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Examining the Dynamic Relationship between Spot and Future Prices of Agricultural Commodities

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ABSTRACT

This study examines the dynamic relationship between spot and futures prices of agricultural commodities. We first briefly discuss what the non-arbitrage and asset pricing theory has to say about the relationship between spot and futures markets. Next, using recent price data for corn, wheat, and soybeans, we perform Granger causality tests to empirically uncover the direction of information flows between spot and futures prices. Linear as well as nonlinear (nonparametric) causality tests are conducted on both spot and futures returns and their volatility. The results indicate that spot prices are generally discovered in futures markets. In particular, we find that changes in futures prices lead changes in spot prices more often than the reverse. These findings also contribute to the debate on alternative instruments to address excessive volatility in grain markets. Our results support, for example, the viability of implementing a global virtual reserve, recently proposed by von Braun and Torero (2008, 2009), to prevent disproportionate spikes in grain spot prices through signals and, if necessary, market assessment in the exchange of futures.

Keywords: agricultural commodity markets, spot prices, futures prices, granger causality

1. THE RELATIONSHIP BETWEEN SPOT AND FUTURES PRICES

Considering that the futures price is the price specified in an agreement (futures contract) to deliver a specified quantity of a commodity at a specific future date, whereas the spot price is the cash price for immediate purchase and sale of the commodity, we should expect a close relationship between the prices of futures contracts and spot prices. In particular, an explicit relationship between spot and futures prices can be derived from the non-arbitrage theory.

Following Pindyck (2001), let $\gamma_{t,T}$ denote the capitalized flow of marginal convenience yield over the period *t* to *t*+*T*.[1] Then, to avoid arbitrage opportunities, the following condition must hold:

$$F_{t,T} = (1 + r_T)P_t - (\gamma_{t,T} - k_T), \qquad (1)$$

where $F_{t,T}$ is the futures price of a (agricultural) commodity at time *t* for delivery at *t*+*T*, P_t is the spot price at *t*, r_T is the risk-free *T*-period interest rate, and k_T is the per-unit cost of physical storage.

To see why equation (1) must be satisfied, note that the stochastic return of holding a unit of the agricultural commodity from *t* to *t*+*T* is equal to $(P_{t+T} - P_t) + \gamma_{t,T} - k_T$. If a farmer also sells a futures contract at *t* (that is, takes a short position), the return of this future contract is $F_{t,T} - P_{t+T}$. So the farmer's total non-stochastic return at *T* is equal to $F_{t,T} - P_t + \gamma_{t,T} - k_T$. Then, the non-arbitrage condition requires this total return to equal the risk-free rate times the price of the commodity at *t*, that is, $r_T P_t$, from which equation (1) follows.

Two implications can be derived from equation (1). First, the futures price could be greater or less than the spot price, depending on the net (of storage costs) marginal convenience yield $\gamma_{t,T} - k_T$. If the net marginal convenience yield is positive and large, the spot price will exceed the futures price (futures market exhibits strong backwardation); however, if the net marginal convenience yield is negative, the spot price will be less than the futures price (the futures market is in contango). Second, spot and futures prices should move together across time to avoid arbitrage opportunities. That is, we expect price movements in spot and futures markets to be correlated.

From the asset pricing theory, we can also establish a relationship between the futures price and the expected future spot price. Assume that at time *t,* a farmer buys one unit of a commodity at price P_t, which he plans to hold until *t*+*T* and then sell it for P_{t+T}. The expected return of this investment is given by $E_t(P_{t+T}) - P_t + \gamma_{t,T} - k_T$. Because P_{t+T} is unknown at *t*, this return is risky and must equal the risk-adjusted discount rate times the price of the commodity at *t*, that is, $\rho_T P_t$. Hence,

$$E_t(P_{t+T}) - P_t + \gamma_{t,T} - k_T = \rho_T P_t. \qquad (2)$$

Substituting (1) into (2), we obtain

$$F_{t,T} = E_t(P_{t+T}) - (\rho_T - r_T)P_t. \qquad (3)$$

It follows that the futures price is a biased estimate of the future spot price because of the risk premium $\rho_T - r_T$. More specifically, the futures price should typically be lower than the expected future spot price due to the positive risk premium (that is, $\rho_T > r_T$). As pointed out by Pindyck (2001), holding the commodity alone entails risk, and as a reward for that risk, we expect the spot price at t+T to be above the current futures price. But besides these explicit relationships between spot, futures, and expected future spot prices, described in (1) and (3), does the theory provide any insights about the direction of causality between spot and futures prices?

[1] The convenience yield is the flow of benefits from holding the physical commodity. Inventory holders of a commodity, for example, may obtain extra profits from temporary local shortages. In general, the convenience yield will increase with market volatility because the option value of keeping the commodity increases with a higher volatility.

Provided that futures markets are generally considered to perform two major roles in commodity markets—a risk-transfer role and, in particular, an informative or price discovery role—we might be tempted to assume that futures markets dominate spot markets. The risk-transfer role results from the fact that a futures market is a place where risks are reallocated between hedgers (producers) and speculators. Producers are then willing to compensate speculators for sharing the risks inherent in their productive activity. Futures prices also transmit information to all economic agents, especially to uninformed producers who, in turn, may base their supply decisions on the futures price. It can also be argued that physical traders use futures prices as a reference to price their commodities due to the greater transparency and (often) greater liquidity of commodity futures over physical commodities.[2]

However, as sustained by Garbade and Silber (1983), the price discovery function of futures markets hinges on whether new information is actually reflected first in changes in futures prices or in spot prices. Identifying the direction of information flows between spot and futures prices, then, appears to be an empirical issue. This study attempts to do so by using recent price data of corn, two varieties of wheat, and soybeans to examine causal links between spot and futures markets. We address the following specific questions: Do changes in futures prices lead changes in spot prices? Or do price changes in spot markets lead price changes in futures markets? Or are there bidirectional information flows between spot and futures markets?

It is worth mention that previous studies have found that spot prices in commodity markets seem to be discovered in futures markets (that is, spot prices move toward futures prices)—for example, Garbade and Silver (1983), in their study of price movements and price discovery in futures and cash markets for seven different storable commodities, including corn and wheat, and Brorsen, Bailey, and Richardson (1984), in their analysis of cash and futures cotton prices.[3] Crain and Lee (1996) also find that the wheat futures market carries out its price discovery role by transferring volatility to the spot market.

The present analysis, then, intends to extend these previous studies by examining causal relationships in spot and futures markets in more recent years, with much more developed futures commodity markets. As a reference, the average daily volume of corn futures traded in the Chicago Board of Trade (CBOT) has increased by more than 280 percent in the last 40 years. In the 1970s, less than 20,000 futures contracts were traded on average every day, whereas in the present decade more than 76,000 futures contracts are traded on average every day in a regular session.

This study also intends to contribute to the debate on alternative instruments to address excessive volatility in grain markets, after the 2007–2008 food crisis. von Braun and Torero (2008, 2009), for example, have recently proposed the implementation of a global virtual reserve to minimize speculative attacks and prevent disproportionate price spikes in food commodity markets through signals and (if necessary) market assessment in the exchange of futures. Determining whether spot prices do in fact move toward futures prices is crucial for the viability of this innovative instrument.

Next, we describe the data used to analyze causal relations between spot and futures prices. As noted, we focus on corn, two varieties of wheat, and soybeans, which are among the most important agricultural commodities.

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[2] The informative role of futures markets could also have a stabilizing effect on spot prices, as sustained by Danthine (1978). Other studies that analyze in detail the role and impact of futures trading in commodity markets, under alternative settings, include McKinnon (1967), Turnovsky (1983), Kawai (1983a, 1983b), and Chari, Jagannathan, and Jones (1990).

[3] Other related studies include Tomek and Gray (1970) and Martin and Garcia (1981), but they are more focused on the price-forecasting role of futures commodity prices over spot prices and do not explicitly carry out Granger causality tests.

2. DATA

The spot data used in the analysis are weekly (Friday) prices obtained from the Food and Agriculture Organization of the United Nations (FAO) International Commodity Prices Database. The specific products considered are U.S. No. 2 yellow corn, No. 2 hard red winter wheat, No. 2 soft red winter wheat, and No. 1 yellow soybeans.[4] The sample period is from January 1994 to June 2009 for corn and soybeans and from January 1998 to June 2009 for the two varieties of wheat. All prices are in U.S. dollars per metric ton (US$/MT).

The futures data are closing prices of futures contracts traded each Friday over the same time period. In the case of corn, soft wheat, and soybeans, the prices correspond to futures contracts traded on the CBOT with deliverable grades at par U.S. No. 2 yellow, No. 2 soft red, and No. 1 yellow, respectively; in the case of hard wheat, the prices correspond to contracts traded in the Kansas City Board of Trade (KCBT), where the wheat deliverable grade at par is precisely U.S. No. 2 hard red. The CBOT is the world's oldest futures and options exchange and a leading agricultural futures exchange. The KCBT is the largest free market for hard red winter wheat. The futures data were obtained from the historical end-of-day dataset of the Chicago Mercantile Exchange Group (CME DataMine) and the futures database of the Commodity Research Bureau (CRB Infotech CD).

Because futures contracts with different maturities are traded every day, the data were compiled using prices from the nearby contract, as in Crain and Lee (1996). The nearby contract is generally the most liquid contract. To avoid registering prices during the settlement month or expiration date, the nearby contract considered is the one whose delivery period is at least one month ahead. Futures prices are denoted in U.S. cents per bushel, so they were converted into US$/MT for comparison purposes with spot prices.[5]

Figures 1–4 show the evolution, in real terms, of spot and futures prices for the four agricultural commodities during the entire sample period. Two patterns emerge from these figures. First, futures markets exhibit strong backwardation—that is, the spot price is on average higher than the price of the nearby futures contract. More specifically, the corn spot price has generally been $10 higher per metric ton than the futures price during the past 15 years. For hard and soft wheat, the average difference between spot and futures prices has been around $18 and $4, respectively, while for soybeans the price difference has been $11. Note also the price hike of 2007 through mid-2008 due to the recent food crisis.[6] The second pattern that emerges is the strong correlation of price movements in spot and futures markets, as predicted by the non-arbitrage theory. Moreover, the futures market seems to dominate the spot market or equivalently, changes in spot prices echo changes in futures prices.

