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PRICE RISKS AND THE LEAD-LAG RELATIONSHIP BETWEEN THE FUTURES AND SPOT PRICES OF SOYBEAN, WHEAT AND CORN

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ABSTRACT

Faced that the dynamics of the global economy and international politics has produced price risks in the agricultural commodity markets of some countries, we study the lead-lag relationship between the futures and spot prices and market volatility of staple commodities to help make forecasts and manage risk. We design some indexes – "long-term equilibrium", "power of short-term error correction", " Granger causality", "share of information" and "spillover effect" to quantify the lead-lag relationship. Characteristics of futures prices are analyzed with statistical methods and E-GARCH model. The results suggest that spot prices can incorporate the information in futures prices, and move affected by futures prices. This study also identifies the characteristics of trends such as seasonality and asymmetric volatility, which sheds light on some of the key price risks in these commodity markets. In addition, when a commodity is to be harvested or its price affected by bullish news and policies, regulators and traders should pay more attention to price risks, particularly for types of futures with long-lasting volatility, such as soybeans.

Contribution/ Originality: The paper's primary contribution is finding important implications to farmers, governors, and traders of staple agricultural futures by providing empirical evidence of the lead-lag relationship between futures price and spot price of the agricultural products and precautions against grain price risks.

1. INTRODUCTION

Managing price volatility risks is always a vital priority to traders and governments in agricultural markets. In recent years, price volatility in major agricultural markets in China has been drastic. As Arnade, Cooke, and Gale (2017) and Hernandez, Ibarra, and Trupkin (2014) pointed out, volatility transmission across exchanges for some grain commodities in China and other countries exists. So long as trade frictions exist, such as the trade friction between China and the US and between Korea and Japan, commodity prices will be affected by factors across countries and may fluctuate greatly. Managing price volatility risks in agricultural markets should be taken very seriously because agriculture is a highly important sector—responsible for food security, poverty alleviation, and even ensuring societal stability.

Confronted with these risks, some researchers suggest futures varieties should be applied as a means of managing sharp volatility or price risks in spot prices. However, some researchers reveal futures varieties may make commodity price volatility even more drastic. In theory, as a forecast, futures prices serve the function of price discovery, for which they are considered to be the primary tool. They lead the spot price to arrive at its equilibrium, which can help stabilize spot prices and manage sharp volatility. However, as a financial market, the futures market has the potential to produce price risks, which can also, in turn, affect the spot market and could create drastic volatility in spot prices. Noussair, Tucker, and Xu (2016) presented evidence of futures markets increasing the volatility of spot prices by conducting an experiment with two treatments. Risks originating from futures markets will affect the spot market if the spot market incorporates information from the futures market. For stocks, studies denote that price volatility in the derivatives market leads to price volatility in stock markets more frequently than the reverse (Chatzivasileiou, 2015). He found violent price fluctuations in commodity futures markets may also lead to drastic price fluctuations in commodity spot markets. In addition, some adverse events have happened in Chinese markets, such as the competition in copper price between Chinese and international traders in 2005 and the stock price collapse in 2015. These events caused extreme commodity price fluctuations, and the price risks had an array of negative consequences.

Regardless of whether futures prices can lead spot prices to arrive at their equilibrium or futures will make prices fluctuate much more drastically, as long as futures prices have an effect on spot prices, we should study their relationship to help manage risks. In recent decades, their relationship has been a focus of research on futures markets. Futures prices incorporate much more new information than spot prices. Markets will incorporate new information to arrive at equilibrium asset prices (Booth, So, & Tse, 1999) however, it is impossible for the spot price to incorporate all relevant information about the future (Grossman, 1977). Expectations regarding future demand and supply conditions tend to have more effect on the prices of deferred futures than on spot prices (Working, 1948). Because futures market may be an indirect means by which additional traders can be attracted to participate in the spot market, futures markets are considered to be more liquid than spot markets. With this advantage as well as its greater transparency, futures markets are considered to be an effective institution for pricing and incorporating information (Newbery, 2008). In most cases, futures prices can lead spot prices to arrive at their equilibrium. The futures price will be the same as the expected future spot price plus a constant or possible time-varying risk premia in efficient markets (McKenzie & Holt, 2002). The nature of the futures price being a forecast of the expected prospective spot price makes it a useful tool to facilitate the effective functioning of spot markets; and, in theory, futures prices lead the spot price to move to its equilibrium. Many researchers have supported the thesis that futures markets play an important leading role based on evidence from different countries (e.g., (Chinn & Coibion, 2014; Easwaran & Ramasundaram, 2008; Figuerola-Ferretti & Gonzalo, 2010; Liu & Zhang, 2006; Yang & Zhang, 2013)). However, for Chinese agricultural commodity futures prices, the leading role varies from variety to variety. Yang and Zhang (2013) and Liu and Zhang (2006) reported some agricultural futures prices were powerful predictors, or lead prices, for spot price. Yang and Zhang (2013) found that soybean futures prices predicted more than 70% of its spot price movements. However, Ronghua and Zhiling (2019) identified that the corn futures market showed this leading role, but the wheat market did not.

