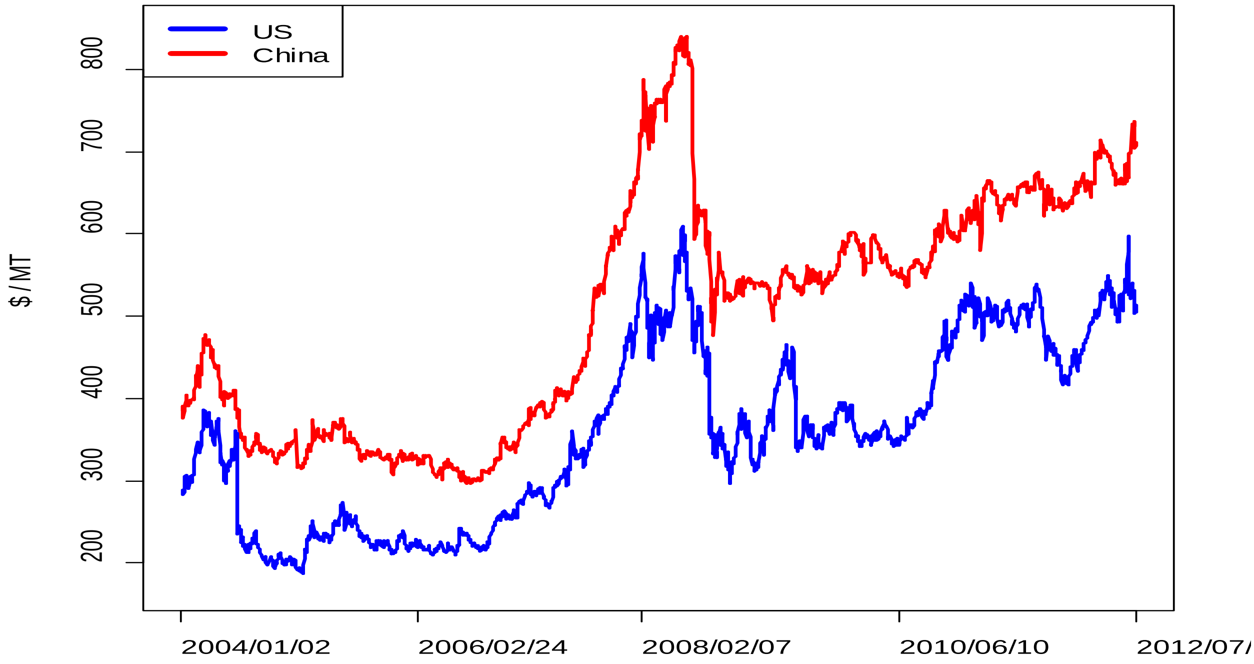
Table 3.2 Descriptive statistics of soybean contracts in China and the U.S.

	China	U.S.
Mean	504.02	358.19
Standard Error	3.17	2.44
Median	537.42	353.68
Mode	338.31	354.96
Standard Deviation	142.36	109.49
Sample Variance	20264.79	11988.09
Kurtosis	-1.13	-1.21
Skewness	0.13	0.18
Range	542.91	423.17
Minimum	296.52	186.40
Maximum	839.43	609.56
Sum	1015595	721736.1
Count	2015	2015

Figure 4.2 displays the soybean price series for both markets. Note that unlike corn prices, soybean prices in the U.S. and China in general moved together and prices in China were always higher than prices in the U.S. Note that during 2007- 2008, the U.S. prices experienced more fluctuations than China prices.

[24] Only 72 Soybean No.2 contracts were traded in 2012/07/12.
Data Source: DCE, http://www.dce.com.cn/PublicWeb/MainServlet, accessed 12 January 2013

Figure 3.2 Daily settle prices for nearby soybean contracts in China and the U.S.



3.4.3 Wheat

Wheat contracts trade on the CBOT and the ZCE. CBOT wheat contracts trade five times per year over a span of about two years and four months. In contrast, ZCE wheat contracts trade six times per year over a span of about one year. In China, there are two types of wheat contracts which are determined by the wheat's quality. In our analysis below, we focus on the regular wheat contract (PU MAI), which has a greater trading volume. Table 3.3 shows the descriptive statistics for the soybean contracts in both markets. All prices are reported as dollars per metric tonne ($/mts).

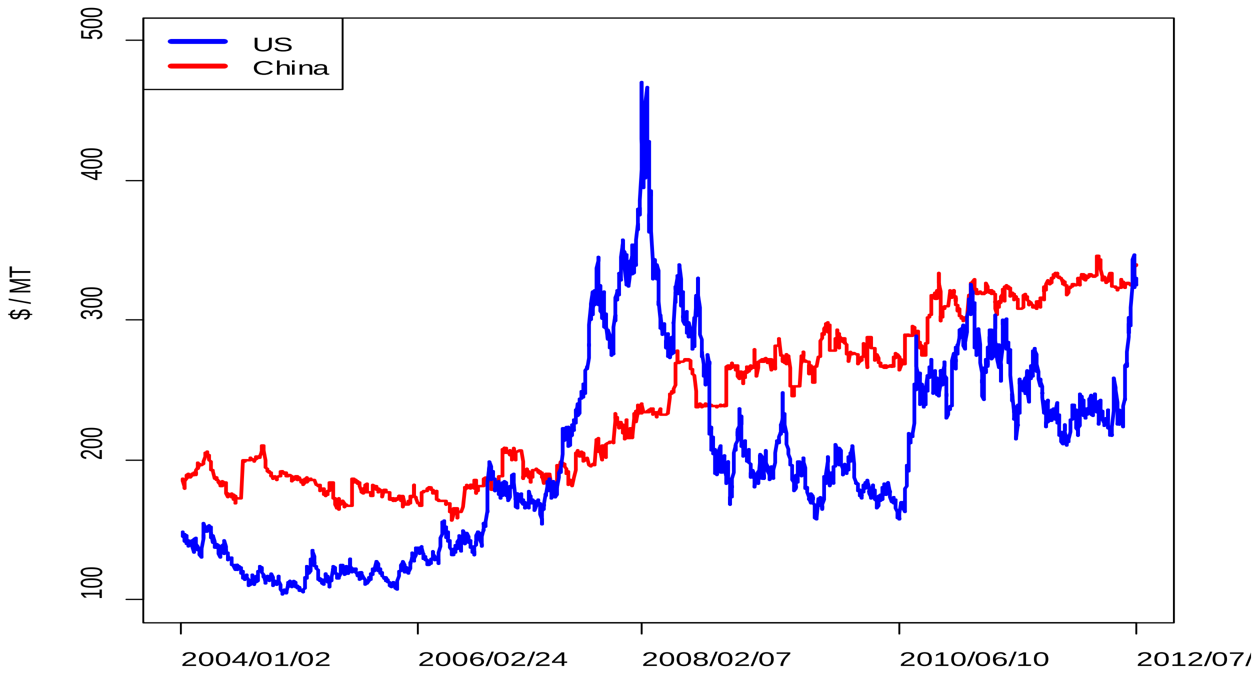
Figure 3.3 displays the wheat price series for both markets. Clearly, the U.S. prices have been much more volatile than China prices over the sample period. With a notable exception of the 2007- 2008 commodity price boom, Chinese prices have generally been higher than the U.S. prices. During the commodity price boom, the U.S. prices rocketed to unprecedented high levels, whereas

Chinese prices were quite stable. Note that by 2012/07/27, which is end of the data series, the U.S. price of wheat has once again surged above the China price.

Table 3.3 Descriptive statistics of wheat contracts in China and the U.S.

	China	U.S.
Mean	240.33	201.77
Standard Error	1.25	1.56
Median	235.09	190.07
Mode	185.95	173.16
Standard Deviation	56.04	69.87
Sample Variance	3140.68	4882.46
Kurtosis	-1.42	-0.19
Skewness	0.26	0.61
Range	189.16	366.36
Minimum	156.76	104.23
Maximum	345.92	470.59
Sum	484265.4	406575
Count	2015	2015

Figure 3.3: Daily settle prices for nearby wheat contracts in China and the U.S.



3.5 Empirical results

3.5.1 Unit root test

Before we set up the ADF model, a practical problem is how to choose the appropriate number of lags in the regression equation. As discussed in Chapter 3, we use the AIC to select the optimal number of lags. In order to make the AIC procedure efficient, we need to specify a reasonable upper bound for the maximum number of lags. Schwert's (1989) rule of thumb for determining the maximum number of lags is based on the number of observations. Specifically, the maximum number of lags is given by:

$$P_{\max} = \text{int}\left[12 * \left(\frac{T}{100}\right)^{\frac{1}{4}}\right] \tag{3.11}$$

where int[x] denotes the integer part of x, and T is the number of observations in the data series.

Based on equation (3.11), we find that the maximum number of lags for corn, soybean, and wheat are equal to 24, 25, and 25, respectively. Now that we have the maximum number of lags we select the number of lags which minimizes the AIC. We summarize the results of this minimization process in Table 3.4 for both the drift-only and a trend plus drift version of the ADF test.