The volatility in the spot and futures markets analyzed also appears to be highly correlated, as shown in Figures 5–8. The volatility measure is the standard deviation of prices for each month in the sample period. As can be seen, the spot and futures volatility rise and fall in a similar manner, with peaks during the price spikes observed in Figures 1–4. However, in this case, it is less clear whether changes in volatility in the spot market echo changes in the futures market. Besides, spot prices are generally more volatile than futures prices, probably due to the higher transparency of the latter.[7]

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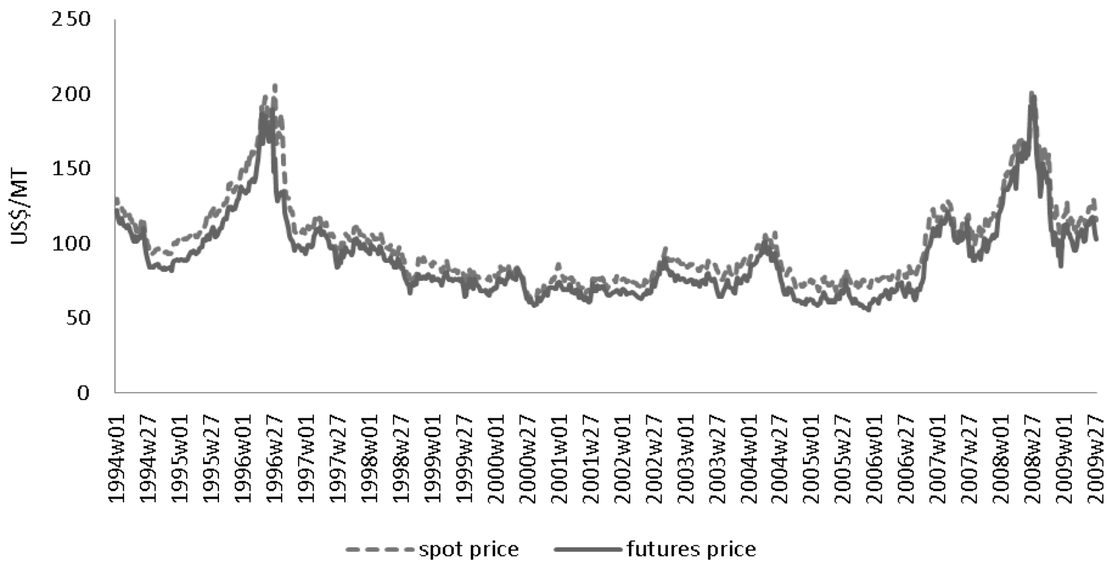
[4] Hard red winter wheat accounts for around 45 percent of total U.S. wheat production and is primarily used for bread making. Soft red winter wheat, in turn, accounts for around 20 percent of total U.S. wheat production and is primarily used to make cakes, cookies, snack foods, crackers, and pastries.

[5] Recall that the quantity, quality, time, and place of delivery are standardized in agricultural futures contracts, and the only negotiable variable in the contract is price. A Chicago Board of Trade (CBOT) corn, wheat, or soybean futures contract, as well as a Kansas City Board of Trade (KCBT) wheat futures contract, represents 5,000 bushels of the corresponding commodity. For corn, 5,000 bushels is around 127 metric tons, and for the other commodities, 5,000 bushels is around 136 metric tons.

[6] Corn and soybean prices also rose considerably in the mid-1990s due to the crop price shock of that period. Similarly, soybean prices showed a rapid increase at the end of 2003 and beginning of 2004 because of harvest shortages and an increase in export demand.

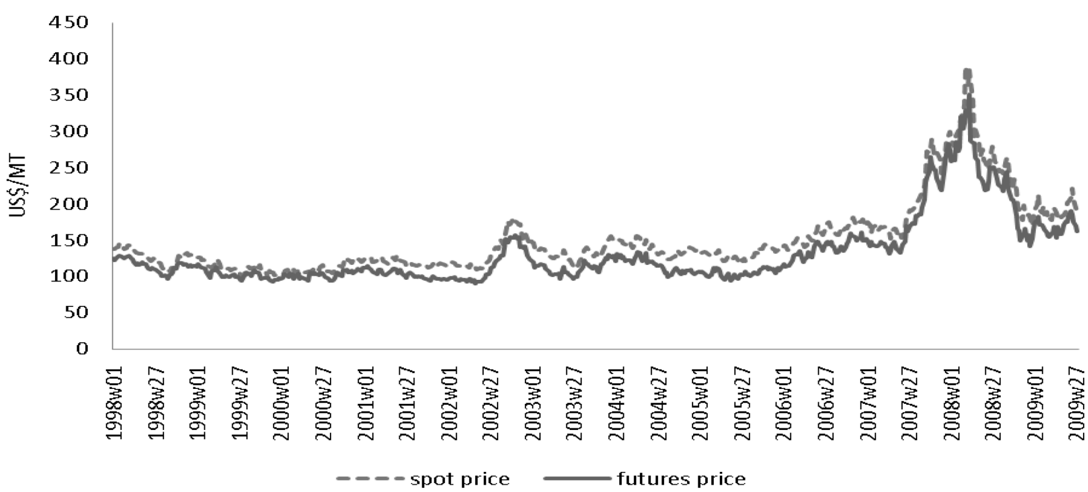
[7] Levene's test statistic for equality of variances between spot and futures prices indicates that the differences in volatility, in the majority of cases, are not significantly different within each year and over the entire sample period.

Figure 1. Corn: Weekly spot and futures prices, 1994–2009



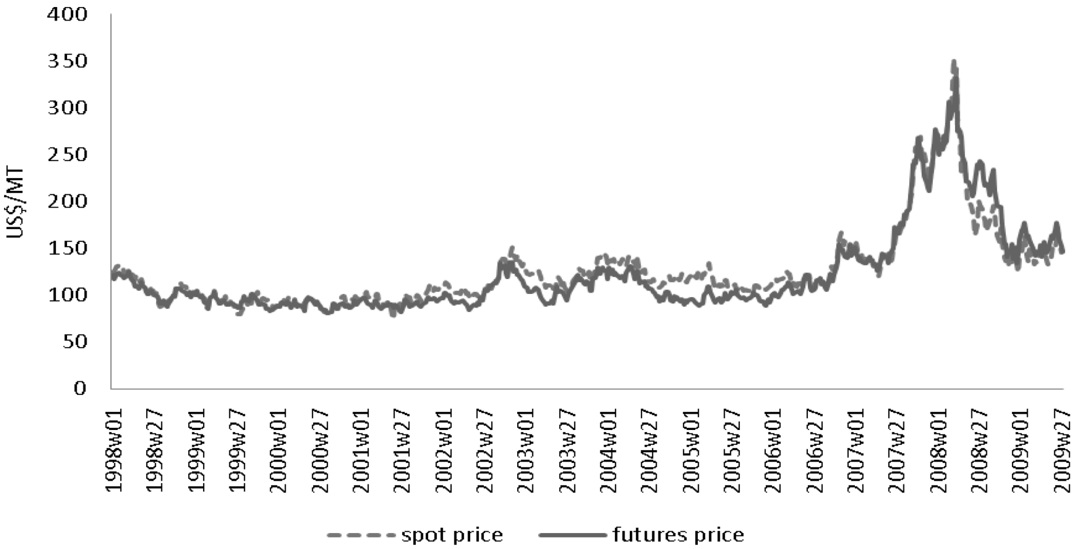
Sources: FAO International Commodity Prices Database, Chicago Mercantile Exchange Group end-of-day dataset (CME DataMine), and Commodity Research Bureau futures database (CRB Infotech CD).
Notes: CPI = Consumer Price Index; US$/MT = U.S. dollars per metric ton; w = week.
Prices deflated by U.S. CPI, January 1994 = 1.

Figure 2. Hard wheat: Weekly spot and futures prices, 1998–2009



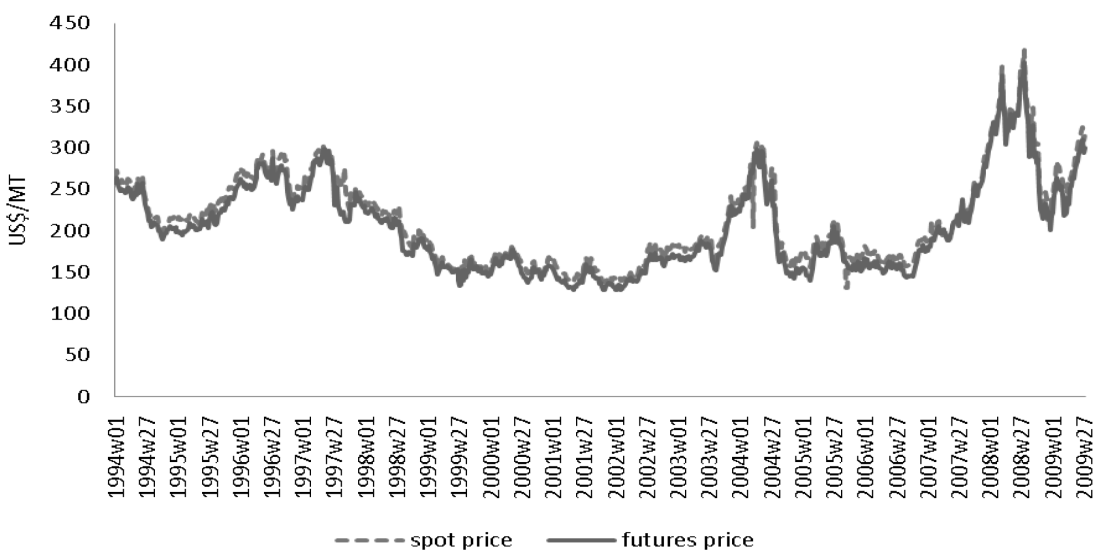
Sources: FAO International Commodity Prices Database, Chicago Mercantile Exchange Group end-of-day dataset (CME DataMine), and Commodity Research Bureau futures database (CRB Infotech CD).
Notes: CPI = Consumer Price Index; US$/MT = U.S. dollars per metric ton; w = week.
Prices deflated by U.S. CPI, January 1998 = 1

Figure 3. Soft wheat: Weekly spot and futures prices, 1998–2009



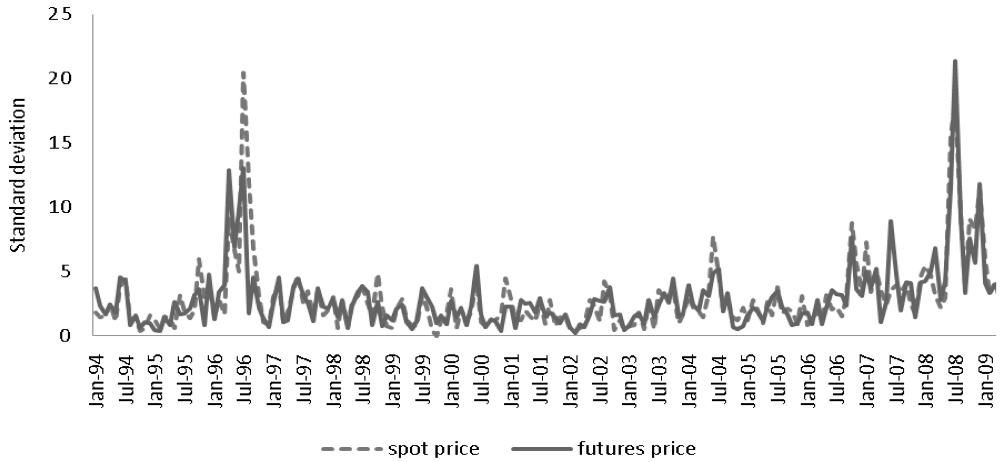
Sources: FAO International Commodity Prices Database, Chicago Mercantile Exchange Group end-of-day dataset (CME DataMine), and Commodity Research Bureau futures database (CRB Infotech CD).
Notes: CPI = Consumer Price Index; US$/MT = U.S. dollars per metric ton; w = week.
Prices deflated by U.S. CPI, January 1998 = 1