In this study, we qualify and quantify the lead-lag relationship for China's three agricultural products—soybean, wheat, and corn—and explore precautionary measures against price risks based on the characteristics of each futures price. This investigation contributes to the literature on the lead-lag relationships for China's markets, which has focused on models at the first moment. However, only taking the first moment into account is not comprehensive and may even lead to spurious results (Chan, Chan, & Karolyi, 1991). Accordingly, some scholars used models that consider both the first and second moments (e.g., McKenzie and Holt (2002)). This study retests the lead-lag relationship in a comprehensive analysis and highlights the necessity for risk management based on the lead-lag relationship and price volatility characteristics. Based on the models and the specific characteristics of futures price volatility that are identified, it can be concluded that if futures prices lead spot prices, traders and regulators should direct more attention to the commodity price risks implied by extreme fluctuations in futures prices.

2. METHODOLOGY

This study uses the co-integration test, vector error correction model (VECM), and Granger causality test. In addition, the information share (IS) and BEKK-GARCH models were applied to determine the spillover effect from the second moment and quantify the relationship. As financial price data are always non-stationary, Engle and Granger (1987) proposed the VECM. In addition, the Granger causality test (Granger, 1988) can be used to replace the co-integrated model to some extent, when data are non-cointegrated but stationary after taking the difference. However, the VECM and Granger causality tests can only measure the lead-lag relationship from a qualitative perspective. In order to quantify this relationship, Hasbrouck (1995); Hasbrouck (2003) proposed the IS model based on the VECM. Both the VECM and IS models are based on the first moment. To explore the relationship based on the second moment, Hamao, Masulis, and Ng (1990) put forward the volatility spillover effect model, arguing that the price fluctuations in one market would partly transfer onto other market prices through the process of information transfer. Additionally, Baba, Engle, Kraft, and Kroner (1990) provided a dynamic GARCH model named the BEKK-GARCH model to measure the volatility spillover effect. Based on these models, the terms "long-term equilibrium," "power of short-term error correction," "Granger causality," "share of information," and "spillover effect" were abstracted as indexes. In addition, this study aimed to identify some characteristics using the E-GARCH model and other statistical methods.

Before introducing these models, the notation should be clarified. If $\Delta \ln(p_t)$is stationary such that $\Delta \ln(p_t) = [\ln(p_t) - \ln(p_{t-1})] \times 100$, then the term after difference is used to satisfy the requirement of a stationary series. The value is multiplied by 100 for more convenient observation of the values after the multiples are expanded, and p represents the futures price (FP) or spot price (SP). The scripts SS, SF, CS, CF, WS, and WF indicate "Soybean spot," "Soybean futures," "Corn spot," "Corn futures," "Wheat spot," and "Wheat futures," respectively. In addition, time series properties must first be tested using the augmented Dickey-Fuller (ADF) test. The results show that $\ln SF$, $\ln SS$, $\ln CF$, $\ln CS$, $\ln WF$, $\ln WS$ are not stationary, but the terms after the first order difference ($\Delta\ln SF$, $\Delta\ln SS$, $\Delta\ln CF$, $\Delta\ln CS$, $\Delta\ln WF$, $\Delta\ln WS$) are stationary. The lag orders in the test of these models are determined by the SC minimum principle. Finally, if some parameters in some items equal 0, within a 95% confidence interval, then these items are not shown in the regression equations.

2.1. Models for Quantifying the Lead-Lag Relationship

Linkages between models and indexes are determined by the co-integration test for "long-term equilibrium," VECM for "power of short-term error correction," VECM or Granger causality test for "Granger causality," IS model for "share of information," and BEKK-GARCH model for "spillover effect," as summarized in Table 1.

Table-1. Models used to test for lead-lag relationships.

Purpose	Methods
To test long-term equilibrium	Co-integration test
To test short-term error correction	VECM
To check Granger causality	VECM or Granger causality test
To calculate the share of information	Variance decomposition
To check the volatility spillover effect	BEKK-GARCH

If there are long-term equilibrium and short-term error correction or Granger causality relationships between futures prices and spot prices, it is concluded that the lead-lag relationship exists. Moreover, if the futures price includes a larger share of information than the spot price and has more volatility spillover effects on spot price than the reverse, it means the futures price had more lead power. In summary, for example, if the futures price is the lead price: (1) there is an equilibrium between futures price and spot price in the long-term, (2) changes in the futures price must be the Granger-causes of changes in spot prices in the short-term, (3) the futures price has a greater share of information than the spot price, and (4) the futures price has a volatility spillover effect on the spot price.