Table 3.4 Optimal number of lags in the ADF test for different commodities

Commodities	Trend & Drift		Drift	
	China	US	China	US
Corn	11	2	14	2
Soybean	13	1	13	1
Wheat	2	13	2	13

The next step is to use the ADF procedure to test for unit roots of the various prices series. Unit root tests for corn, soybean, and wheat are based on equations (3.7)—(3.9) and we summarize the results in Table 3.5. Indeed, Table 3.5 lists the τ statistics associated with estimates of π^* in equations

(3.7) to (3.9).Table 3.6 gives the corresponding critical values, which are provided by MacKinnon (2010).

Table 3.5 τ statistics in the ADF test results for different commodities

ADF	China			US		
	Trend & Drift	Drift alone	1st Difference	Trend & Drift	Drift alone	1st Difference
corn	-2.78	0.19	-15.38***	-2.09	-0.685	-29.78***
soybean	-2.00	-0.86	-11.85***	-2.62	-1.32	-32.27***
wheat	-3.41**	-0.52	-33.44***	-2.41	-1.62	-11.67***

* denotes reject the null hypothesis with 90% confidence

** denotes reject the null hypothesis with 95% confidence

*** denotes reject the null hypothesis with 99% confidence

Table 3.6 Critical values for the ADF test

ADF	Critical Values		
Significance Level	Trend & Drift	Drift alone	1st Difference
1%	-3.96	-3.43	-3.96
5%	-3.41	-2.86	-3.41
10%	-3.12	-2.57	-3.12

As discussed earlier, we set up the unit root null hypothesis against the alternative hypothesis of a trend stationary series. Based on the results reported in Tables 3.5 and 3.6, we can conclude that corn and soybean prices in the U.S. and Chinese markets and the wheat price series in the U.S. market are both I(1) processes. For Chinese wheat, we find that in different models, we generate different results. Based on the test result, we conclude that this series is trend stationary under (3.7) (i.e. ADF test with both trend and drift). In addition, we find that U.S. wheat series is I(1) process. Therefore we can claim that wheat prices in two markets are not cointegrated. However, to be conservative, we conduct the cointegration tests for wheat as well.

3.5.2 Cointegration test

As discussed earlier, we follow the Engle-Granger method to test the null hypothesis of no cointegration against the alternative that the dual prices series are cointegrated. Recall that this test for cointegration involves testing for the stationarity of the residuals of equation (3.10). According to the AIC, the optimal lags of the residuals series are 1, 23, and 12 for corn, soybean, and wheat respectively. Estimation of π^* are summarized in Table 3.7. Table 3.6 gives the critical values.

Table 3.7 Engle-Granger cointegration tests

	Engle & Granger	
	Trend & Drift	Drift
corn	-2.72	-2.73*
soybean	-4.50***	-4.47***
wheat	-2.36	-2.33

* denotes reject the null hypothesis with 90% confidence
** denotes reject the null hypothesis with 95% confidence
*** denotes reject the null hypothesis with 99% confidence

From the table, we can conclude that the corn and wheat prices series for the two countries are not cointegrated, whereas the soybean prices series are cointegrated. This results holds for both the drift alone and the trend plus drift specification of the model.[25]

3.6 Policy implication

In chapter 2, we have discussed Chinese main policies on its agricultural sector. Now, let us review these policies and their corresponding effects from the perspective of market integration.

[25] In this study, we consider the test result with 95% or above confidence as a significant result.

3.6.1 Self-sufficiency strategy

Our empirical result that soybean prices are cointegrated is exactly the same as what we expected. China opened its soybean market in 1995 and now it is the biggest importer in the world. The free market scenario in Chinese soybean markets ensures the smooth prices transmission between countries, which in turn results in an integrated market.

However, the story is quite different for the corn and wheat markets. These markets in China have been subjected to a tight self sufficiency policy. The 95% self-sufficiency goal enables China not to rely on international markets to meet domestic demands, thus leading to relatively isolated markets. In the above cointegration test, we found no long term equilibrium relationships (i.e. no cointegration relationship) between corn and wheat prices in China and the U.S. markets. This result agrees with our expectation as well.

3.6.2 China's WTO commitments

China joined the WTO in 2001. Previous studies which used prior-WTO data (1996 – 1999) demonstrated that the soybean prices were cointegrated (Wu, 2001). Brotcke demonstrated it again by using data from 1999-2001. This study, we use the post-WTO data (2004-2012) and verify that prices continue to be cointegrated. The positive cointegration result is consistent with Figure 3.2 which shows that the two prices series tend to move in tandem throughout the 2004 to 2012 period. Additionally, this result is reasonable because the soybean market has been relatively free since 1995, so WTO membership was not expected to have much impact on the level of cointegration in this market.

A more interesting issue is about the corn and wheat markets. Wu (2001) used data from 1996 to 1999 and confirmed the price integration for corn and wheat when comparing the Chinese and U.S. markets. However, our result shows that corn and wheat markets between China and the U.S. are not cointegrated during 2004-2012. This result is puzzling, because WTO encourages free trade among markets. It is reasonable to believe that China's corn and wheat markets would become more global in nature and thus the Chinese and global markets would be more integrated after China's accession to the WTO in 2001.

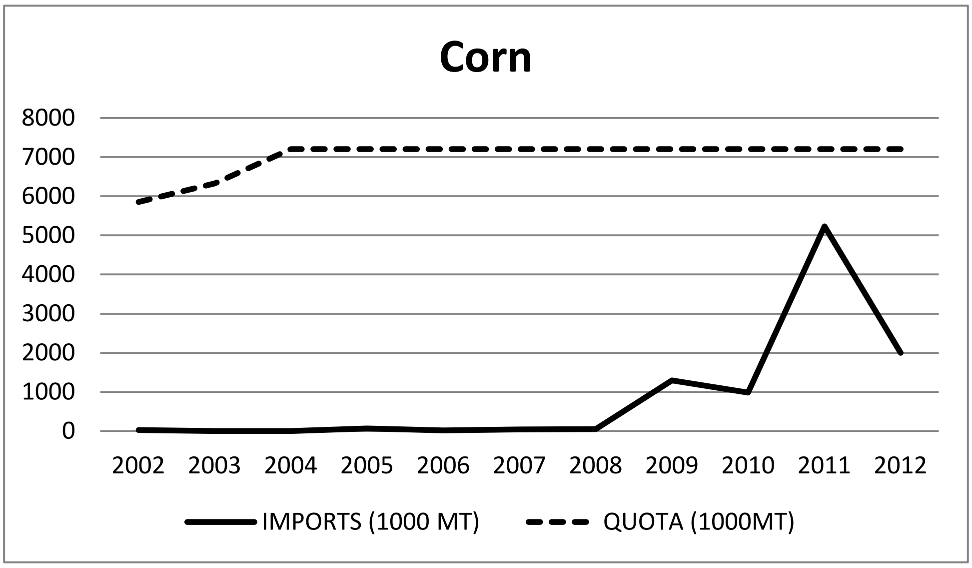
We first re-examine the related WTO agreements to understand this puzzling result. In China's case, the WTO agreements for agricultural commodities can be mainly categorized into three categories: market access, domestic support, and export subsidies (Huang and Rozelle, 2008). For market access, China has agreed to use a tariff-rate quota system (TRQ), which is widely used by WTO members. For domestic support, China has agreed to support less than 8.5 percent of the total production in its agricultural sector. For export subsidies, China has agreed not to subsidize any of its agricultural exports.

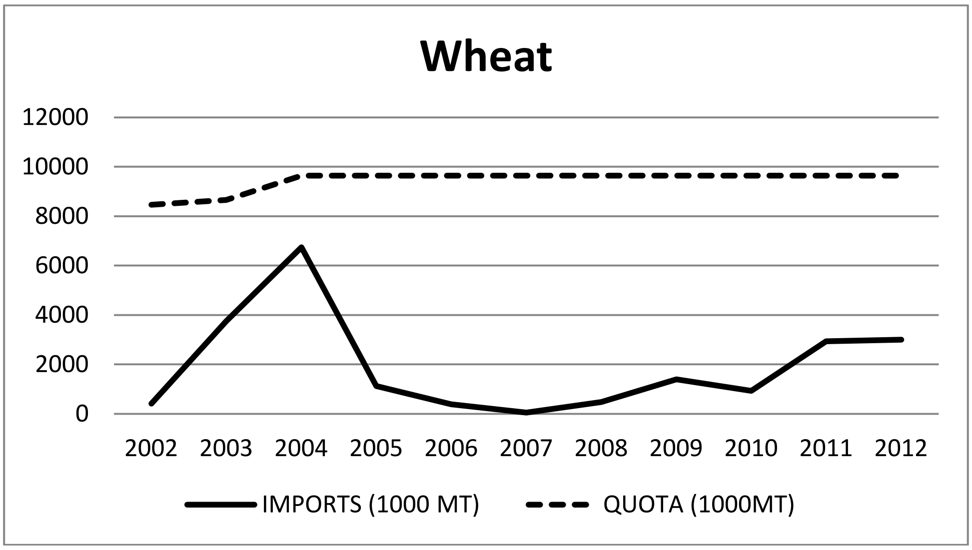
From the first sight, all these agreements were intended to open China's agricultural markets to global competition. However, by closer examination, we observe that these WTO agreements are largely not binding for China. Figure 3.4 illustrates the TRQ outcome for corn and wheat. Note that the TRQ restriction does not improve the trade because Chinese imports for both corn and wheat have remained far below the set quota. Zhou and Kang (2009) attributed China's low utilisation of grain TRQs to China's domestic supply-demand circumstances, and related policies on productions; however, they failed to prove that. The main reason of China's low utilisation of TRQ is still not clear, but in this thesis, we do not focus on this issue.