Figure 4. Soybeans: Weekly spot and futures prices, 1994–2009



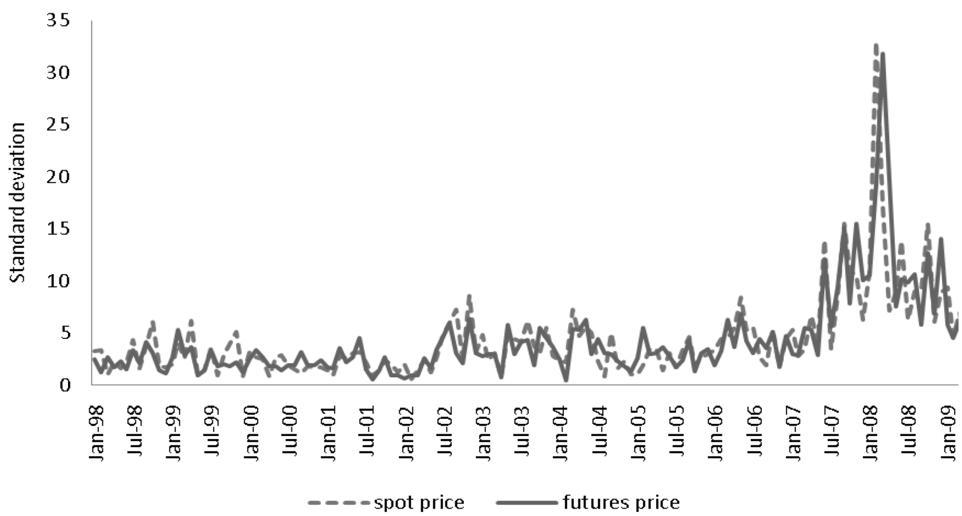
Sources: FAO International Commodity Prices Database, Chicago Mercantile Exchange Group end-of-day dataset (CME DataMine) and Commodity Research Bureau futures database (CRB Infotech CD).
Notes: CPI = Consumer Price Index; US$/MT = U.S. dollars per metric ton; w = week.
Prices deflated by U.S. CPI, January 1994 = 1

Figure 5. Corn: Monthly volatility in spot and futures prices, 1994–2009



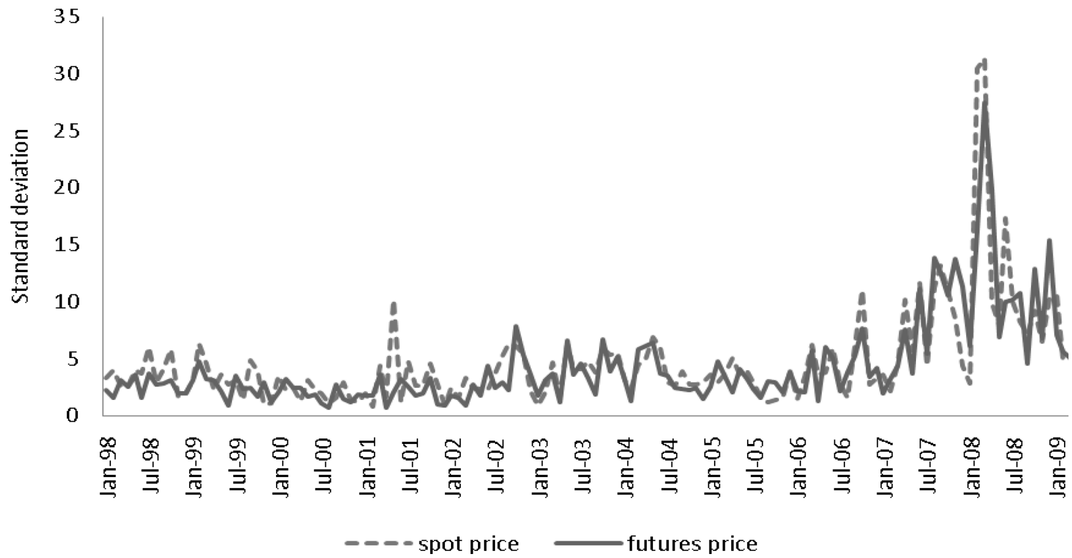
Sources: FAO International Commodity Prices Database, Chicago Mercantile Exchange Group end-of-day dataset (CME DataMine), and Commodity Research Bureau futures database (CRB Infotech CD).
Note: Monthly volatility based on weekly spot and futures prices.

Figure 6. Hard wheat: Monthly volatility in spot and futures prices, 1998–2009



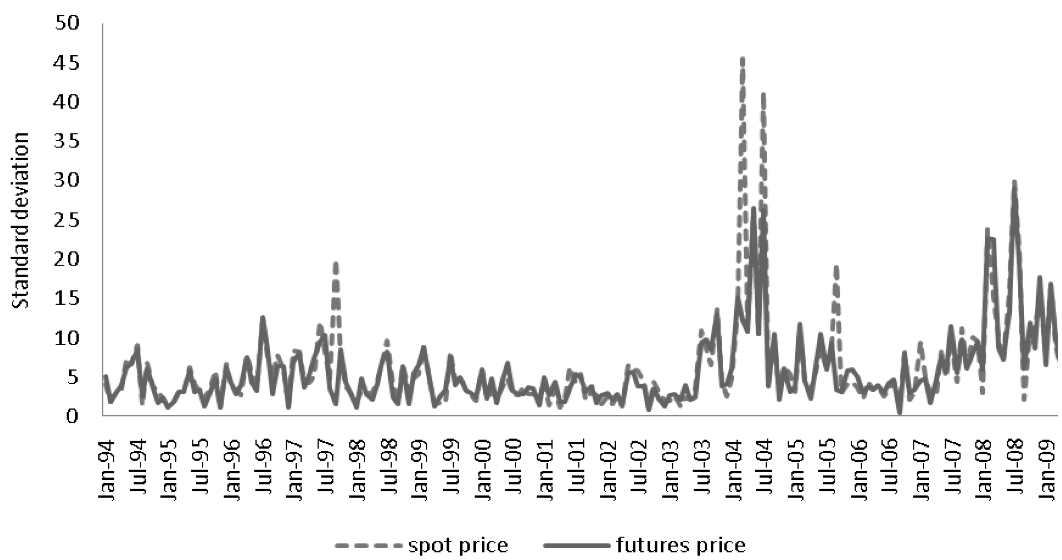
Sources: FAO International Commodity Prices Database, Chicago Mercantile Exchange Group end-of-day dataset (CME DataMine), and Commodity Research Bureau futures database (CRB Infotech CD).
Note: Monthly volatility based on weekly spot and futures prices.

Figure 7. Soft wheat: Monthly volatility in spot and futures prices, 1998–2009



Sources: FAO International Commodity Prices Database, Chicago Mercantile Exchange Group end-of-day dataset (CME DataMine), and Commodity Research Bureau futures database (CRB Infotech CD).
Note: Monthly volatility based on weekly spot and futures prices.

Figure 8. Soybeans: Monthly volatility in spot and futures prices, 1994–2009



Sources: FAO International Commodity Prices Database, Chicago Mercantile Exchange Group end-of-day dataset (CME DataMine), and Commodity Research Bureau futures database (CRB Infotech CD).
Note: Monthly volatility based on weekly spot and futures prices.

3. CAUSALITY TESTS

To formally analyze the dynamic relationship between spot and futures prices, linear and nonlinear (nonparametric) Granger causality tests were conducted. The Appendix outlines the technical details of these methodologies. These tests allow us to examine whether changes in the price of futures contracts lead changes in spot prices, whether changes in spot prices lead changes in futures prices, or both. The idea is to make some inferences about the direction of information flows between spot and futures markets.

The analysis was conducted on spot and futures returns because the logs of spot and futures prices of all four agricultural commodities were found to be nonstationary (see Table A.1). The spot return of a commodity is defined as $RS_t = \ln S_t - \ln S_{t-1}$, where S_t is the price in the spot market at time (week) *t*, while the futures return is defined as $RF_t = \ln F_t - \ln F_{t-1}$, where F_t is the futures price of the nearby contract at time *t*. Causal relationships were also examined on the volatility of spot and futures returns. The measure of volatility used is the absolute deviation of the return from the sample average, as in Crain and Lee (1996). So the spot volatility of a commodity at time *t* is given by $VS_t = |RS_t - \overline{RS}|$, while the futures volatility is equal to $VF_t = |RF_t - \overline{RF}|$, where $\overline{RS}$ and $\overline{RF}$ are the corresponding sample averages.

Linear Granger Causality Test

The linear Granger causality test examines whether past values of one variable can help explain current values of a second variable, conditional on past values of the second variable. Intuitively, it determines whether past values of the first variable contain additional information on the current value of the second variable that is not contained in past values of the latter. If so, the first variable is said to Granger-cause the second variable. In this case, we evaluate whether futures returns Granger-cause spot returns (that is, whether the return in the spot market at time *t* is related to past returns in the futures market, conditional on past spot returns), whether spot returns Granger-cause futures returns, or both. Similarly, we evaluate whether volatility in the futures market Granger-cause volatility in the spot market, whether volatility in the spot market Granger-cause volatility in the futures market, or both.

Linear causality tests were performed over the entire sample period, as well as on sample subperiods, to analyze whether the dynamic relationship between corn spot and futures prices has changed across time. Prices for agricultural commodities are inherently subject to demand and supply shocks, and it is possible that these structural changes affect the dynamic relationship between spot and futures prices. Additionally, this relationship might be affected by changes in the relative importance of different trading mechanisms or, as argued by Crain and Lee (1996), by changes in farm policies.

The test results for spot and futures returns for all four agricultural commodities and for the whole sample period are presented in Table 1. The upper section of the table reports the F-statistic for the null hypothesis that futures returns does not Granger-cause spot returns; the lower section reports the F-statistic for the null hypothesis that spot returns does not Granger-cause futures returns. As is similar to previous studies, test results for different lag structures are included (1–10 lags). As can be seen, the null hypothesis that the returns in futures markets does not Granger-cause the returns in spot markets is uniformly rejected at the 1 percent significance level in all four cases and for all lags, with the F-statistic decreasing as the number of lags increases. In contrast, only in the case of corn does spot returns Granger-cause futures returns for lag 1 at a 1 percent significance level and for lags 7 and 8 at a 5 percent significance level.