The co-integration test and VECM are described as below. First, all of the series must be integrated of the same order. Then, if a linear combination of this collection is integrated of order zero, the collection is said to be co-integrated. The Engle-Granger method was used to test co-integration (Engle & Granger, 1987). In this study, it is necessary to check only whether series $\ln FP_t$ and $\ln SP_t$ are integrated at order 1, and if so, they can be used in these models. Based on the co-integration of order 1, the VECM can be created:

$$\Delta lnSP_t = \sum_{i=1}^{n} \alpha_{1i}\, \Delta lnSP_{t-i} + \sum_{j=1}^{n} \beta_{1j}\, \Delta lnFP_{t-j} + \lambda_1 ERR_{t-1} + \mu_{1t} \quad (1)$$

$$\Delta lnFP_t = \sum_{i=1}^{m} \alpha_{2i}\, \Delta lnSP_{t-i} + \sum_{j=1}^{m} \beta_{2j}\, \Delta lnFP_{t-j} + \lambda_2 ERR_{t-1} + \mu_{2t} \quad (2)$$

$$ERR_{t-1} = lnSP_{t-1} - \alpha lnFP_{t-1} - c \quad (3)$$

ERR_{t-1} is the error term at time *t-1* from Equation 3. μ_{1t} and μ_{2t} are white-noise disturbance terms. If $\lambda \neq 0$, the correction mechanism exists. If $\beta_{1j} \neq 0$, changes in futures prices are Granger-causes of changes in spot prices, which is a unilateral Granger causality. If $\alpha_{2i} \neq 0$, changes in spot prices are a unilateral Granger cause of changes in futures prices. If they are both Granger-causes to each other, the relationship is bilateral. If neither price Granger-causes changes in the other, there is no Granger causality between futures prices and spot prices.

The VECM can check Granger causality, but not all price series are suitable for the VECM because co-integration is a precondition in the VECM. When the VECM cannot be applied, the Granger causality test (Granger., 1969) is used to check for Granger causality. The specification of the Granger test in this paper is similar to the VECM with $\lambda = 0$. There are two hypotheses concerning the Granger causality test—H1-1: A change in the wheat spot price does not Granger-cause a change in wheat futures prices; H1-2: A change in the wheat futures price does not Granger-cause a change in the wheat spot price.

The variance decomposition in the IS model indicates the amount of information each variable contributes to the other variables in the autoregression. It determines how much of the forecast error variance of each of the variables can be explained by exogenous shocks to the other variables (Lütkepohl, 2005).

The BEKK-GARCH model is a multivariate model, which is described below:

$$\Delta lnFP_t = c_1 + \alpha_1 \Delta lnFP_{t-1} + \mu_{1t} \quad (4)$$

$$\Delta lnSP_t = c_2 + \alpha_2 \Delta lnSP_{t-1} + \mu_{2t} \quad (5)$$

$$\begin{aligned}\begin{pmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{pmatrix} &= \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}^T \begin{pmatrix} \mu_{1,t-1}^2 & \mu_{1,t-1}\mu_{2,t-1} \\ \mu_{1,t-1}\mu_{2,t-1} & \mu_{2,t-1}^2 \end{pmatrix} \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \\ &+ \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix}^T \begin{pmatrix} h_{11,t-1} & h_{12,t-1} \\ h_{21,t-1} & h_{22,t-1} \end{pmatrix} \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix} \\ &+ \begin{pmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{pmatrix}^T \begin{pmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{pmatrix}\end{aligned} \quad (6)$$

$h_{ii,t}$ stands for the variance of the error term μ_i at time *t*. h_{ij} is the covariance of μ_i and μ_j ; $i,j \in (1,2)$. To check for the spillover effect, three null hypotheses from the BEKK-GARCH model are proposed: H2-1: If $a_{12} = b_{12} = a_{21} = b_{21} = 0$, there is no spillover effect; H2-2: If $a_{12} = b_{12} = 0$, futures prices have no spillover effect on spot prices; H2-3: If $a_{21} = b_{21} = 0$, spot prices have no spillover effect on futures prices.

2.2. Exploratory Methods

There may be some characteristic trends in the volatility of futures prices, such as seasonal volatility, symmetry or asymmetry, and long or short duration of fluctuations. Seasonal volatility means the price fluctuations are different at different times of the year. Symmetry considers that, if the impact power of a piece of bullish news and a piece of bearish news are the same, the absolute values of price volatility caused by them must be the same. If the values are different, it implies asymmetry. Fluctuation duration represents how long fluctuations last when news comes to impact a price.