Regarding domestic support, Wu (2006) estimated that China's support level for its agricultural sector in 2006 was only 0.6 percent, which was far less than the maximum of 8.5 percent. In terms of export subsidies, after joining the

WTO, China used a value added tax to both support grain exports and reduce the cost of transporting grains. These policies have the same expected outcome as an export subsidy because they either lift the price or reduce the cost, which both benefit the exporters.

Figure 3.4 China's utilisation of TRQs for corn and wheat





Data source:
Imports data from: Foreign Agricultural Service, USDA;
http://www.fas.usda.gov/psdonline/psdquery.aspx, accessed 11 January 2012;
Quota data from: National Development and Reform Commission, http://en.ndrc.gov.cn/, accessed 13 January 2012.

In sum, we can see these WTO agreements are not binding for China, which can potentially explain why corn and wheat markets between China and the U.S. are cointegrated before instead of after China's accession to WTO in 2001.

3.6.3 China's agricultural policies in 2007-2008

As can be seen in Figure 3.1 and Figure 3.3, the movement of Chinese corn and wheat prices was quite different to the movement of world corn and wheat prices during 2007 – 2008 food price crisis. Recall that in Chapter 2, we described several policies which isolated China's market during the food crisis. The divergent paths of corn and wheat prices during the food crisis clearly broke down the cointegration relationship between these markets. Thus, structural change provides important clues regarding the so-called puzzle (i.e., the lack of integration for Chinese and U.S. prices despite China joining the WTO). Specifically, if we account for structural change in our regressions and now find evidence of cointegration within the corn and wheat markets, then we can conclude that it is the structural change and not a failure of the WTO that is the reason for failing to find cointegration in the earlier analysis. However, if we allow for structural change and still fail to detect cointegration relationships in the corn and wheat markets, then the puzzling result concerning the failure of the WTO to achieve Chinese pricing integration remains.

Some other studies may be helpful on solving this puzzle. For instance, Krugman (1986) pointed out that domestic oligopolistic and collusion behaviour may keep the price difference between domestic and international markets higher than the price difference determined by transaction costs, which might further hinder the market integration. Solving this puzzle is beyond our scope of analysis. The main purpose of this study is to re-examine the integration of Chinese agricultural commodity markets.

In Chapter 3, we conduct the cointegration test and determined that only in the soybean market were prices cointegrated. The test results clearly show that during 2004 – 2012, China's corn and wheat markets are not integrated with the world markets. Previous studies employing prior-WTO data successfully detect the cointegration relationships within corn, soybean, and wheat markets. Our result is puzzling because it is reasonable to expect more integration after China's entry to WTO. After closer examination of Chinese food policies, we proposed three potential explanations. One of them is about the structural change effect, which is discussed in detail in Chapter 4.

Chapter 4 Cointegration Allowing for One Structural Change

4.0 Roadmap

At the end of Chapter 3, we claimed that structural change can potentially solve the puzzle about why China and U.S. prices in the corn and wheat markets are not cointegrated despite China joining the WTO. In this Chapter, we conduct the cointegration tests allowing for one structural change in an attempt to provide clues regarding the structural change should be blamed for the lack of integration of China's agricultural markets during the post-WTO period. Specifically, Chapter 4 discusses the cointegration tests allowing for one structural change and the corresponding empirical results. Section 4.1 discusses the relationship between the usual cointegration and the cointegration allowing for one structural change. Section 4.2 introduces the test for structural change. Section 4.3 and Section 4.4 explain the unit root and cointegration test when allowing for one structural change in detail. Section 4.5 summaries and discusses the empirical results.

4.1 Structural change and validity of cointegration test

A structural break/change will occur if the coefficient of the regression equation changes after some breakpoint. Perron (1989, 1990) re-examined the Great Depression and the first oil crisis and showed that the DF/ADF test would be contaminated by a structural break and would therefore be no longer reliable. The structural change(s) biases the unit root test because a change in the trend or drift of the regression equation may generate different estimations. Structural change(s) can arise from a variety of reasons including newly released policies/regulations, fundamental shifts when the supply-demand condition changes, and new calculation methods for the variables and etc. In practice, we can test for structural change by employing the ExpF and AveF test.[26] Details of these two tests are provided below.

From Figure 3.1-3.3, we can see that agricultural commodity prices surged to an unprecedented high level in world markets during 2007- 2008. Indeed, according to the CBOT, between April, 2007 and August, 2008 the prices of corn, soybean and wheat increased about 147%, 128% and 205% respectively. However in China, the corresponding price increases were 39%, 123% and 32% respectively. As we mentioned in Section 3.6.1, because of the difference in the rate of price increase in the U.S. and China, we are can confidently conclude that corn and wheat prices are not cointegrated if the usual Engle-Granger method is used. Therefore, the influential impacts of the 2007-2008 price spike implies that it is necessary to allow for structural change in our cointegration test. The impact of the price spike can be temporary or permanent. However, even if the break occurs only in one period, it will be accumulated, thus having a lasting effect (Pfaff, 2011). Therefore, in the following analysis, we treat the structural change as a permanent change, which can be verified from the dummy variables added to the deterministic term in the equations.

4.2 Test for structural change

Chow (1960) first proposed the Chow-test, which can be used to test the significance of a single structural break with the assumption that the breakpoint time, t^{break}, is known. We define a dummy variable d which equals to 1, if $t > t^{break}$ and 0 otherwise. We can then set up a structural change hypothesis test it via the following model.

$$y_t = \mu + \alpha x_t + \beta d + \gamma d x_t + e_t \tag{4.1}$$

[26] Bai and Perron (1998, 2003) and Perron (2005) provide a rigorous method to detect multiple structural changes. In our paper we would allow only one structural change to highlight the period in 2007/2008 when food crisis happened.

Within equation (4.1) β and γ denote the level of change in the intercept and slope when *t* reaches t^{break} , respectively. The null hypothesis of no structural change can be expressed as $\beta = \gamma = 0$. This hypothesis can be tested using a standard F-test.

As noted above, the Chow test requires us to know the break date in advance. Although we estimate that the break should occur during the 2007- 2008 food crisis, we do not know when exactly the break occured. Quandt (1960) suggested using the QLR statistic which is equal to the maximal F-statistics to deal with the unknown breakpoint problem. However, he could not find the right distribution of the statistic because a "nuisance"[27] parameter exists in the alternative hypothesis. This problem was not solved until 30 years later. Andrews (1993) formally proved that the QLR statistic would no longer follow the F distribution and he provided the critical values by simulation.

Andrews and Ploberger (1994) derived the asymptotically optimal tests for statistic tests where the nuisance parameter only exists in the alternative hypothesis. They claimed that the optimal test should be of an average exponential form and showed that these optimal tests, which are referred to as the ExpF and AveF tests, have higher power as compared to the QLR test.

In a structural change model, let $({\beta_1}', {\beta_2}')'$ denote the parameter vector before the change and let $(\beta_1' + \lambda', {\beta_2}')'$ denote the parameter vector after the change. Assume the structural change occurs at time t and let F_t denotes the F-statistic for testing $\lambda = 0$ against $\lambda \neq 0$, then the test statistic for asymptotic significance level α is

[27] The nuisance parameter is the parameter that does not appear in the null but in the alternative.

$$(1+c)^{-p/2} \int \exp\left(0.5 * \frac{c}{1+c} * F_t\right) dJ(t) \tag{4.2}$$

Within equation (3.12) p is the dimension of λ, $J(\cdot)$ is the weight function over t (in the one-time structural change case, this is a uniform function on $[t, 1-t]$) and c is a scalar constant depending on the weight function over λ.

Andrews and Ploberger (1994) continued to show that when $c \to \infty$, then (4.2) equals the ExpF statistic and when $c \to 0$, then (4.2) equals the AveF statistic, which are calculated using the following equations. They also proved that if λ is small in value, then the AveF test will have more power. If λ is large in value, then the ExpF test will have more power. The equations in question can be expressed as:

$$expF = \ln\left(\frac{1}{\bar{t}-\underline{t}+1}\sum_{t=\underline{t}}^{\bar{t}} \exp(0.5 * F_t)\right) \tag{4.3a}$$

$$aveF = \frac{1}{\bar{t}-\underline{t}+1}\sum_{t=\underline{t}}^{\bar{t}} F_t \tag{4.3b}$$

Within this pair of equations $\underline{t} \le t \le \bar{t}$ denotes the interval for all potential change points and F_t is the chow statistic for each possible break. In general, we use the interval [0.15,0.85] for the whole data period, i.e., t=0.15. (Andrews and Ploberger, 1994) Later, Hansen (1997) gave the computing method for calculating asymptotic p-values for these test statistics.

In this study, we examine whether the structural change occurs in the joint prices series. Let $(\beta_1, \beta_2, \beta_3)'$ denote the parameter vector before the change and let $(\beta_1+\lambda, \beta_2+\lambda, \beta_3+\lambda)'$ denote the parameter vector after the change. We test the null that $\lambda = 0$ against $\lambda \neq 0$ by an F-test. As discussed above, the critical values are no longer following the regular F distribution but one specific distribution. The table of the critical values were provided by Andrews and Ploberger (1994).