Table 1. Granger causality tests of weekly returns in spot and futures markets, 1994–2009

# lags	H0: Futures returns does not Granger-cause spot returns							
	Corn		Hard Wheat		Soft Wheat		Soybeans	
1	167.47	***	263.03	***	169.85	***	15.44	***
2	116.20	***	186.92	***	106.61	***	21.24	***
3	77.58	***	135.27	***	75.33	***	20.74	***
4	58.56	***	100.84	***	57.92	***	16.93	***
5	48.65	***	79.91	***	46.38	***	14.57	***
6	40.63	***	65.92	***	38.36	***	12.41	***
7	34.76	***	56.21	***	32.90	***	11.51	***
8	30.95	***	49.91	***	29.37	***	10.35	***
9	27.62	***	44.64	***	26.09	***	9.38	***
10	24.80	***	40.89	***	23.44	***	9.05	***
	H0: Spot returns does not Granger-cause futures returns							
	Corn		Hard Wheat		Soft Wheat		Soybeans	
1	6.10	***	2.20		0.40		0.55	
2	2.09		0.02		0.01		0.47	
3	2.24	*	0.11		0.27		1.75	
4	2.08	*	0.97		1.50		1.41	
5	1.66		1.32		1.59		1.28	
6	1.59		1.21		1.64		1.06	
7	2.12	**	1.45		1.76	*	0.96	
8	1.97	**	1.21		1.46		1.06	
9	1.58		1.10		1.25		1.04	
10	1.45		1.21		1.21		1.03	

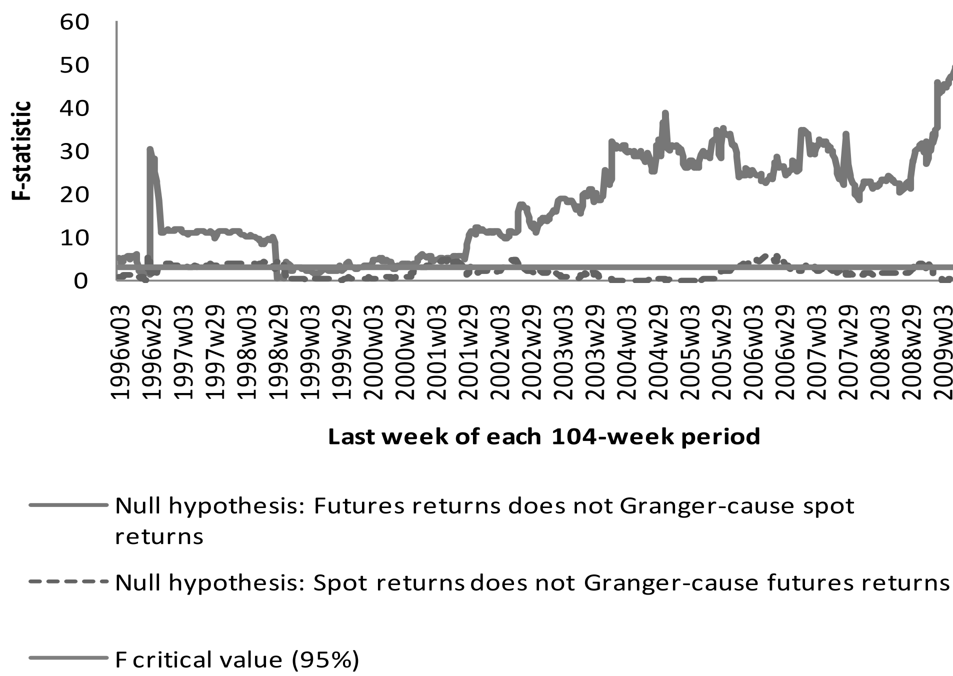
Source: Authors' estimations.
Notes: The Schwartz Bayesian Criterion (SBC) suggests lag structures of 2, 3, 2, and 3for corn, hard wheat, soft wheat, and soybeans, respectively. The Akaike Information Criterion (AIC) suggests lag structures of 8, 3, 4, and 5, respectively. Period of analysis: January 1994 – July 2009 for corn and soybeans, and January 1998 – July 2009 for hard and soft wheat. H_0 = null hypothesis.
*10%, **5%, ***1% significance. F-statistic reported.

These results are consistent with previous studies and suggest that futures markets dominate spot markets for the commodities analyzed or, equivalently, that the spot price is discovered in the futures market. The return in the spot market today is significantly related to past returns in the futures market up to at least 10 weeks ago, whereas the impact of past spot returns on today's futures return is generally not significant. The information flow from futures to spot markets also appears to have intensified in the past years, because the causal relationship is remarkably strong in comparison to previous studies. This apparent increase in information flows could be related to the increase in the relative importance of electronic trading of futures contracts over open auction trading during the past years, which results in more transparent and widely accessible prices.

When segmenting the sample by two-year periods, as shown in Tables A.2–A.5, we still find strong evidence that futures markets dominate spot markets across all time periods, specifically for the two varieties of wheat and corn. In the case of soybeans, the evidence is less clear, although returns in the futures market lead returns in the spot market more often than the reverse. A similar pattern is observed when dividing the sample into subperiods corresponding to the different farm programs in the U.S. (that is, the 1990, 1996, 2002, and 2008 Farm Bills). The causal relationship from futures to spot markets does not seem to have been much affected by the farm programs. Refer to Tables A.6–A.9 for details.

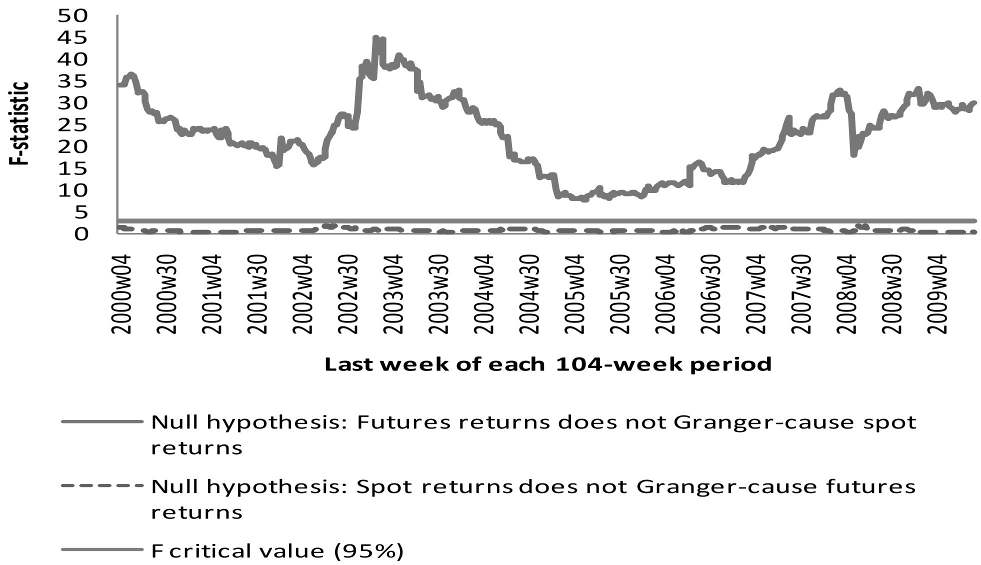
Another way to examine whether the causal link between spot and futures returns has changed across time is to conduct rolling Granger causality tests, as in Robles, Torero, and von Braun (2009) and Cooke and Robles (2009). Repeated tests over 104-week (2-year) periods were carried out by rolling the subsample period one week ahead until the available data were exhausted. The results of this procedure for each agricultural commodity are presented in Figures 9–12. Again, it is clear that futures returns Granger-cause spot returns, at least for hard and soft wheat and corn. Note also that in all four cases, spot returns do not seem to Granger-cause futures returns across all sample subperiods.

Figure 9. Corn: Rolling Granger causality tests of weekly returns in spot and futures markets, 1994–2009



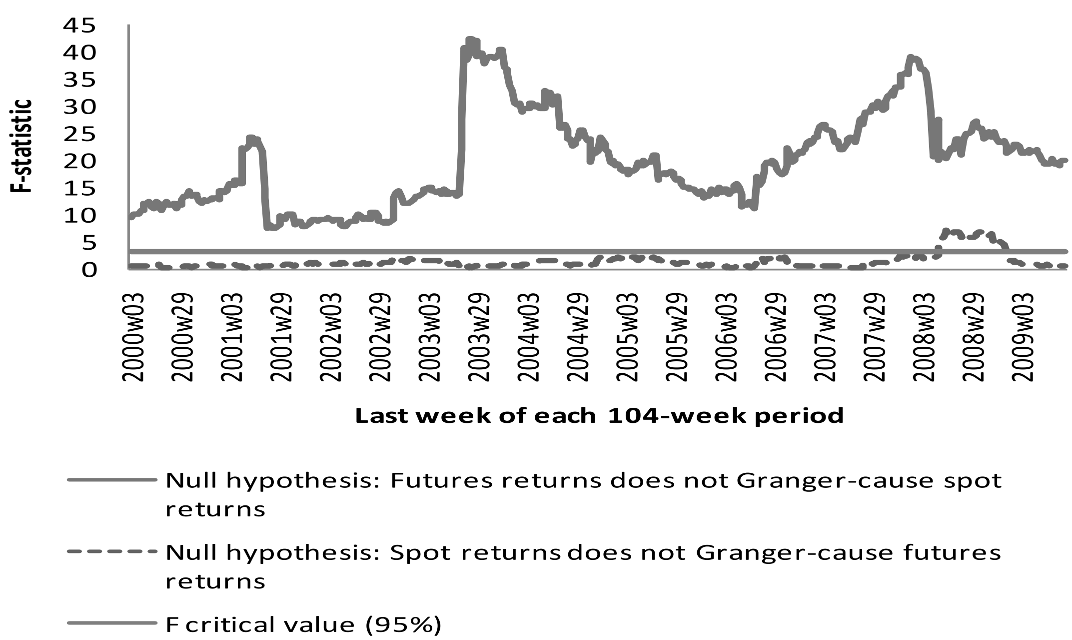
Source: Authors' estimations.
Notes: A lag structure of 2 is assumed according to the Schwartz Bayesian Criterion (SBC). w = week.