To identify these characteristics, the main methods used are statistical methods as well as the E-GARCH model. The E-GARCH model is:

$$\Delta lnFP_t = c_1 + \sum_{i=1}^{p} \alpha_i \Delta lnFP_{t-i} + \mu_t + \sum_{j=1}^{q} \beta_i \mu_{t-j} \tag{7}$$

$$\ln(h_t) = \omega + \gamma \left| \frac{\mu_{t-1}}{\sqrt{h_{t-1}}} \right| + \delta \frac{\mu_{t-1}}{\sqrt{h_{t-1}}} + \tau ln(h_{t-1}) \tag{8}$$

h_t stands for the variance of $\ln FP_t$ at time t and $\frac{\mu_{t-1}}{\sqrt{h_{t-1}}}$ is the standardized residual term. If $\delta \neq 0$, it means "asymmetry" exists and if $\delta = 0$, it means "symmetry" exists. τ is an index of the degree of volatility persistence; the larger τ is, the higher the volatility persistence degree a price has.

3. DATA DESCRIPTION

All the futures and spot prices of soybean and corn originated from the *iFinD* database. Spot prices of wheat for analysis were high gluten wheat prices from the database of *Zhengzhou Commodity Exchange*. All prices were daily prices from 4 Apr. 2013 to 6 Jun. 2017, excluding Saturdays, Sundays, and national holidays in China. Specifically, settlement prices for continuous contracts of *Soybean No. 1* (soybean), *Corn*, and *Strong gluten wheat* (wheat) were selected for analysis. In Chinese commodity futures, the trading volumes of soybean, corn, and wheat are relatively large, and their contracts' liquidity is strong. (*Soybean No. 1* is related to non-GMO soybeans, mainly produced in China.) Other kinds of agricultural commodity futures exhibit lower liquidity. They are not suitable for data in this analysis. A price of a continuous contract is the price closest to the delivery date. So, this price contains minimal time-varying risks and in theory, it can be an unbiased forecaster of the future spot price. In addition, continuous contract settlement prices were chosen instead of closing prices. This is a measure that has been used widely in publications because closing prices are the prices of the last daily transaction, which are more random and more prone to manipulation. Settlement prices are weighted average prices of daily deals, which are more representative.

4. EMPIRICAL ANALYSIS

4.1. Long-Term Equilibrium

In the co-integration test, integration of the same order is required. According to the results of the ADF test, the price series in Table 2 were subject to integration of order one. Therefore, the co-integration test can be performed, and the results are shown below.

Table-2. The results verifying the co-integration relationship.

Items	P-Value	Stability of residual	Result
Soybean prices	0.079	Stationary	Co-integrated
Corn prices	0.000	Stationary	Co-integrated
Wheat prices	0.456	Stationary	Not co-integrated

Co-integration is a relationship between futures and spot prices at the same order, which indicates the long-term equilibrium. Table 2 suggests that there was a long-term equilibrium between the futures and spot prices of soybeans and corn. However, there was no long-term equilibrium relationship between wheat futures and spot prices.

4.2. Short-Term Error Correction and Granger Causality

VECM was utilized to check short-term error corrections and Granger causality for soybean and corn prices because there was only long-term equilibrium in the soybean and corn prices. The Granger causality test was used to test the Granger causality of wheat prices. The results of these two models are presented below.

$$\ln SS_{t-1} = 1.701 + 0.794 \ln SF_{t-1} + \mu_{t-1} \quad (9)$$

$$\begin{aligned}\vartriangle \ln SS_t = -0.004\mathrm{ecm}_{t-1} + 0.009 \vartriangle \ln SF_{t-1} - 0.011 \vartriangle \ln SF_{t-2} + 0.248 \vartriangle \ln SS_{t-1} \\ + 0.159 \vartriangle \ln SS_{t-2} + 0.09 \vartriangle \ln SS_{t-3} + 0.131 \vartriangle \ln SS_{t-4} + \mu_{1t}\end{aligned} \quad (10)$$

$$\vartriangle \ln SF_t = 0.016\mathrm{ecm}_{t-1} - 0.072 \vartriangle \ln SF_{t-3} + \mu_{2t} \quad (11)$$

From Equations 9 to 11, first, it was clear that futures and spot prices of soybean had a long-term equilibrium relationship. In the long-term, when the soybean futures price changed by 1 unit, the spot price would change by 0.794 units at the same time. Second, there was a short-term error correction relationship between the futures and spot prices of soybeans. When the futures or spot prices deviated from the long-term equilibrium, there was a power that would correct and return them to the equilibrium. Third, evidence of unilateral Granger causality existed whereby changes in futures prices were Granger-causes of changes in spot price, but the reverse was not true.

$$\ln CS_{t-1} = -0.597 + 0.921 \ln CF_{t-1} + \mu_{t-1} \quad (12)$$

$$\begin{aligned}\vartriangle \ln CS_t = -0.01\mathrm{ecm}_{t-1} + 0.02 \vartriangle \ln CF_{t-2} + 0.199 \vartriangle \ln CF_{t-1} \\ +0.185 \ln CS_{t-2} + 0.109 \ln CS_{t-3} + \mu_{1t}\end{aligned} \quad (13)$$

$$\vartriangle \ln CF_t = 0.067\mathrm{ecm}_{t-1} + 0.344 \ln CS_{t-1} + 0.376 \ln CS_{t-2} + \mu_{2t} \quad (14)$$