We use a simple error correction model (ECM) similar to Hansen (1992b) to test for relative structural change in the joint prices series.

$$e_t = P_{cc,t} - \alpha_1 - \alpha_2 P_{uc,t} \tag{4.4a}$$

$$\Delta P_{cc,t} = \beta_1 + \beta_2 \widehat{e_{t-1}} + \beta_3 \Delta P_{uc,t} + u_t, \tag{4.4b}$$

Within equation (4.4), P_{cc} denotes the price of Chinese corn and P_{uc} denotes the price of U.S. corn. We estimate the cointegration equation (4.4a) first by OLS and derive the residuals. Next, we use the residual as a regressor in equation (4.4b). Specifically, we run regression of the increase of China's corn price on the residuals, on the increase in the U.S. corn price, and on a constant term. The usage of error correction model can eliminate the non-stationary problem so that our F-test is valid. Otherwise, we are only allowed to use (4.4a) to test whether the relative structural change occurred between two cointegrated series. The null hypothesis of no relative structural change will be rejected if the expF/aveF statistics are large enough.

4.3 Unit root test allowing for one structural change

Perron (1988, 1989) pointed out that the Great Depression and the First Oil Crisis in 1973 were good examples of structural changes which contaminated the traditional unit root tests. To address this shortcoming, he then derived the Perron's unit root test which assumes a known breakpoint. Later, Zivot and Andrews (1992) used a "data-dependent" algorithm to transfer the finding breakpoint problem endogenously. In our paper, we follow Zivot and Andrews's method to test unit roots in the time series data.

Perron (1989) discussed three different kinds of models in which the break point is known and occurs at time $1 < T_B < T$. Model A allows a one-time shift in the levels, Model B allows a change in the rate of growth and Model C allows both. The null hypotheses that the series has a unit root allowing for a structural break is given by the following set of equations:

Model (A): $y_t = \mu + dD(T_B)_t + y_{t-1} + e_t$ (4.5a)

Model (B): $y_t = \mu_1 + DU_t(\mu_2 - \mu_1) + y_{t-1} + e_t$ (4.5b)

Model (C): $y_t = \mu_1 + dD(T_B)_t + DU_t(\mu_2 - \mu_1) + y_{t-1} + e_t$ (4.5c)

Within equation (4.5), $D(T_B)_t = 1$ if $t = T_B + 1$ and 0 otherwise; $DU_t = 1$ if $t > T_B$ and 0 otherwise, and the error process can be represented as $A(L)e_t = B(L)\varepsilon_t$ with ε_t i.i.d., where $A(L)$ and $B(L)$ assigns lag polynomials for different orders.

The corresponding alternative hypotheses that the series is stationary allowing for a structural change in occurring at time T_B is given by the following (4.6a, b, c)

Model (A): $y_t = \mu_1 + \beta t + (\mu_2 - \mu_1)DU_t + e_t$ (4.6a)

Model (B): $y_t = \mu + \beta_1 t + (\beta_2 - \beta_1)DT_t^* + e_t$ (4.6b)

Model(C): $y_t = \mu + \beta t + (\mu_2 - \mu_1)DU_t + (\beta_2 - \beta_1)DT_t^* + e_t$ (4.6c)

where $DT_t^* = t - T_B$ if $t > T_B$ and 0 otherwise.

Perron (1989) then applied ADF tests onto each model to test unit roots. The regression equations are given by the following set of equations:

$$y_t = \hat{u}^A + \hat{\theta}^A DU_t + \hat{\beta}^A t + \hat{d}^A D(T_B)_t + \hat{\alpha}^A y_{t-1} + \sum_{j=1}^{k} \hat{c}_j{}^A \Delta y_{t-j} + \hat{e}_t \qquad (4.7a)$$

$$y_t = \hat{u}^B + \hat{\beta}^B t + \hat{\gamma}^B DT_t^* + \hat{\alpha}^B y_{t-1} + \sum_{j=1}^{k} \hat{c}_j{}^B \Delta y_{t-j} + \hat{e}_t \qquad (4.7b)$$

$$y_t = \hat{u}^C + \hat{\theta}^C DU_t + \hat{\beta}^C t + \hat{\gamma}^C DT_t^* + \hat{d}^C D(T_B)_t + \hat{\alpha}^C y_{t-1} + \sum_{j=1}^{k} \hat{c}_j{}^C \Delta y_{t-j} + \hat{e}_t \qquad (4.7c)$$

The test statistic for testing $\hat{\alpha}^i = 1$ is the student-t ratio $t_{\hat{\alpha}^i}(\lambda)$, $i = A, B, C$. However, because the statistic is dependent on λ, which equals to T_B/T, we cannot use the traditional t-table as the critical values but the one provide by Perron (1989).

Based on Perron's work, Zivot and Andrews (1992) endogenized the choosing breakpoint problem. They proposed that $t_{\hat{\alpha}^i}\left[\hat{\lambda}_{inf}^i\right] = \inf_{\lambda \in \Delta} t_{\hat{\alpha}^i}(\lambda)$, where Δ is a closed subset of (0,1). The regression equations for different kinds of models are given by the following set of equations:

$$y_t = \hat{u}^A + \hat{\theta}^A DU_t(\hat{\lambda}) + \hat{\beta}^A t + \hat{\alpha}^A y_{t-1} + \sum_{j=1}^{k} \hat{c}_j{}^A \Delta y_{t-j} + \hat{e}_t \qquad (4.8a)$$

$$y_t = \hat{u}^B + \hat{\beta}^B t + \hat{\gamma}^B DT_t^*(\hat{\lambda}) + \hat{\alpha}^B y_{t-1} + \sum_{j=1}^{k} \hat{c}_j{}^B \Delta y_{t-j} + \hat{e}_t \qquad (4.8b)$$

$$y_t = \hat{u}^C + \hat{\theta}^C DU_t(\hat{\lambda}) + \hat{\beta}^C t + \hat{\gamma}^C DT_t^*(\hat{\lambda}) + \hat{\alpha}^C y_{t-1} + \sum_{j=1}^{k} \hat{c}_j{}^C \Delta y_{t-j} + \hat{e}_t \qquad (4.8c)$$

Within equation (4.8), $DU_t(\lambda) = 1$ if $t > T\lambda$ and 0 otherwise; $DT_t^*(\lambda) = t - T\lambda$ if $t > T\lambda$ and 0 otherwise. The critical values are provided by Zivot and Andrews (1992).

In our analysis below, we test for structural breaks in the U.S. and China commodity prices using all three types of models. We also plot the path of the test statistic which gives the potential breakpoint and explicitly shows the level of significance. The null hypothesis that the series has a unit root with an exogenous structural change can be rejected if the test statistic for testing $\hat{\alpha}^i = 1$, where $i = A, B, C$, i.e. $\inf_{\lambda \in \Delta} t_{\hat{\alpha}^i}(\lambda)$, is less than the critical value proposed by Zivot and Andrews (1992). Otherwise, we claim that the series is stationary when allowing for one structural change.

4.4 Cointegration test allowing for one structural change

Recall equation (3.10), $y_t = \mu + \alpha x_t + e_t$, which is the standard equation of cointegration relationship between two series. We conclude that if $e_t \sim$I(0), then y_t and x_t are cointegrated. Gregory and Hansen (1996) added dummy variables into equation (3.10), thereby allowing for a structural change. They specified the dummy variable *DU* to take on a value of 1 if after the breakpoint, and 0 otherwise. They also endogenized the "finding breakpoint" problem. Moreover, they set up three kinds of models, which they refer to as C, C/T, C/S and which are given by the following set of equations:

C: $y_t = \mu_1 + \mu_2 DU_t + \alpha x_t + e_t$ (4.9a)

C/T: $y_t = \mu_1 + \mu_2 DU_t + \beta t + \alpha x_t + e_t$ (4.9b)

C/S: $y_t = \mu_1 + \mu_2 DU_t + \alpha_1 x_t + \alpha_2 x_t DU_t + e_t$ (4.9c)

Specifically, Model C allows a level shift in the standard cointegration model. Model C/T allows a level shift in the cointegration model including a trend variable. Model C/S is based on Model C but allows both a level shift and a change of slope parameter. The null hypothesis that no cointegration exists is the same as the one in Engle-Granger's method, i.e., e_t is a unit root process. For each possible break time π, we use the OLS to compute the residual $e_{\pi,t}$, which depends on the break time π, in C, C/T and C/S. Next we use ADF test to regress $\Delta e_{\pi,t}$ on $e_{\pi,t-1}$ and $\Delta e_{\pi,t-1}, \Delta e_{\pi,t-2}, \dots, \Delta e_{\pi,t-p}$ as (4.10).

$$\Delta e_{\pi,t} = \beta_1 + \beta_2 t + \pi^* e_{\pi,t-1} + \sum_{j=1}^{p} \delta_j \Delta e_{\pi,t-j} + u_t \quad (4.10)$$

We apply AIC to choose the optimal lag p. Gregory and Hansen proposed the GH statistic as the minimum t-value of π^*. They also gave the critical values of this GH statistic by the Monte Carlo simulation. The null hypothesis is rejected if the GH statistic is sufficient small.

4.5 Empirical results

4.5.1 Test for structural change

We use the test discussed in Section 4.2 to find whether relative structural change occurred or not. Intuitively, a relative structural change means a significant different movement at some time of two prices series. More formally, a relative structural change means a one-time parameters change in the equation in which two prices are related. In this study, we use the simple error correction model (ECM) as given by equations (4.4), which is similar to Hansen (1992b). We summarize the results in Table 4.1. Table 4.2 specifies the critical values when we have three variables in the equation (Andrews and Ploberger, 1994).