Figure 10. Hard wheat: Rolling Granger causality tests of weekly returns in spot and futures markets, 1998–2009



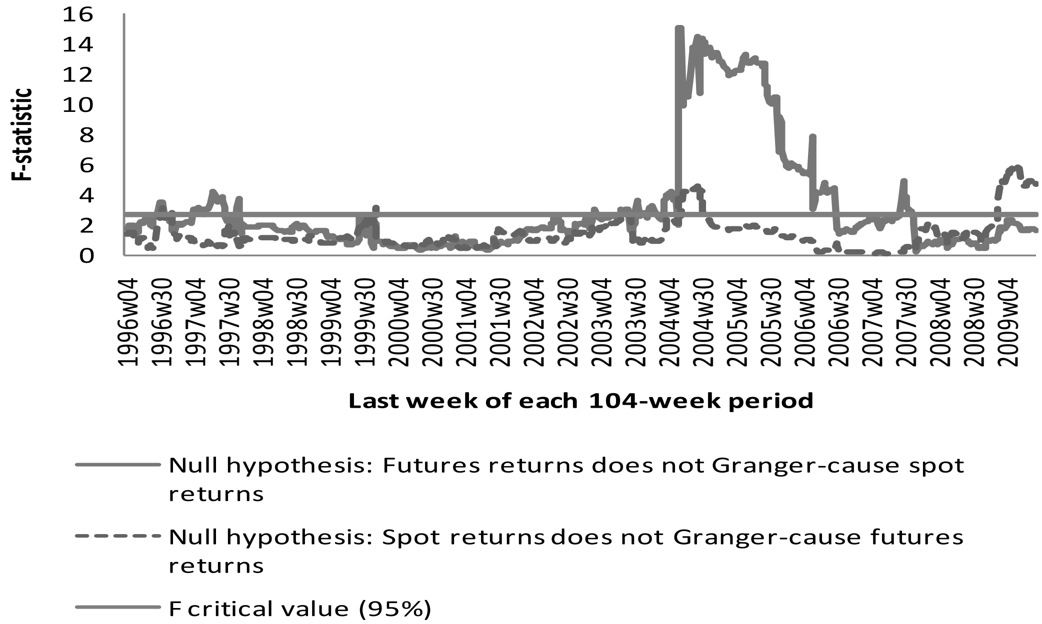
Source: Authors' estimations.
Notes: A lag structure of 3 is assumed according to the Schwartz Bayesian Criterion (SBC). w = week.

Figure 11. Soft wheat: Rolling Granger causality tests of weekly returns in spot and futures markets, 1998–2009



Source: Authors' estimations.
Notes: A lag structure of 2 is assumed according to the Schwartz Bayesian Criterion (SBC). w = week.

Figure 12. Soybeans: Rolling Granger causality tests of weekly returns in spot and futures markets, 1994–2009



Source: Authors' estimations.
Notes: A lag structure of 3 is assumed according to the Schwartz Bayesian Criterion (SBC). w = week.

A similar causality analysis was conducted for each commodity to explore how volatility in one market is related to volatility in the other. The test results for the whole sample period and for models including 1 to 10 lag structures are reported in Table 2. The upper section of the table shows the F-statistic for the null hypothesis that futures volatility does not Granger-cause spot volatility, and the lower section reports the F-statistic for the null hypothesis that spot volatility does not Granger-cause futures volatility. As in the case of returns, when considering the whole sample period, the null hypothesis that futures volatility does not Granger-cause spot volatility is uniformly rejected at the 1 percent significance level in all four cases and basically for all lag structures. The F-statistic also decreases as the number of lags increases.

However, except for soybeans, spot volatility also seems to Granger-cause futures volatility for several lag levels at the 1 and 5 percent significance levels. Furthermore, in the case of hard wheat, the causal link from spot to futures volatility is robust to all lag structures considered. But the impact of past spot volatility on today's futures volatility is not as strong and persistent as the impact of past futures volatility on today's spot volatility. Overall, these findings suggest that futures markets also carry out their price discovery role by transferring volatility to spot markets, but the results are not as conclusive as in the case of returns.

The analysis by sample subperiods also reveals that volatility in the futures market leads volatility in the spot market more often than the reverse, particularly for corn and soybeans (see Tables A.10–A.13). Similar results are obtained when dividing the sample by different farm programs in the U.S., as shown in Tables A.14–A.17. In the case of corn, the causal link from futures to spot markets seems robust across most farm programs.

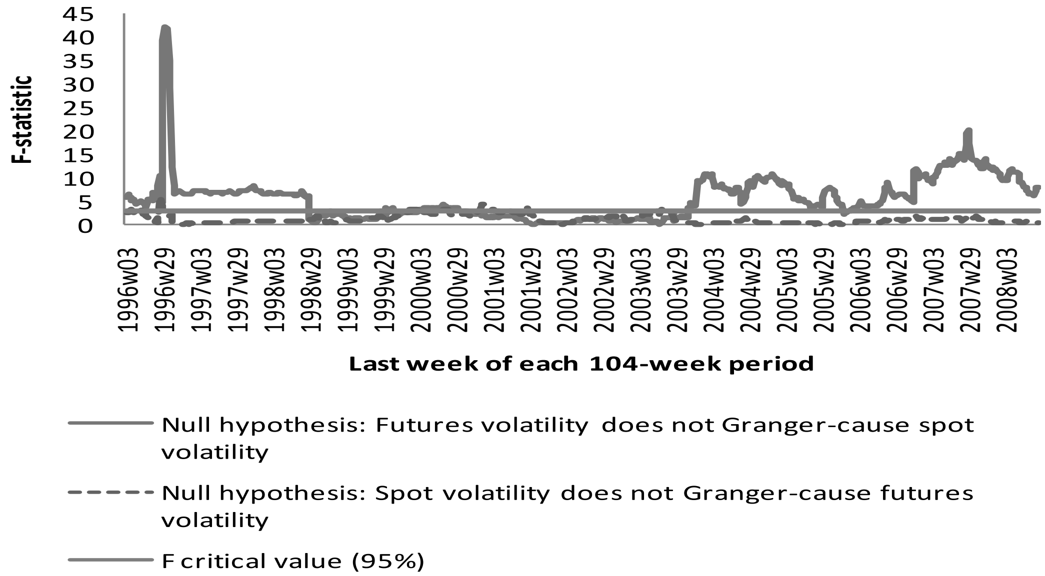
Table 2. Granger causality tests of weekly volatility in spot and futures markets, 1994–2009

# lags	H_0: Futures volatility does not Granger-cause spot volatility							
	Corn		Hard Wheat		Soft Wheat		Soybeans	
1	85.85	***	33.40	***	18.11	***	1.32	
2	50.54	***	20.71	***	7.05	***	5.66	***
3	33.52	***	16.69	***	4.58	***	4.98	***
4	24.72	***	11.29	***	4.28	***	5.27	***
5	19.04	***	9.51	***	4.05	***	4.22	***
6	18.92	***	8.11	***	3.51	***	3.52	***
7	16.39	***	6.98	***	3.14	***	3.30	***
8	14.88	***	6.38	***	3.17	***	2.84	***
9	13.21	***	5.36	***	2.75	***	2.63	***
10	12.51	***	5.46	***	2.33	***	2.51	***
	H_0: Spot volatility does not Granger-cause futures volatility							
	Corn		Hard Wheat		Soft Wheat		Soybeans	
1	7.02	***	6.74	***	10.88	***	0.14	
2	1.15		4.62	***	7.03	***	0.13	
3	0.53		7.74	***	4.67	***	0.14	
4	4.41	***	5.13	***	3.16	**	0.11	
5	3.04	***	4.90	***	2.38	**	0.35	
6	2.35	**	4.22	***	1.74		0.43	
7	2.08	**	3.63	***	1.60		0.87	
8	2.01	**	3.24	***	1.41		0.91	
9	2.06	**	3.05	***	1.42		1.58	
10	1.57		4.08	***	2.01	**	1.42	

Source: Authors' estimations.
Notes: Volatility measured as absolute deviations of weekly spot and futures returns from the sample average. The Schwartz Bayesian Criterion (SBC) suggests lag structures of 2, 1, 1, and 2 for corn, hard wheat, soft wheat, and soybeans, respectively. The Akaike Information Criterion (AIC) suggests lag structures of 10, 10, 2, and 5, respectively. Period of analysis: January 1994 – July 2009 for corn and soybeans, and January 1998 – July 2009 for hard and soft wheat. H_0 = null hypothesis. *10%, **5%, ***1% significance. F-statistic reported.

The rolling Granger causality tests, reported in Figures 13–16, indicate that the volatility transfer from spot to futures markets is very weak for all commodities. More specifically, under this estimation procedure, the transfer of volatility from futures to spot markets is more recurrent than the reverse, but there are also several subperiods where both markets are disjoint from each other.

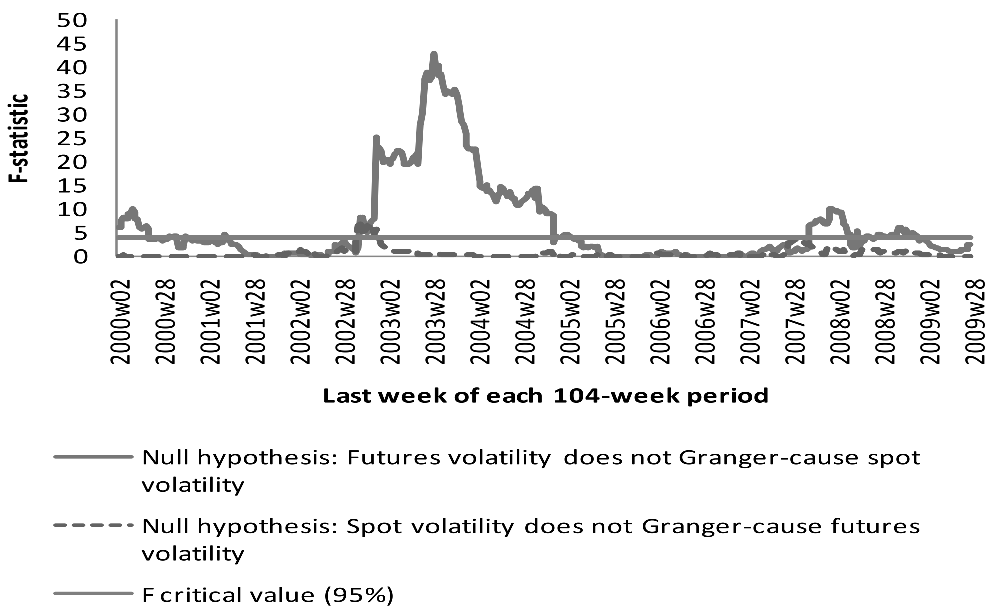
Figure 13. Corn: Rolling Granger causality tests of weekly volatility in spot and futures markets, 1994–2009



Source: Authors' estimations.

Notes: Volatility measured as absolute deviations of weekly spot and futures returns from the sample average. A lag structure of 2 is assumed according to the Schwartz Bayesian Criterion (SBC). w = week.