It is concluded from Equations 12 to 14 that, similar to soybean prices, corn prices also had relationships of long-term equilibrium and short-term error correction. However, the relationship shows that both price series had an influence on each other, which means there was evidence of bilateral causality. The equilibrium coefficient of corn prices was 0.921, which was larger than the 0.794 of soybean prices, which means changes in corn futures and spot prices were more similar than that of soybean prices. Reasons typically proposed for this similarity were that one price had absolute dominance to lead the other or both futures and spot prices reflected market information to a large extent. The latter was valid for corn prices because of the bilateral Granger causality.

Table-3. The results of the granger causality test for wheat prices.

Lag order	Null hypothesis	P-value	Result
2	H1-1	0.781	Accepted
	H1-2	0.126	Accepted
4	H1-1	0.948	Accepted
	H1-2	0.104	Accepted
6	H1-1	0.973	Accepted
	H1-2	0.240	Accepted
8	H1-1	0.963	Accepted
	H1-2	0.388	Accepted

Price updates are mainly impacted by recent price impacts. If changes in recent prices cannot help forecast the changes in price, it can be said that changes in previous prices do not predict future prices. Thus, if recent spot prices do not forecast futures price and recent futures prices do not forecast spot price, then there is no Granger causality between futures price and spot price. The results show that there was no Granger causality between the wheat futures and spot prices, which is described in Table 3.

4.3. Share of Information

The more information a price can reflect, the more information or lead power it shows. This power is reflected in the contribution to price variance. Therefore, variance decomposition was applied to obtain the contribution of variance. Variance decomposition is based on VECM in this paper, and the results are shown below.

Table-4. Variance decomposition of soybean price changes.

Lag order	Change of SF (%)		Change of SS (%)	
	SF's contribution	SS's contribution	SF's contribution	SS's contribution
1	99.045	0.955	0.000	100.000
2	98.494	1.506	0.197	99.803
3	98.156	1.844	0.155	99.845
…	…	…	…	…
48	89.791	10.209	16.028	83.972
49	89.642	10.358	16.456	83.544
50	89.494	10.506	16.881	83.119

Note: SF and SS represent soybean futures prices and soybean spot prices, respectively.

Table-5. Variance decomposition of corn price changes.

Lag order	Change of CF (%)		Change of CS (%)	
	CF's contribution	CS's contribution	CF's contribution	CS's contribution
1	99.095	0.905	0.000	100.00
2	97.995	2.005	0.331	99.669
3	96.129	3.871	1.477	98.523
…	…	…	…	…
48	61.725	38.275	23.243	76.757
49	61.382	38.618	23.417	76.583
50	61.047	38.953	23.585	76.415

From Table 4, for soybean prices, when the lag order was 50, the average variance contribution of the soybean futures price was 53.188%, and that was 46.812% of the soybean spot price. These figures were 42.316% and 57.684% for the corn futures and spot prices, respectively, as illustrated by Table 5.

4.4. Volatility Spillover Effect

Table 6 shows the results of the BEKK-GARCH model.

Table-6. Results of the BEKK-GARCH model.

Parameter	Coefficient			Null Hypothesis	F-statistic		
	Soybean	Corn	Wheat		Soybean	Corn	Wheat
a_{11}	0.369***	0.772***	0.656***	H2-1	7.086***	16.131***	1.312
a_{12}	0.309***	0.018**	-0.004*	H2-2	12.641***	31.770***	2.204
a_{21}	-0.058	-0.007	-0.008	H2-3	0.361	0.469	0.518
a_{22}	-0.013**	0.286***	0.596***				
b_{11}	0.790***	-0.088	0.815***				
b_{12}	0.933***	0.012	0.003**				
b_{21}	0.101	0.188	0.035				
b_{22}	0.021***	0.952***	0.889***				

Note: *, ** and *** indicate that the null hypothesis is rejected within a confidence interval at 90%, 95%, 99%, respectively.

From Table 6, it can be seen that there were volatility spillover effects from the soybean futures price and corn futures price on their respective spot prices. The spillover effects for soybean and corn were unilateral, whereby the spillover effects were from the futures price to the spot price. On the contrary, there was no spillover effect between futures price volatility and spot price volatility for wheat.

4.5. Summary

Based on the above analyses, the models' results are summarized in Table 7.

Table-7. Summary of results.

Item	Equilibrium	Error correction	Granger causality	Share of information	Spillover effect
Soybean prices	Yes	Weaker	Unilateral	Futures>Spot	Unilateral
Corn prices	Yes	Stronger	Bilateral	Spot>Futures	Unilateral
Wheat prices	No	--	None	--	None

Note: "unilateral" means the path from futures price on spot price.