Table 4.1 ExpF and AveF tests results for joint prices series

	Corn	Soybean	Wheat
ExpF	5.89***	13.01***	5.17**
AveF	8.56***	11.22***	7.39**

* denotes reject the null hypothesis with 90% confidence
** denotes reject the null hypothesis with 95% confidence
*** denotes reject the null hypothesis with 99% confidence

Table 4.2 Critical values for ExpF and AveF tests when p=3 (three variables)

Confidence Level	ExpF	AveF
1%	5.7	8.21
5%	4.22	6.07
10%	3.49	5.1

The null hypothesis that there is no structural change in the parameters in the error correction process can be rejected if the expF/aveF statistics are greater than their respective critical values. Our results in Table 4.1 support the conjecture that there is a relative structural change during the testing period for all commodities. These results imply the need to conduct the ZA and GH test, which is the unit root and cointegration test allowing for one structural change.

4.5.2 Unit root test allowing for one structural change

Now we move to reanalyze the unit root outcome with a new procedure allowing for one structural change. Zivot and Andrews (1992) developed the ZA test which is the extension of ADF test allowing for one structural change.

Different kinds of change were modeled in equations (4.8a), (4.8b) and (4.8c). Specifically, equation (4.8a) allows one change in the drift alone, equation (4.8b) allows one change in the trend only, and equation (4.8c) allows for both. The null hypothesis that the price series has a unit root when allowing for one structural change can be rejected if the ZA statistic is less than the critical value. The ZA statistic is the smallest t-statistic over all possible change dates. In fact, the ZA statistic is the t-statistic that gives the least favorable result for not rejecting the null hypothesis. Table 4.3 summarizes the regression results for testing the null hypothesis: $\hat{\alpha}^i = 1$ in equations (4.8a), (4.8b) and (4.8c). Table 4.3 lists the critical values for the ZA statistic in different models. Figures 4.1-4.3 plot the path for the ZA statistics of corn, soybean and wheat for the different models in both countries.

Table 4.3 ZA statistic for different commodities

ZA	China			U.S.		
	Change in Trend & Drift	Change in Trend	Change in Drift	Change in Trend & Drift	Change in Trend	Change in Drift
Corn	-5.52**	-4.40*	-4.17	-3.93	-2.51	-4.05
Soybean	-3.05	-2.32	-3.19	-3.40	-3.25	-3.41
Wheat	-5.50**	-5.27***	-4.87**	-4.18	-2.83	-4.17

* denotes reject the null hypothesis with 90% confidence
** denotes reject the null hypothesis with 95% confidence
*** denotes reject the null hypothesis with 99% confidence

Table 4.4 Critical values for the ZA test

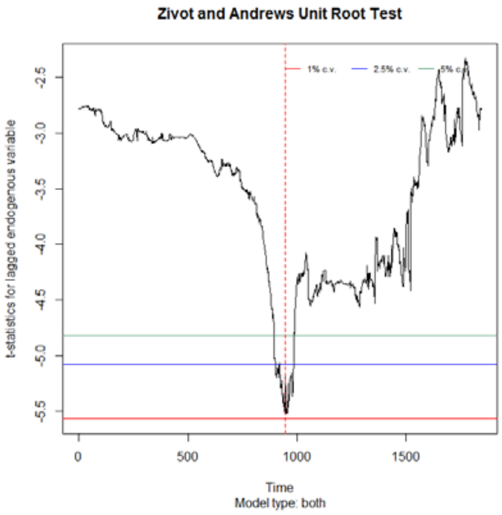
Significance Level	Critical Values		
	Change in Trend & Drift	Change in Trend	Change in Drift
1%	-5.57	-4.93	-5.34
5%	-5.08	-4.42	-4.8
10%	-4.82	-4.11	-4.58

After comparing the ZA statistic and the critical values, we can conclude that the price series of Chinese wheat is stationary and that the price series of Chinese corn is stationary in the equation (4.8a) model. To be conservative, we cannot conclude that whether the Chinese corn price is stationary or not. However, for the case of Chinese wheat, we can confidently conclude that the price series is stationary. These results are slightly different than our ADF test results. Specifically, Chinese corn and wheat prices are more likely to be stationary under the ZA test. These results are reasonable intuitively, because, as discussed above, the Chinese government imposed heavy regulations on corn and wheat. The paths of ZA statistic are plotted over the full sample period in Figure 4.1-4.3. The possible change date (i.e. the date when the t-value is smallest) is denoted by the red dot vertical line when the null hypothesis is rejected at 95% confidence.

Figure 4.1 Paths of ZA statistics of corn for different models in China and the U.S.

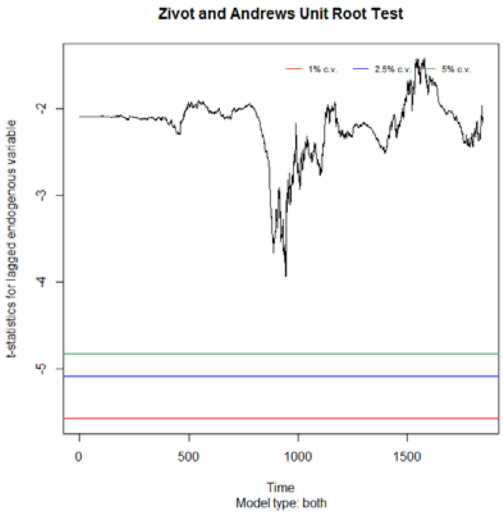
China

Change in Trend & Drift

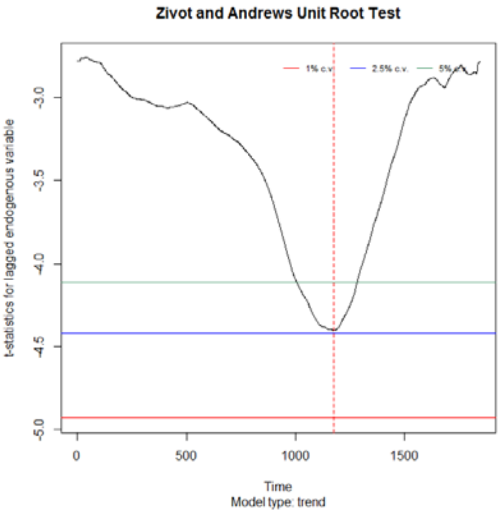


U.S.