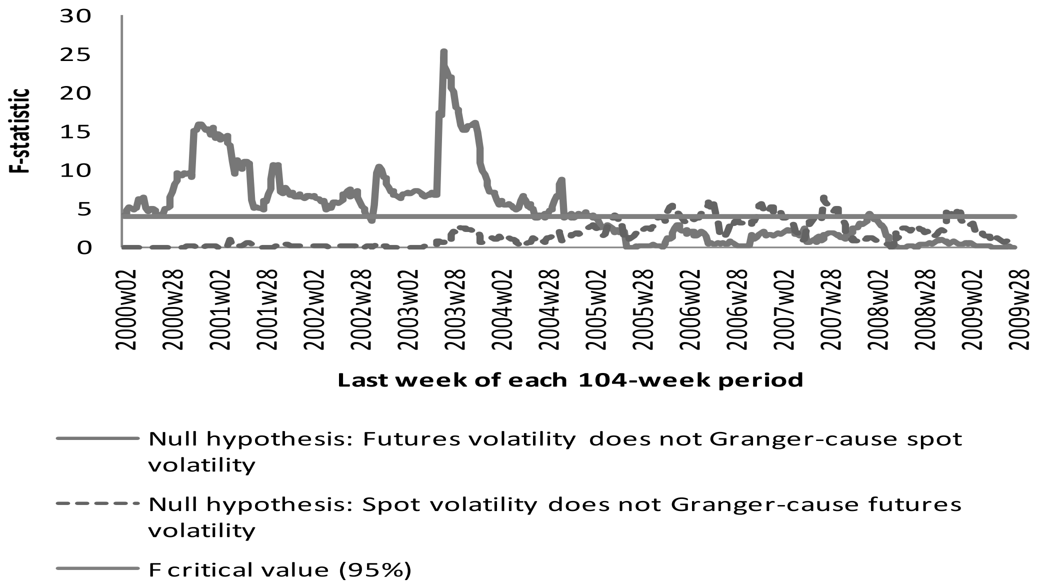
Figure 14. Hard wheat: Rolling Granger causality tests of weekly volatility in spot and futures markets, 1998–2009



Source: Authors' estimations.

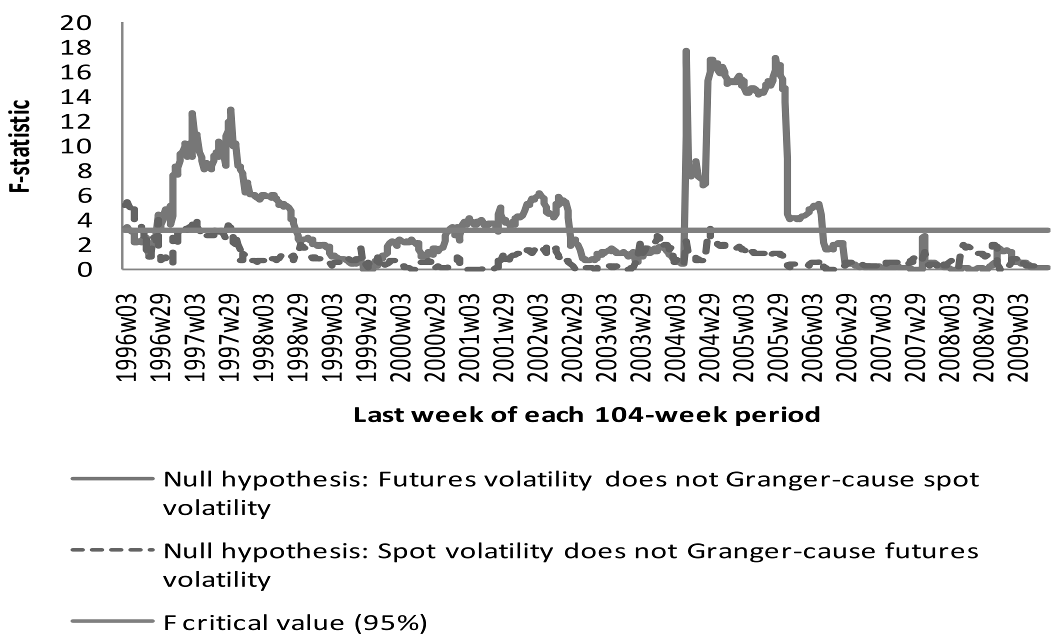
Notes: Volatility measured as absolute deviations of weekly spot and futures returns from the sample average. A lag structure of 1 is assumed according to the Schwartz Bayesian Criterion (SBC). w = week.

Figure 15. Soft wheat: Rolling Granger causality tests of weekly volatility in spot and futures markets, 1998–2009



Source: Authors' estimations.
Notes: Volatility measured as absolute deviations of weekly spot and futures returns from the sample average. A lag structure of 1 is assumed according to the Schwartz Bayesian Criterion (SBC). w = week.

Figure 16. Soybeans: Rolling Granger causality tests of weekly volatility in spot and futures markets, 1994–2009



Source: Authors' estimations.
Notes: Volatility measured as absolute deviations of weekly spot and futures returns from the sample average. A lag structure of 2 is assumed according to the Schwartz Bayesian Criterion (SBC). w = week.

Nonparametric Granger Causality Test

The linear Granger causality tests support the price discovery role of futures markets or, alternatively, that changes in spot prices echo changes in futures prices. The evidence is clearer when analyzing returns than when analyzing volatility in spot and futures markets. Linear causality tests have high power in identifying linear causal relations, but their power against nonlinear causal links might be low, as pointed out by Hiemstra and Jones (1994). Nonlinear dynamic relations might arise, for example, when allowing for heterogeneous market participants or different types of risk-averse agents in spot and futures markets.

Considering, then, that linear causality tests might overlook nonlinear dynamic relations between spot and futures prices, the nonparametric causality test proposed by Diks and Panchenko (2006) was conducted.[8] In particular, we want to rule out the possibility of nonlinear causality from changes in spot prices to changes in futures prices, provided that there is no major evidence of linear causality in this direction.[9]

To remove any linear dependence, the nonparametric causality test was applied to the residuals of vector autoregressive (VAR) models with spot and futures returns and spot and futures volatility for each commodity. Tables 3 and 4 report the T values for Diks and Panchenko's test statistic applied to the returns and their volatility, respectively, in both directions and for different lag lengths (1–5 lags). Causality tests on sample subperiods were not performed in this case because the nonparametric test relies on asymptotic theory.

Even after removing the linear dependence, futures returns Granger-cause spot returns, particularly for corn and hard wheat. For soft wheat, the causal relationship goes in the reverse direction, while for soybeans there are bidirectional information flows. In terms of volatility, futures markets seem to transfer volatility to spot markets for all four commodities, but there is also volatility transfer from spot to futures markets for soft wheat and soybeans. In sum, the nonparametric results provide little evidence of nonlinear causality from changes in spot prices to changes in futures prices. If there is any strong nonlinear causal relationship, it is from futures to spot markets, at least for corn and hard wheat.

Table 3. Nonparametric Granger causality tests of weekly returns in spot and futures markets, 1994–2009

$l_x = l_y$	H_0: Futures returns does not Granger-cause spot returns			
	Corn	Hard Wheat	Soft Wheat	Soybeans
1	2.96 ***	1.61 **	0.50	1.69 **
2	3.17 ***	2.71 ***	1.07	3.10 ***
3	3.32 ***	3.30 ***	1.16	3.63 ***
4	2.86 ***	2.95 ***	1.25 *	4.20 ***
5	1.94 **	2.85 ***	1.12	3.72 ***

[8] For further details on the nonparametric causality test implemented, refer to the Appendix.
[9] Identifying a specific source of nonlinear dependence between spot and futures prices is beyond the scope of this study.

Table 3. Continued

	H0: Spot returns does not Granger-cause futures returns			
	Corn	Hard Wheat	Soft Wheat	Soybeans
1	2.41***	2.02**	3.13***	1.67**
2	1.24	1.88**	3.03***	1.65**
3	1.89**	1.92**	2.94***	1.74**
4	2.12**	2.02**	3.05***	1.79**
5	1.36*	1.38*	2.52***	2.24**

Source: Authors' estimations.
Notes: Bandwidth values set according to the time series length and considering a conditional heteroskedastic process with one lag dependence (Diks and Panchenko, 2006). Period of analysis: January 1994 – July 2009 for corn and soybeans, and January 1998 – July 2009 for hard and soft wheat. H_0 = null hypothesis. $l_x = l_y$ = number of lags of spot and futures returns.
*10%, **5%, ***1% significance. Diks and Panchenko's (1996) T ratios reported.

Table 4. Nonparametric Granger causality tests of weekly volatility in spot and futures markets, 1994–2009

$l_x = l_y$	H0: Futures volatility does not Granger-cause spot volatility			
	Corn	Hard Wheat	Soft Wheat	Soybeans
1	4.60***	3.09***	2.37***	1.91**
2	3.29***	2.74***	1.96**	2.29**
3	2.79***	3.56***	2.33***	1.53*
4	2.54***	3.79***	2.93***	2.02**
5	2.20**	3.39***	2.37***	2.02**
	H0: Spot volatility does not Granger-cause futures volatility			
	Corn	Hard Wheat	Soft Wheat	Soybeans
1	2.95***	1.34*	2.46***	1.17
2	2.12**	1.17	2.03**	1.92**
3	1.64*	1.39*	2.47***	2.12**
4	0.63	0.59	2.18**	1.94**
5	0.54	0.93	2.70***	1.82**

Source: Authors' estimations.
Note: Volatility measured as absolute deviations of weekly spot and futures returns from the sample average. Bandwidth values set according to the time series length and considering a conditional heteroskedastic process with one lag dependence (Diks and Panchenko, 2006). Period of analysis: January 1994 – July 2009 for corn and soybeans, and January 1998 – July 2009 for hard and soft wheat. H_0 = null *10%, **5%, ***1% significance. Diks and Panchenko's (1996) T ratios reported.
hypothesis. lx = ly = number of lags of spot and futures volatility.

4. CONCLUSIONS

The causality tests performed indicate that the futures markets analyzed generally dominate the spot markets. Price changes in futures markets lead price changes in spot markets more often than the reverse, especially when examining returns. These findings support then the price discovery role of futures markets. Compared with previous studies, the identified causal link also appears to be stronger and more persistent. This finding suggests that the information flow from futures to spot markets has intensified in the past 15 years, probably due to the increase in the relative importance of electronic trading of futures contracts over open auction trading, which results in more transparent and widely accessible prices.

This result has important implications for alternative instruments recommended to address disproportionate volatility in grain markets after the recent food crisis. In particular, von Braun and Torero (2008, 2009) have proposed the implementation of a global virtual reserve to minimize speculative attacks and avoid excessive spikes in spot prices. The idea is to specify a price band that would be a signal (threat) to speculators that a market assessment is likely if futures prices exceed the upper limit of this band. If, despite the signal, there is evidence of an excessive price spike, a progressive number of short sales in the futures market (at market prices) will then be executed so that futures and eventually spot prices will decline to reasonable levels. The fact that spot prices move toward futures prices supports the viability of this innovative intervention mechanism.