As shown in Table 7, soybean prices were co-integrated. Futures price changes showed unilateral Granger causality on spot prices, and futures price had a higher share of information than spot prices. There was also a spillover effect of price fluctuations from soybean futures prices to soybean spot price. Thus, there was a lead power in futures prices, and the spot prices for soybeans was the lag price. For corn prices, there was evidence of co-integration. Price changes show bilateral Granger causality, and spot price had a higher share of information. The spillover effect was the same as for soybean prices. It cannot be determined whether either future or spot prices were the lead or the lag price of corn prices based on these models' results. However, it can be said that they both had strong power and had more effect on each other than soybean prices because corn prices exhibit bilateral Granger causality and a stronger power of error correction. Either due to the weaker power of error correction and unilateral Granger causality in soybean prices or, identically, because the balance of power from the spot price was relatively low, when extreme volatility or a price risk occurs in futures prices, it would guide the spot price and make it fluctuate. Regarding wheat prices, there was no lead-lag relationship between futures and spot prices, which is a sign of unsound wheat markets. The situation in wheat prices was the result of the low liquidity of futures contracts. Initially, this was because policies that support the wheat price made the price changes small; thus, participating in futures trading did not make much sense.

In summary, the results indicated that corn futures prices had lead power and wheat futures prices had no lead power, which is the same as the results reported by Ronghua and Zhiling (2019). Additionally, soybean futures prices had leading power, and the lead power of the soybean futures price was stronger than that of corn futures prices.

5. EXPLORATORY ANALYSIS OF PRICE VOLATILITY

To assist in the interpretation of certain characteristics, the movements of the futures and spot prices are reported by year. Furthermore, the E-GARCH model was used to check their fluctuation duration and identify symmetry or asymmetry. These methods revealed four characteristics: (1) the volatility range of futures prices was larger than the volatility in spot prices, (2) their volatility may be greatly affected by policies, (3) their movements were seasonal, and (4) their volatility had characteristics of asymmetry and different degrees of persistence for different markets.