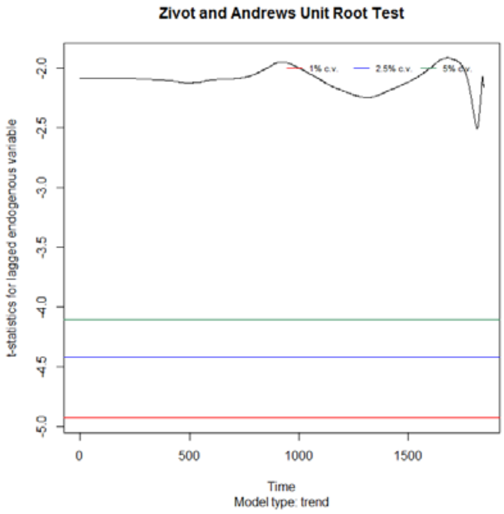
Change in Trend & Drift



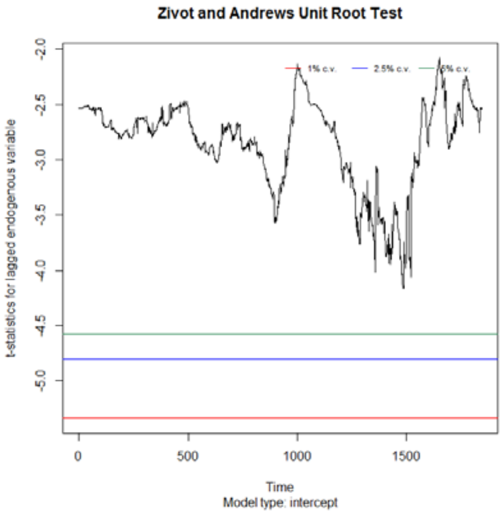
Change in Trend



Change in Trend



Change in Drift



Change in Drift

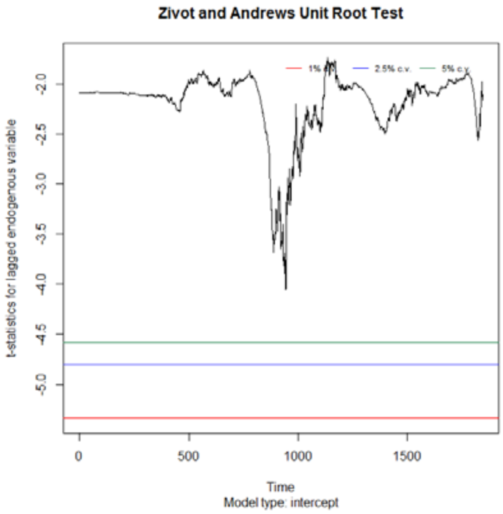
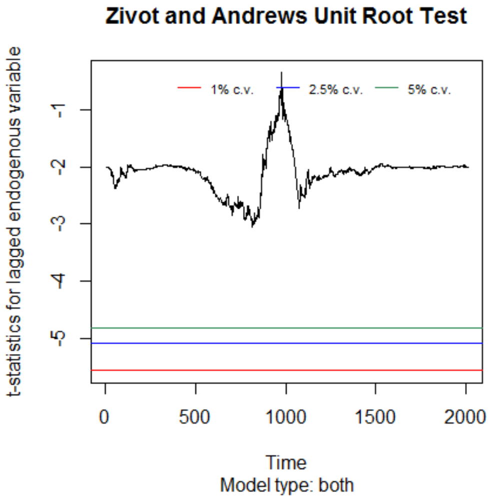
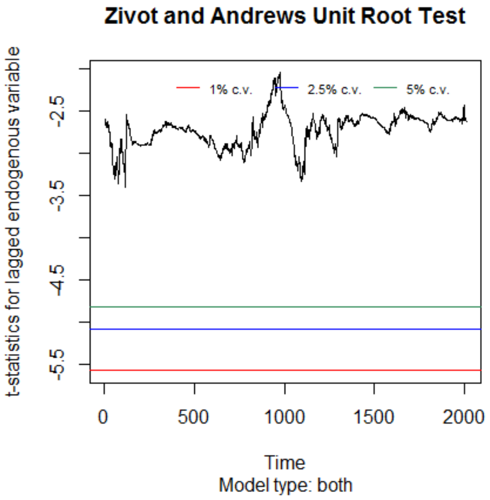


Figure 4.2 Paths of ZA statistics of soybean for different models in China and the U.S.

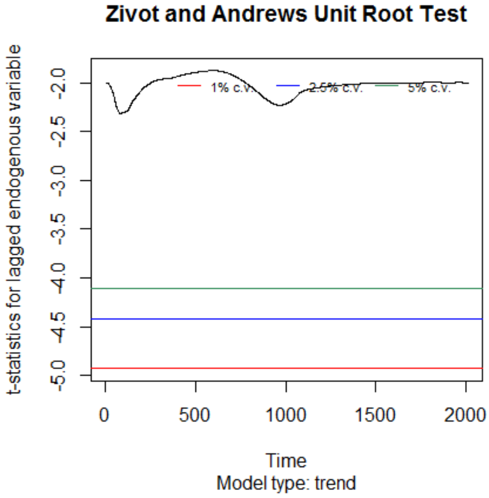
China | U.S.

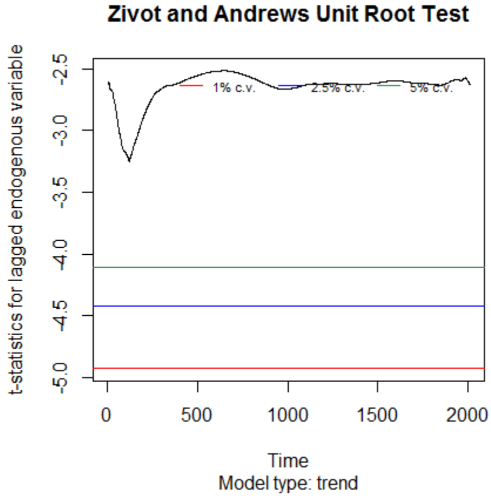
Change in Trend & Drift



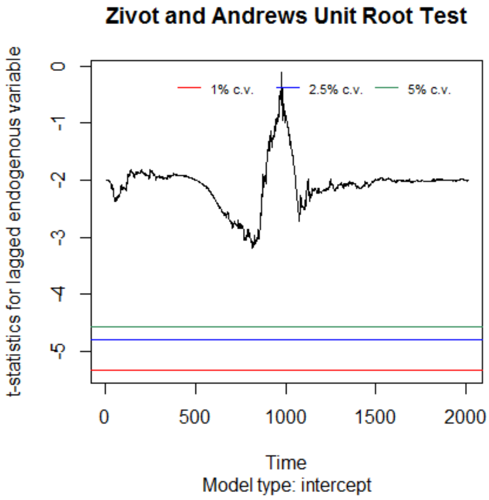


Change in Trend





Change in Drift



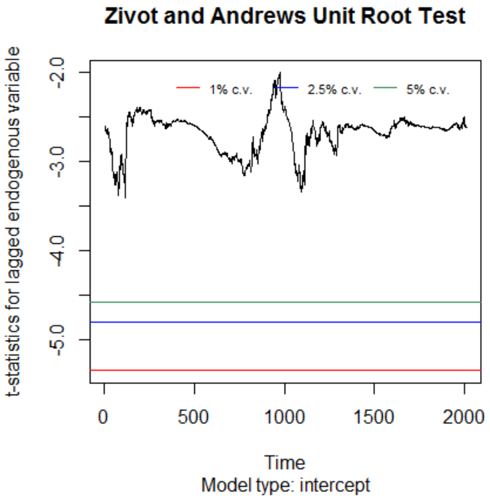
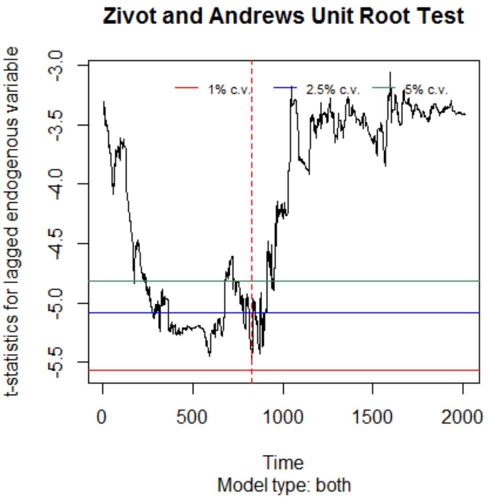


Figure 4.3 Paths of ZA statistics of wheat for different models in China and the U.S.

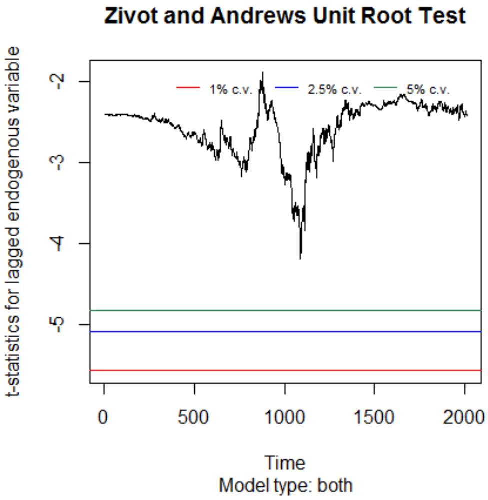
China

Change in Trend & Drift

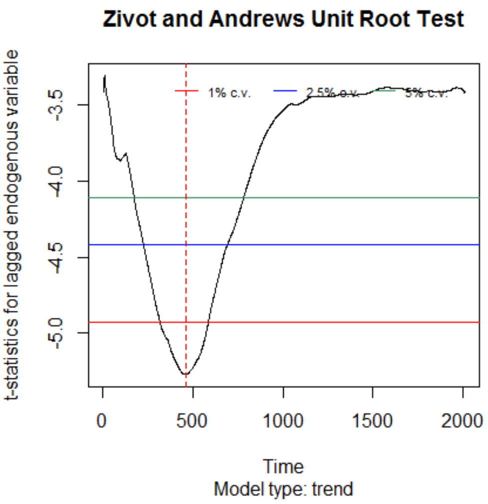


U.S.

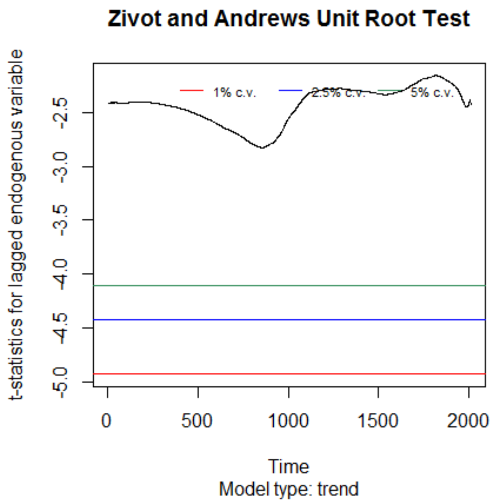
Change in Trend & Drift



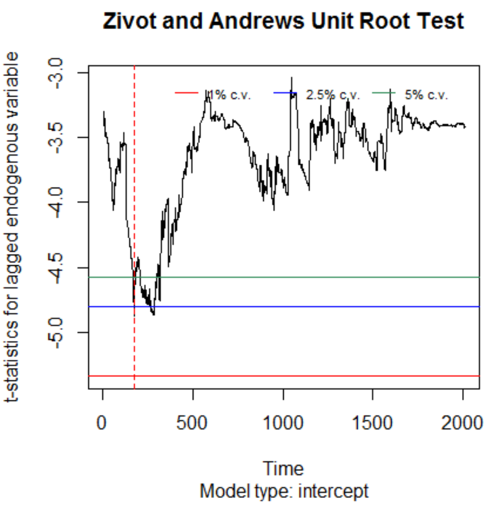
Change in Trend



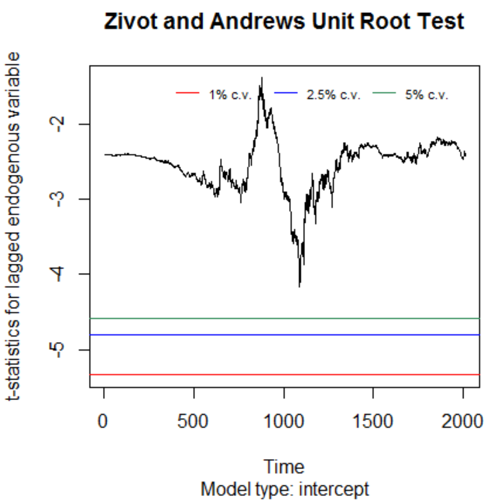
Change in Trend



Change in Drift



Change in Drift



4.5.3 Cointegration test allowing for one structural change

As seen in Figure 3.1-3.3, Chinese and U.S. corn and wheat prices followed distinctively different patterns during the 2007- 2008 commodity price boom. In Section 4.5.1, we proved that there was a relative structural change for corn and wheat during the testing period by testing the significance of the parameter changes. Based on this result, we can argue that one possible reason why the Chinese corn and wheat markets are not integrated with the U.S. markets is the structural break occurred in 2007- 2008. Therefore doing the cointegration test allowing for one structural change is essential for determining whether the Chinese and U.S. corn, soybean and wheat future markets are integrated.