APPENDIX: GRANGER CAUSALITY TESTS

This appendix describes in detail the linear and nonlinear (nonparametric) Granger causality tests performed in the study. The order of integration of both spot and futures prices of all four agricultural commodities was first examined using the Augmented Dickey–Fuller (ADF) unit-root test, after taking logs. The ADF tests included a constant, and the appropriate lag length was selected according to the Schwartz Bayesian Criterion (SBC). Formally, the following test equation was estimated for each spot and futures commodity price,

$$\Delta y_t = \alpha + \beta y_{t-1} + \sum_{i=2}^{p} \gamma_i \Delta y_{t-i+1} + \varepsilon_t, \tag{A.1}$$

where $\Delta y_t = y_t - y_{t-1}$, y_t is the log of the spot (S_t) or futures price (F_t) at time (week) t, p is the lag length used, and ε_t is the error term. Testing the null hypothesis that the series has a unit root or is integrated of order 1—that is, I(1)—is equivalent to testing if $\beta = 0$. Both the log of spot and futures prices of each commodity are found to be I(1), suggesting the use of first differences in the causality analysis (see Table A.1).

As a robustness check, Perron's unit-root test in the presence of structural breaks was performed on the log of spot and futures prices, provided that if a series has a structural change (as suspected due to the crop price shock during the mid 1990s or the recent food crisis), the ADF statistic is biased toward the non-rejection of a unit root. The test results also provide strong evidence for the unit root hypothesis.[10]

Causality tests were then carried out on the (weekly) returns of the spot and futures prices of each commodity, defined as $RS_t = \ln S_t - \ln S_{t-1}$ and $RF_t = \ln F_t - \ln F_{t-1}$, respectively. Both returns are found to be I(0) for all four commodities, as expected. Causality links were also examined on the volatility of the spot and futures returns. Following Crain and Lee (1996), volatility is measured as the absolute deviation of the return from the sample average. Thus, the volatility of the spot return at time t is given by $VS_t = |RS_t - \overline{RS}|$, where $\overline{RS}$ is the sample average. The volatility of the futures return at time t, in turn, is defined as $VF_t = |RF_t - \overline{RF}|$. The volatility measures are also found to be I(0) in all cases.

Linear Granger Causality Test

The linear Granger causality test conducted basically consists of examining whether the return in the spot market at time t is related to past returns in the futures market, conditional on past spot returns; whether futures returns are related to past spot returns, conditional on past futures returns; or both. More specifically, the following regression model was estimated for each commodity to analyze the relationship between RS_t and p lagged values of RS_t and RF_t:

$$RS_t = a_0 + \sum_{k=1}^{p} a_{1k} RS_{t-k} + \sum_{k=1}^{p} a_{2k} RF_{t-k} + e_t. \tag{A.2}$$

As in previous studies, the model was estimated for different lag lengths, considering also that the Schwartz Bayesian Criterion (SBC) and the Akaike Information Criterion (AIC) suggested different lag structures within each commodity.[11] The F-statistic for the null hypothesis that the lagged coefficients of RF_t are equal to zero was used to test whether RF_t does not Granger-cause RS_t. Intuitively, it is tested whether past futures returns contain additional information on the current spot return that is not contained

[10] For further details on testing for unit roots in the presence of a structural change, refer to Enders (2004).

[11] The difference between the Schwartz Bayesian Criterion (SBC) and the Akaike Information Criterion (AIC) is the weight they give to the number of parameters (or complexity) of the model. The SBC has a larger penalty for having extra parameters (that is, for lack of parsimony). Consequently, the AIC is designed to select the model that will predict best, and it is less concerned with having more parameters. The SBC is more concerned with selecting the true number of lags in an autoregressive process.

in past spot returns. Conversely, RF_t is the dependent variable to test whether RS_t does not Granger-cause RF_t. The test results are presented in Table 1.

A similar test was conducted for volatility. The regression model estimated for each commodity to examine whether volatility in the spot market is related to past volatility in the futures market, conditional on past spot volatility, is given by

$$VS_t = b_0 + \sum_{k=1}^{p} b_{1k} VS_{t-k} + \sum_{k=1}^{p} b_{2k} VF_{t-k} + u_t.$$

Again, the F-statistic for the null hypothesis that the lagged coefficients of VF_t are equal to zero was used to test whether VF_t does not Granger-cause VS_t. Similarly, VF_t is the left-hand-side variable to test whether VS_t does not Granger-cause VF_t. The test results are reported in Table 2.

Linear Granger causality tests of spot and futures returns and their volatility were also conducted on sample subperiods to analyze whether the dynamic relationship between spot and futures prices for each commodity has changed across time. This relationship might be affected by structural changes in the dynamics of prices, by changes in the relative importance of different trading mechanisms, or by changes in farm policies as indicated by Crain and Lee (1996). In particular, the following additional estimations considering the frequency of the data and the sample size were carried out:

1. Causality tests for separate two-year periods: 1994–1995, 1996–1997, 1998–1999, 2000–2001, 2002–2003, 2004–2005, 2006–2007, and 2008–2009 semester 1. Recall that for hard and soft wheat we do not have information for the years 1994–1997. Refer to Tables A.2–A.5 for causality tests on returns and Tables A.10–A.13 for causality tests on their volatitily.
2. Causality tests for each sample subperiod corresponding to a different farm program in the U.S. The first subperiod corresponds to the sample period during the 1990 Farm Bill (01/07/94–04/03/96); the second subperiod, to the 1996 Farm Bill (04/04/96–05/12/02); the third subperiod, to the 2002 Farm Bill (05/13/02–06/17/08); and the last subperiod, to the 2008 Farm Bill (06/18/08–06/26/09). For hard and soft wheat, the 1996 Farm Bill subperiod corresponds to 01/02/98–05/12/02. See Tables A.6–A.9 for causality tests on returns and Tables A.14–A.17 for causality tests on their volatitily.
3. Rolling causality tests as in Robles, Torero, and von Braun (2009) and Cooke and Robles (2009): repeated tests over 104-week (2-year) periods by rolling the subsample period 1 week ahead until the available data are exhausted. The lag structure was set according to the SBC. Thus, for example, in the case of corn spot and futures returns, a total of 702 causality tests were conducted, as the period of analysis moved one week ahead every time, while in the case of hard wheat spot and futures returns, a total of 493 causality tests were performed. Figures 9–12 report the rolling causality tests for returns while Figures 13–16 report the tests for volatility.

Nonparametric Granger Causality Test

As a complementary analysis, nonparametric Granger causality tests were performed on spot and futures returns of each commodity and their volatility to uncover potential nonlinear dynamic relations between spot and futures markets. Traditional linear Granger causality tests have high power in identifying linear causal relations, but their power against nonlinear causal relations can be low (see Hiemstra and Jones, 1994). The nonparametric Granger causality test proposed by Diks and Panchenko (2006) was conducted. The authors argue that their causality test reduces the risk of overrejection of the null hypothesis of noncausality, observed in the Hiemstra and Jones widely used test.[12]

[12] Considering that the null hypothesis of Granger non-causality can be rephrased in terms of conditional independence of two vectors *X* and *Z* given a third vector *Y*, Diks and Panchenko (2006) show that the Hiemstra and Jones test is sensitive to variations in the conditional distributions of *X* and *Z* that may be present under the null hypothesis. To overcome this problem, they replace the global test statistic by an average of local conditional dependence measures.

Dicks and Panchenko's nonparametric causality test can be summarized as follows.[13] Consider two stationary series, $\{X_t\}$ and $\{Y_t\}$, such as the spot and futures returns or the volatility measures defined previously. When testing for Granger causality, the aim is to detect evidence against the null hypothesis H_0: $\{X_t\}$ does not Granger-cause $\{Y_t\}$. In a nonparametric setting, this null hypothesis is equivalent to testing for the conditional independence of Y_t on $X_{t-1}, \ldots, X_{t-l_x}$, given $Y_{t-1}, \ldots, Y_{t-l_y}$; that is,

$$H_0: Y_t|(X_{t-1}^{l_x}; Y_{t-1}^{l_x}) \sim Y_t|Y_{t-1}^{l_y}, \tag{A.4}$$

where $X_{t-1}^{l_x} = (X_{t-l_x}, \ldots, X_{t-1})$ and $Y_{t-1}^{l_y} = (Y_{t-l_y}, \ldots, Y_{t-1})$. So the null hypothesis is a statement about the invariant distribution of the $(l_x + l_y + 1)$–dimensional vector $W_t = (X_{t-1}^{l_x}, Y_{t-1}^{l_y}, Z_t)$, where $Z_t = Y_t$. For ease of notation, assume that $l_x = l_y = 1$, and drop the time index. Then, under the null hypothesis, the conditional distribution of Z given $(X, Y) = (x, y)$ is the same as that of Z given only $Y = y$, and the joint probability density function $f_{X,Y,Z}(x, y, z)$ and its marginals must satisfy

$$\frac{f_{X,Y,Z}(x,y,z)}{f_Y(y)} = \frac{f_{X,Y}(x,y)}{f_Y(y)} \frac{f_{Y,Z}(y,z)}{f_Y(y)} \tag{A.5}$$

for each vector (x, y, z) in the support of (X, Y, Z). Diks and Panchenko further show that the null hypothesis implies

$$q \equiv E\left[f_{X,Y,Z}(X,Y,Z) f_Y(Y) - f_{X,Y}(X,Y) f_{Y,Z}(Y,Z)\right] = 0. \tag{A.6}$$

If $\hat{f}_W(W_i)$ is a local density estimator of a d_W-variate random vector W at W_i, defined by $\hat{f}_W(W_i) = \frac{(2\epsilon_n)^{-d_W}}{n-1} \sum_{j,j\neq i} I_{ij}^W$ where $I_{ij}^W = I(\|W_i - W_j\| < \epsilon_n)$, $I(\cdot)$ is an indicator function, and ϵ_n is the bandwidth, the estimator of q simplifies to

$$T_n(\epsilon_n) = \frac{n-1}{n(n-2)} \sum_i (\hat{f}_{X,Y,Z}(X_i, Y_i, Z_i) \hat{f}_Y(Y_i) - \hat{f}_{X,Y}(X_i, Y_i) \hat{f}_{Y,Z}(Y_i, Z_i)). \tag{A.7}$$

For a sequence of bandwidths $\epsilon_n = Cn^{-\beta}$, with $C > 0$ and $\beta \in \left(\frac{1}{4}, \frac{1}{3}\right)$, this test statistic satisfies

$$\sqrt{n} \frac{T_n(\epsilon_n) - q}{S_n} \xrightarrow{D} N(0,1), \tag{A.8}$$

where S_n is the asymptotic variance of $T_n(\epsilon_n)$.