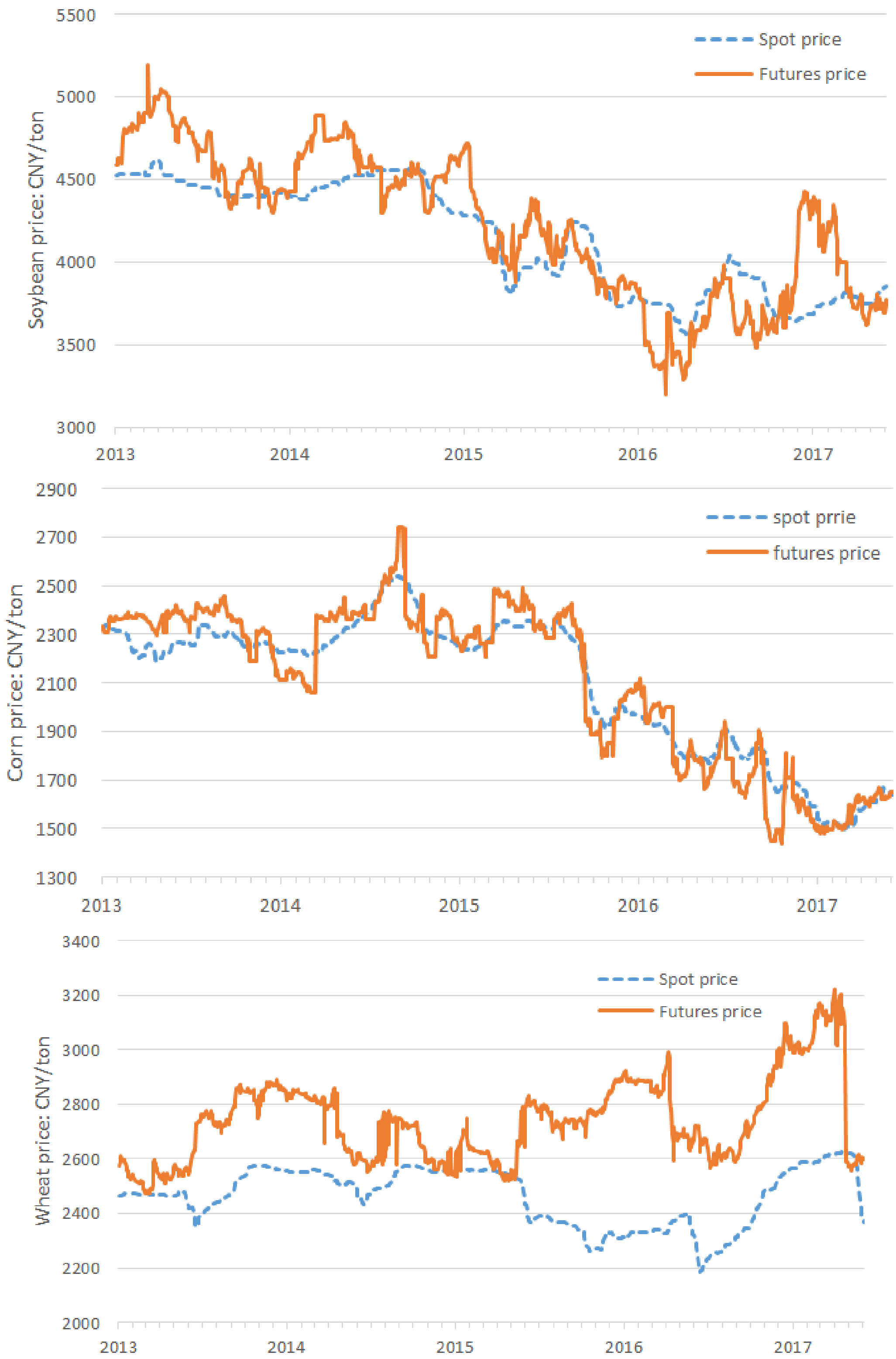

Figure-1. Movements of futures prices and spot prices.
Source: *iFinD* database and Zhengzhou Commodity Exchange (daily settlement price).

The futures price volatility range was larger than the spot price volatility, and the volatility may be strongly affected by policies. From Figure 1, it can be easily seen that futures price volatility was higher than spot price volatility. In addition, since the abolishment of the soybean and corn storage policy in 2014 and 2016, respectively, extreme drops were seen in soybean price and corn price. (These policies encouraged the cultivation of these agricultural products through the purchase and storage of some of these products by the Chinese government and were meant to increase the income of farmers.) For wheat, the price support policy was maintained to ensure higher prices and support farmers. It can be predicted that if this support policy was abolished, the wheat price would face a sharp decline. Apart from the storage policy and price support policy, China has other policies that significantly affect grain prices, including import policies (e.g., the policies for soybean because of trade friction), subsidy policies, and the "red line" for arable areas. In addition, Zhang, Ding, and Scheffel (2018) revealed that the interaction of new government policies and market forces drove volatilities in commodity markets in China.