Gregory & Hansen (1996) derived the cointegration test allowing for one structural change. They set up three models as given by equations (4.9a), (4.9b) and (4.9c) which allow for a level shift, a trend model with a level shift, and a combination of level shift and a slope change, respectively. In this section, we examine all these three models. The null hypothesis that the prices series are not cointegrated when allowing for one structural change can be rejected if the GH statistic is less than the critical value. The GH statistic is the smallest number over all t-value of π^* in (4.10). Table 4.5 summarizes the GH statistics for testing the null hypothesis. Critical values are listed in Table 4.6.

Table 4.5 GH test results for different commodities

	Gregory & Hansen		
	C	C/T	C/S
Corn	-4.15	-4.33	-4.32
Soybean	-5.64***	-5.86***	-7.46***
Wheat	-4.10	-4.13	-4.84*

* denotes reject the null hypothesis with 90% confidence

** denotes reject the null hypothesis with 95% confidence

*** denotes reject the null hypothesis with 99% confidence

Table 4.6 Critical values for the GH test

Significance level	C	C/T	C/S
1%	-5.13	-5.45	-5.47
5%	-4.61	-4.99	-4.95
10%	-4.34	-4.72	-4.68

After comparing the GH statistic and corresponding critical values, we reject the null hypothesis that no cointegration exists when allowing for a structural change for soybean, but we fail to reject the null for corn and wheat.

The result that only soybean prices are cointegrated is similar to the result derived from the Engle-Granger cointegration test. In Chapter 3, we claimed that the different price responses of corn and wheat within China and the U.S. to the 2007- 2008 commodity price boom may interrupt the cointegration relationship. In this Chapter, we still find no cointegration relationships for corn and wheat prices between China and the U.S, when allowing for a structural change. Therefore, we are confident with our original conclusions--that Chinese corn and wheat markets are not integrated and that Chinese soybean markets are integrated—were precise.

In this Chapter, we conduct the cointegration test allowing for one structural change and obtain the result that only soybean prices series are cointegrated. This result strengthens our claim in Chapter 3 that during 2004 – 2012, Chinese corn and wheat markets are not integrated and Chinese soybean market is integrated with the world. The result we derived in this Chapter also helps us to exclude out one potential explanation of the puzzle (i.e. the structural change) regarding why Chinese corn and wheat markets are integrated prior to the WTO instead of after the WTO. Therefore, researchers interested in solving this problem should focus other on reasons we proposed in the end of Chapter 3, which include non binding WTO agreements, domestic monopoly power and etc.

Chapter 5 Conclusion

5.0 Roadmap

Section 5.1 summarizes this study. Section 5.2 discusses the limitations of this study and provides some suggestions for future research.

5.1 Summarize

The integration of spatially separated markets was accelerated by intense trade in the last few decades. China started to open its markets since 1978 and now it plays an important role in the world trade. However, China’s impact on agricultural commodity markets is limited and its impact varies across different commodities. This study discusses the prices performance of corn, soybean, and wheat in China and the U.S. The integration process of Chinese agricultural commodity markets after China’s entry to WTO (i.e. 2004-2012) is examined.

Time series methodologies are applied on each pair of commodity. Prices data are derived from the prices of corresponding rolling contracts in two countries’ commodity futures markets. Applying the ADF test, we show, apart from the Chinese wheat price, the existence of unit roots in all prices series. Further, we apply the Engle-Granger cointegration test and successfully detect the cointegration relationship between soybean markets. However, in corn and wheat markets, such relationship does not exist. The lack of integration in corn and wheat markets is the same as what we expected. Primary reason may be China’s different trade policies on soybean, and corn and wheat markets. Chinese soybean market is considered as a free market with few trade barriers. In contrast, the Chinese government actively intervenes the corn and wheat markets.

Previous research demonstrated that a structural change would bias the Engle-Granger cointegration test. During the 2007- 2008 food price boom, the difference between China and the U.S. price volatility is substantial. Given this result, first we theoretically prove that a structural change exist in our testing period. Next, we apply the ZA test to check the existence of unit roots in the case of one structural change. Under the ZA test, the results are slightly different than the results of the ADF tests: Chinese corn and wheat prices are more likely to be stationary. Further, we conduct the GH test -- the cointegration test allowing for one structural change -- and get the same result as we get from the traditional cointegration test. This result strengthens our claim that Chinese corn and wheat markets are not integrated with the world markets and that Chinese soybean market is integrated with the world.

We discuss some important Chinese policies of corn, soybean and wheat, especially the self-sufficiency policy. The self-sufficiency goal set on corn and wheat successfully makes China independent of the international supply. Meanwhile, China's soybean market relies heavily on the imports to meet its demand. The different trade patterns between soybean, and corn and wheat in China imply different integration levels. Therefore, we expect that China's markets will be integrated if the Chinese government does not insist on the self-sufficiency goal and encourages more international trade. Moreover, it was widely anticipated that China's agriculture commodity markets would integrate closer to the world market after China's accession to the WTO. However, by closer examination the most important WTO agreements for agricultural sector, we find the WTO agreements are not binding in China's case. Therefore, we question the efficiency of the WTO agreements for accelerating the integration process of China's agricultural commodity markets.

5.2 Limitations and suggestions for future research

Although China acceded to the WTO more than ten years ago, there are only a few studies about the integration of Chinese agricultural markets. Our thesis examines the integration process of three agricultural commodity markets. In the same way, studies should extend to other agricultural commodity markets such as rice, cotton and etc. After we test more commodities, we can have a more comprehensive picture about the role of WTO membership in Chinese agricultural commodity markets.

The best dataset for checking the market integration is spot prices. In this study, we employ the commodity futures prices in China and the U.S. However, there is no guarantee that the futures exchanges in both countries are perfectly efficient. We should carry out the efficiency tests which focus on the spot and futures prices. If the futures markets are not efficient, in other words the spot and futures prices are not cointegrated, integration studies should employ the spot prices in China and the U.S. and should apply similar tests as we proposed in this paper.

We claim that after China joined the WTO, Chinese corn and wheat markets are not integrated with the world markets. However, previous studies testing the prior WTO period gave the opposite results. In this thesis, we do not discuss the reasons of this unexpected issue in details. More formal studies in exploring the reasons should be carried out.

Transaction cost is important in trade analysis with two dimensions: value and volatility. A big transaction cost between markets can potentially prevent trade from happening. A high volatility of transaction cost may hold-up trades by generating a high sunk cost. In China, both the value and volatility of transaction cost is not neglectable. However, the cointegration test ignores the transaction cost in its analysis. One possible approach focuses on correcting this issue is the threshold cointegration. The threshold cointegration takes the transaction cost into account by allowing the price change to transmit only if the prices difference of the two countries exceeds some critical threshold. However, threshold cointegration does not consider the volatility of the transaction cost. As shown in Chapter 2, China's frequent changes of agricultural policy make China an unpredictable player in the world grain markets. The high volatility of transaction costs makes the threshold cointegration test not proper in China's case. Therefore, further studies should be conducted to estimate the volatility of transaction cost. Furthermore, researchers can better examine the markets integration by using the cointegration tests which allow for a floating threshold.

Bibliography

Andrews, Donald W. K. (1993). Tests for Parameter Instability and Structural Change with Unknown Change Point. Econometrica, Vol. 61, No.4, pp. 821-856.

Andrews, Donald W. K. and Ploberger, Werner. (1994). Optimal Tests when a Nuisance Parameter Is Present Only under the Alternative. Econometrica, Vol. 62, No.6, pp. 1383-1414.

Anderson, Ronald W. (1986). Regulation of Futures Trading in the United States and the United Kingdom. Oxford Review Economic Policy, Vol. 2, issue 4, pp. 41-57.

Ardeni, Pier Giorgio. (1989). Does the Law of One Price Really Hold for Commodity Prices? American Journal of Agricultural Economics, Vol. 71, issue 3, pp.661-669.

Ashton, Basil, Hill, Kenneth, Piazza, Alan and Zeitz, Robin. (1984). Famine in China, 1958-1961. Population and Development Review, Vol. 10, No. 4, pp. 613-645.