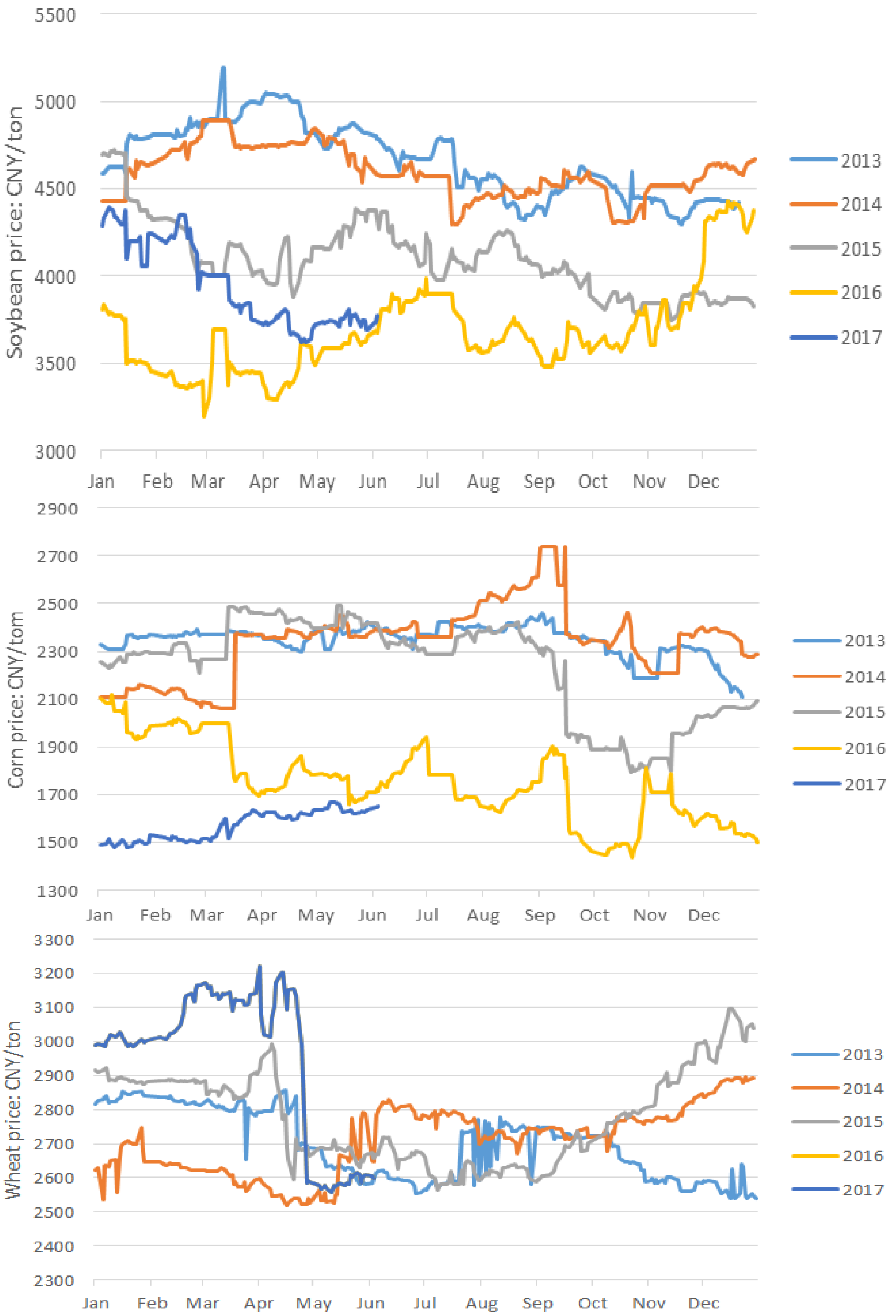

Figure-2. Movements of futures prices by year.

Source: *iFinD* database and Zhengzhou Commodity Exchange (daily settlement price).

Figure 2 shows that the movements of soybean, corn, and wheat futures prices are seasonal. As shown by the reported data of the National Bureau of Statistics of China, 86.21% of China's soybean supply was imported in 2017, mainly from the three major soybean producing countries Brazil, Argentina, and the US. Therefore, China's soybean price was greatly affected by the soybean prices of these three countries. Soybean harvest time in Brazil and Argentina was in April and May each year, and it was in September and October in China and the United States. China's soybean price always appeared to drop in April, May, September, and October, as shown in Figure 2. Regarding corn and wheat, China was able produce most of what it needed to meet demand, unlike soybeans. There were some deep price drops because of the harvest in September and October for corn and April and May for wheat. This is also visible in Figure 2.

The E-GARCH model was used to check the characteristics of futures price fluctuations caused by news impacts, including fluctuation duration and symmetry or asymmetry. These characteristics of futures prices are reported in Table 8.

Table-8. Characteristics of fluctuations caused by news impacts.

Item	τ	Lasting	γ	δ	Symmetry or Asymmetry
P_{SF}	0.867***	Long	0.159***	0.046***	Asymmetry
P_{CF}	-0.173***	short	0.414***	0.352***	Asymmetry
P_{WF}	0.889***	Long	0.644***	0.083***	Asymmetry

Note: *** indicates that the null hypothesis is rejected within a 99% confidence interval.

As shown in Table 8, price fluctuations had characteristics of asymmetry and fluctuation duration in futures prices differs for the different commodities. There were strong degrees of volatility persistence in soybean and corn futures prices, while it was weak in wheat futures prices. Fluctuations were asymmetric in all three futures prices, which indicates bullish news would bring stronger fluctuations than bearish news.

6. CONCLUSIONS AND RECOMMENDATIONS

The primary goal of this study was to quality and quantifies the lead-lag relationship of three agricultural futures prices in China and identifies the volatility characteristics to enable efficient risk management in commodity markets. Based on the above analysis, two conclusions were reached: First, futures prices had strong leading power for soybean spot prices, corn futures prices had weaker lead power, and wheat futures prices had no lead power. Second, we found four characteristics in the movements and fluctuations of futures prices. Namely, (1) the volatility range of the futures price was larger than the volatility in spot prices, (2) price fluctuations may be significantly affected by policies, (3) price movements were seasonal, and (4) price fluctuations had characteristics of asymmetry and a different degree of fluctuation duration for different markets. Given comprehensive consideration of these characteristics and the lead-lag relationship, we can identify when and which futures prices contain more risks. For example, when bullish news shocks soybean markets, soybean prices will contain more risks because bullish news can have a bigger impact on futures prices and the soybean futures price has strong power to affect its spot price.

Based on the above analysis and conclusions, this paper advances the following suggestions for regulators and traders. First, according to these characteristics of futures prices, futures markets contain more risks than spot markets. When a commodity is to be harvested or is affected by bullish news and policies, regulators and traders should pay more attention to price risks. This is particularly important for futures varieties whose volatility lasts for a long time. Confronted with this situation, we suggest that Chinese policymakers avoid changing existing policies and launching new policies related to agricultural commodity markets to ensure they remain stable. Traders should reduce speculation in the futures market, especially, those containing more risks, and use futures as a hedging tool to avoid risks. Second, given the strong lead power of some commodity futures prices, it is necessary to manage the risk of sharp fluctuations in futures prices and decrease risks. The tripartite cooperation between the government, enterprises, and farmers should be strengthened to reduce the proportion of individual investors and, thus, reduce extreme price fluctuations caused by excessive speculation.

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