Boetel, Brenda L. and Liu, Donald J. (2008). Incorporating Structural Changes in Agricultural and Food Price Analysis: An Application to the U.S. Beef and Pork Sectors. Working Papers 44076, University of Minnesota, The Food Industry Center.

Brotcke, Liming. (2006). Cointegration of Agricultural Commodity Futures Between Spatially Separated Markets. Doctoral Dissertation, University of Illinois at Chicago.

Charnani, Niti Nandini. (2009). Commodity Markets: Operations, Instruments, and Applications. Tata McGraw Hill Education Private Limited (Noida).

China Securities Regulatory Commission. (2007). China’s Securities and Futures Markets.http://www.csrc.gov.cn/pub/csrc_en/Informations/publication/200812/P020090225568827507804.pdf., accessed 24 Feburary 2013.

Chow, Gregory C. (1960). Tests of Equality Between Sets of Coefficients in Two Linear Regression. Econometrica, 28, 591-605.

Davidson, Russel and MacKinnon, James, G. (2004) Econometric Theory and Methods. Oxford University Press (New York).

Dickey, David A. and Fuller Wayne A. (1979). Distribution of the Estimators for Autoregressive Time Series with a Unit Root. Journal of the American Statistical Association, Vol. 74, issue 366, pp.427-431.

Elliott, Graham, Rothenberg, Thomas J. and Stock, James H. (1996). Efficient Tests for an Autoregressive Unit Root. Econometrica, Vol. 64, No.4, pp. 813-836.

Engle, Robert F. and Granger, Clive W. J. (1987). Co-integration and Error Correction: Representation, Estimation, and Testing. Econometica, Vol. 55, issue 2, pp. 251-276.

Feenstra, Robert C. and Wei, Shang-Jin. (2009). Introduction to “China’s Growing Role in World Trade”. NBER Working Paper, No. 14716.

Ghosh, Madhusudan. (2011). Agricultural Policy Reforms and Spatial Integration of Food Grain Markets in India. Journal of Economic Development, Vol. 36, No.2, 2011.

Granger, Clive W. J. (1981). Some Properties of Time Series Data and Their Use in Econometric Model Specification. Journal of Econometrics, 16, 121-130.

Granger, Clive W. J. and Newbold, Paul. (1974). Spurious Regression in Econometrics. Journal of Econometrics, 2, pp.111-120.

Gregory, Allan W. and Hansen, Bruce E. (1996). Residual-Based Tests for Cointegration in Models with Regime Shifts, Journal of Econometrics, Vol. 70, pp. 99-126.

Hamilton, James D. (1994). Time Series Analysis. Princeton University Press (Princeton).

Hansen, Bruce E. (1992). Parameter Instability in Linear Models. Journal of Policy Modeling, vol. 14, 517-533.

Hansen, Bruce E. (1997). Approximate Asymptotic P Values for Structural-Change Tests. Journal of Business and Economic Statistics, Vol. 15, No. 1, pp. 60-67.

Hua, Renhai and Chen, Baizhu. (2007). International linkages of the Chinese futures markets. Applied Financial Economics, 17:16, 1275-1287.

Huang, Jikun and Rozelle, Scott. (2008). Agricultural development and policy before and after China’s WTO accession. Agriculture and food security in China: what effect WTO accession and regional trade agreements? Canberra: Asia Pacific Press, pp. 27-54.

Isard, Peter (1997). How Far Can We Push the “Law of One Price”? The American Economic Review, Vol. 67, Issue 5, 942-948.

Krugman, Paul (1986). Pricing to Market when the Exchange Rate Changes. NBER Working Paper, No. 1926.

Jain, Pankaj K. (2005). Financial Market Design and the Equity Premium: Electronic versus Floor Trading. The Journal of Finance, Vol. 60, No. 6, pp. 2955-2985.

Jha, Shika, and P.V. Srinivasan (2000), "Liberalisation of Foodgrain Markets: Implications for Food Security and Price Stability," in N. Krishnaji and T.N. Krishnan eds., Public Support for Food Security: The Public Distribution System in India, New Delhi: Sage Publications, 144-179.

Lomar, Bryan, Gale, Fred, Tuan, Francis and Hansen, Jim. (2009). China's Ongoing Agricultural Modernization: Challenges Remain After 30 Years of Reform. Economic Information Bulletin No. 51, U.S. Department of Agriculture, Economic Research Service.

Lurie, Jonathan (1979). The Chicago Board of Trade 1859-1905. University of Illinois Press (Champaign).

ManKinnon, James G. (2010). Critical Values for Cointegration Tests. Queen's Economics Department Working Paper No. 1227.

Ministry of Finance and State Taxation Bureau. (2002). Notice on zero value-added tax to rice, wheat and corn exports. www.chinatax.gov.cn, accessed 13 January 2013.

Ministry of Finance and State Taxation Bureau. (2003). Notice on zero value-added tax to rice, wheat and corn exports. www.chinatax.gov.cn, accessed 13 January 2013.

Murray, Michael P. (1994). A Drunk and Her Dog: An Illustration of Cointegration and Error Correction. The American Statistician, Vol. 48, No. 1, pp. 37-39.

OECD. (2009a). Agricultural Policies in Emerging Economies: Monitoring and Evaluation, OECD, Paris.

OECD. (2011). Agricultural Policy Monitoring and Evaluation 2011: OECD Countries and Emerging Economies, OECD, Paris

Perron, Pierre. (1989). The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis. Econometrica, 57, 1361-1401.

Perron, Pierre. (1990). Testing for a Unit Root in a Time Series with a Changing Mean. Journal of Business and Economic Statistic, 8, 153-162.

Pfaff, Bernhard. (2008). Analysis of Integrated and Cointegrated Time Series with R. Spinger (Heidelberg).

Phillips, Peter C. B. and Perron, Pierre. (1988). Testing for a unit root in time series regression. Biometrika, Vol. 75, issue 2, pp. 335-346.

Plosser, Charles I. and Schwert G. William. (1978). Money, Income, and Sunspots: Measuring Economic Relationships and the Effects of Differencing. Journal of Monetary Economics, 4, 637-660.

Quandt, Richard. E. (1960). Tests of the Hypothesis that a Linear Regression System Obeys Two Separate Regimes. Journal of the American Statistical Association, Vol, 55, No. 290, pp. 324-330.

Rapsomanikis, Georege, Hallam, David, and Conforti, Piero. (2006). Market integration and price transmission in selected food and cash crop markets of developing countries: review and applications. Book: Agricultural commodity markets and trade: new approaches to analyzing market structure and instability, pp. 187-217.

Said, Said E. and Dickey, David A. (1984). Testing for Unit Roots in Autoregressive-Moving Average Models of Unknown Order. Biometrika, Vol. 71, No.3, pp. 599-607.

Santos, Joseph. (2002). Did Futures Markets Stabilize U.S. Grain Prices? Journal of Agricultural Economics, Vol. 53, No. 1, 25-36.

Schwert, G. W. (1989). Tests for unit roots: A Monte Carlo investigation. Journal of Business and Economics Statistics, 7, 147-159.

Solot, Ilan B. (2006). The Chinese Agricultural Policy Trilemma. Perspectives. Vol. 7, No. 1, pp. 36-46.

State Development and Planning Commission. (2002). Notice on exemption of railway construction levies for grains, cotton and other bulky agricultural products. http://www.ndrc.gov.cn/zcfb/zcfbtz/2007tongzhi/t20071010_163968.htm, accessed 17 Jan 2013.

Vercammen, James (2011). Agricultural Marketing: Structural Models for Price Analysis. Routledge (New York).

Wang, Dabin and Tomek, William G. (2007). Commodity Prices and Unit Root Tests. American Journal of Agricultural Economics, Vol. 89, issue 4, pp. 873-889.

Wang, H. Holly and Ke, Bingfan. (2005). Efficiency Tests of Agricultural Commodity Futures Markets in China. Australian Journal of Agricultural and Resource Economics, v. 49, iss. 2, pp. 125-41.

Williams, Jeffrey C. (1982) The Origin of Futures Markets. Agricultural History, Vol. 56 306-316.

Wu, Laping. (2006). Chinese Grain Trade Policy and its Effects. China Food Industry, No.4.

Wu, Laping. (2001). Integration of China's Major Agricultural Product Markets. Paper presented to the 3rd International Conference on Chinese Economy "Has China become a Market Economy?" Clermont-Ferrant, France.

Yao, Shunli. (2006). Chinese Agricultural Reform, the WTO and FTA Negotiations. Asia-Pacific Research and Training Network on Trade Working Paper Series, No. 15.

Yu, Wusheng and Jensen, Hans G. (2012). Trade policy responses to food price crisis and implications for existing domestic support measures: the case of China in 2008. Selected Paper prepared for presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguaçu, Brazil, 18-24.

Zivot, Eric and Andrews, Donald W.K. (1992). Further Evidence on the Great Crash, the Oil Price Shock, and the Unit Root Hypothesis. Journal of Business & Economic Statistics, Vol. 10, No.3, pp. 251-270.

Zhao, Jinwen. (2002). Cointegration Analysis of Commodity Futures Prices in Dalian, China and Chicago. Journal of Emerging Markets, V. 7, iss. 1, pp. 17-27.

Zhou, Zhangyue and Kang, Xia. (2009). Uncover the Causes of China’s Low Utilization of Grain TRQ. Australian Agribusiness Review, Vol. 17, pp. 22-46.