To remove any linear dependence, the test in equation (A.8) was applied to the residuals of a VAR model with the pair of variables of interest for each agricultural commodity, that is, spot and futures returns and spot and futures volatility. The tests were performed for different lag values, $l_x = l_y = 1, 2, \ldots, 5$. Following Dicks and Panchenko (2006), the bandwidths were selected according to the time series length and considering a conditional heteroskedastic process with one lag dependence.[14] The test results for the returns and their volatility are presented in Tables 3 and 4. Because nonparametric tests rely on asymptotic theory, causality tests on sample subperiods were not performed in this case.

[13] It is worth mentioning that nonparametric causality tests detect nonlinear causal relationships with high power, but do not provide any guidance regarding the source of the nonlinear dependence. Identifying a specific nonlinear dynamic relationship between spot and futures markets is beyond the scope of the present study.

[14] We actually could not reject, at the 10 percent significance level, the presence of autoregressive conditional heteroskedasticity (ARCH) effects in the residuals of the estimated models for each commodity.

Table A.1. Augmented Dickey–Fuller (ADF) test for unit root

Variable	Corn	Hard Wheat	Soft Wheat	Soybeans
Log spot price	-2.054	-1.354	-1.975	-2.133
Log futures price	-2.269	-1.526	-1.629	-1.748
Spot return	-29.495***	-23.888***	-24.990***	-30.860***
Futures return	-30.609***	-25.824***	-25.542***	-28.496***
Spot volatility	-9.144***	-6.443***	-10.339***	-13.363***
Futures volatility	-10.808***	-15.227***	-15.797***	-8.321***

Source: Authors' estimations.
Notes: The spot (futures) return is the first difference of the log of the spot (futures) price. The spot (futures) volatility is the absolute return deviation from the sample average. The ADF tests include an intercept. The appropriate lag lengths were selected according to the Schwartz Bayesian Criterion (SBC).
*10%, **5%, ***1% significance. ADF t-statistic reported.

Table A.2. Corn: Granger causality tests of weekly returns in spot and futures markets by two-year periods, 1994–2009

# lags	H_0: Futures returns does not Granger-cause spot returns							
	'94–'95	'96–'97	'98–'99	'00–'01	'02–'03	'04–'05	'06–'07	'08–'09s1
1	10.86***	1.06	5.88**	21.07***	57.32***	47.85***	39.38***	65.85***
2	4.14**	10.58***	3.45**	11.32***	30.74***	25.56***	21.95***	52.94***
3	5.04***	7.04***	2.40*	7.28***	23.05***	19.46***	14.07***	34.31***
4	4.44***	5.65***	1.70	5.49***	17.56***	13.39***	11.03***	27.85***
5	3.71***	5.55***	2.36**	4.24***	14.79***	10.75***	8.78***	22.30***
6	3.40***	4.33***	2.15*	3.89***	13.56***	8.90***	7.45***	18.77***
7	2.60**	4.57***	1.83*	3.98***	11.67***	7.80***	6.82***	15.88***
8	2.33**	4.96***	1.54	3.69***	10.27***	7.09***	6.09***	15.68***
9	2.25**	4.75***	1.48	3.59***	9.82***	6.24***	5.36***	14.90***
10	1.98**	4.66***	1.39	3.23***	9.37***	5.67***	5.01***	13.27***
	H_0: Spot returns does not Granger-cause futures returns							
	'94–'95	'96–'97	'98–'99	'00–'01	'02–'03	'04–'05	'06–'07	'08–'09s1
1	0.80	7.95***	0.90	2.77*	0.66	6.06**	2.05	0.48
2	0.75	3.76**	0.58	1.84	0.01	3.72**	1.43	0.83
3	1.57	3.11**	0.29	2.82**	0.04	3.14**	1.03	0.53
4	1.36	2.32*	0.51	4.15***	0.12	2.32*	0.56	2.00*
5	1.12	2.19*	0.76	3.20***	0.45	2.25*	0.44	1.98*
6	0.77	1.79	0.73	3.50***	0.64	1.72	0.40	1.67
7	0.72	1.35	0.76	3.26***	0.72	1.79*	0.44	1.38
8	0.65	1.38	0.73	2.78***	0.86	1.37	0.40	1.46
9	0.96	0.93	0.91	2.41**	0.76	1.24	0.35	1.29
10	1.03	1.05	0.82	2.14**	1.14	1.29	0.56	1.30

Source: Authors' estimations.
Notes: The Schwartz Bayesian Criterion (SBC) suggests a lag structure of 2, whereas the Akaike Information Criterion (AIC) suggests a lag structure of 8.
H_0 = null hypothesis. s = semester.
*10%, **5%, ***1% significance. F-statistic reported.

Table A.3. Hard wheat: Granger causality tests of weekly returns in spot and futures markets by two-year periods, 1998–2009

# lags	H0: Futures returns does not Granger-cause spot returns					
	'98–'99	'00–'01	'02–'03	'04–'05	'06–'07	'08–'09s1
1	63.71***	31.47***	69.23***	30.98***	54.23***	26.03***
2	42.18***	32.67***	40.82***	15.71***	47.27***	20.73***
3	31.91***	21.06***	28.38***	10.18***	32.36***	18.96***
4	25.47***	15.85***	20.70***	7.93***	23.86***	14.97***
5	21.23***	13.62***	17.21***	6.17***	18.63***	11.47***
6	17.02***	10.87***	14.05***	6.71***	15.99***	9.81***
7	15.44***	10.60***	12.47***	6.11***	13.71***	7.72***
8	14.57***	10.59***	11.14***	5.36***	11.96***	7.47***
9	13.19***	9.90***	9.84***	4.55***	10.44***	6.79***
10	12.09***	8.75***	8.65***	4.79***	9.26***	6.11***
	H0: Spot returns does not Granger-cause futures returns					
	'98–'99	'00–'01	'02–'03	'04–'05	'06–'07	'08–'09s1
1	0.13	4.43**	1.20	0.78	0.39	0.51
2	0.10	1.24	0.60	1.41	0.26	0.02
3	1.47	0.47	0.28	0.24	0.35	0.22
4	0.60	0.56	0.06	0.17	0.07	1.22
5	0.74	1.33	0.59	0.26	0.57	1.66
6	0.47	0.53	0.90	1.61	0.38	1.41
7	0.43	0.67	0.67	1.47	0.55	1.16
8	1.11	0.69	0.57	1.47	0.45	1.05
9	0.71	0.73	0.52	1.30	0.53	0.83
10	0.68	0.72	0.52	1.18	0.53	0.83

Source: Authors' estimations.
Notes: Both the Schwartz Bayesian Criterion (SBC) and the Akaike Information Criterion (AIC) suggest a lag structure of 3. H_0 = null hypothesis. s = semester.
*10%, **5%, ***1% significance. F-statistic reported.

Table A.4. Soft wheat: Granger causality tests of weekly returns in spot and futures markets by two-year periods, 1998–2009

# lags	H0: Futures returns does not Granger-cause spot returns					
	'98–'99	'00–'01	'02–'03	'04–'05	'06–'07	'08–'09s1
1	15.82***	14.19***	48.39***	29.32***	63.17***	16.58***
2	9.10***	9.08***	28.97***	15.77***	38.93***	11.01***
3	6.35***	5.89***	24.90***	10.50***	25.99***	9.24***
4	5.74***	4.59***	19.21***	8.08***	19.36***	7.82***
5	6.14***	3.64***	14.65***	6.92***	15.51***	5.98***
6	5.15***	3.13***	11.89***	6.15***	12.77***	5.15***
7	4.79***	3.12***	10.05***	6.21***	10.98***	4.34***
8	4.14***	2.80***	8.93***	5.31***	9.53***	4.16***
9	3.64***	2.41**	7.86***	5.08***	8.28***	4.20***
10	3.28***	1.92**	7.08***	4.62***	7.33***	3.74***
	H0: Spot returns does not Granger-cause futures returns					
	'98–'99	'00–'01	'02–'03	'04–'05	'06–'07	'08–'09s1
1	0.00	0.11	0.00	0.11	0.02	0.27
2	0.38	0.70	0.45	0.47	1.98	0.01
3	0.85	0.39	1.38	0.26	2.29*	0.36
4	0.32	0.43	1.48	0.19	1.85	1.48
5	0.37	0.50	1.17	0.56	2.23*	1.60
6	0.52	1.05	1.06	0.85	1.86*	1.47
7	0.44	0.82	0.81	0.86	2.01*	1.09
8	0.49	0.72	1.47	1.15	1.74	0.82
9	0.79	0.97	1.36	1.24	1.52	0.72
10	0.55	0.83	1.37	1.04	1.48	0.80

Source: Authors' estimations.
Notes: The Schwartz Bayesian Criterion (SBC) suggests a lag structure of 2, whereas the Akaike Information Criterion (AIC) suggests a lag structure of 4. H_0 = null hypothesis.
s = semester.
*10%, **5%, ***1% significance. F-statistic reported.

Table A.5. Soybeans: Granger causality tests of weekly returns in spot and futures markets by two-year periods, 1994–2009

# lags	H₀: Futures returns does not Granger-cause spot returns							
	'94–'95	'96–'97	'98–'99	'00–'01	'02–'03	'04–'05	'06–'07	'08–'09s1
1	0.01	1.60	0.33	1.29	3.76*	6.62***	0.34	2.42
2	2.42*	1.95	0.58	1.77	2.18	5.52***	0.87	1.73
3	1.77	1.85	0.57	1.71	2.90**	5.86***	0.71	1.43
4	1.31	1.74	0.46	1.21	2.42**	4.88***	0.57	1.01
5	1.12	1.38	2.31*	2.20*	2.53**	4.27***	0.87	0.68
6	1.13	1.13	2.05**	1.92*	2.02*	3.84***	1.26	1.34
7	0.91	1.24	2.08*	1.78*	1.69	3.28***	1.22	1.46
8	0.93	1.27	1.80	1.41	1.99*	3.14***	1.04	1.88*
9	0.79	1.20	1.62	1.24	2.00**	3.54***	0.91	2.00**
10	0.67	1.38	1.40	1.07	1.71*	3.69***	0.91	2.40**
	H₀: Spot returns does not Granger-cause futures returns							
	'94–'95	'96–'97	'98–'99	'00–'01	'02–'03	'04–'05	'06–'07	'08–'09s1
1	0.46	0.04	0.83	0.08	1.03	0.46	4.81**	10.83***
2	2.10	0.12	0.38	0.70	1.06	0.46	2.46*	4.70***
3	1.38	1.07	0.83	0.91	1.54	1.15	1.69	3.88***
4	1.33	1.23	0.71	0.73	1.30	0.84	1.91	3.14**
5	0.99	0.96	1.74	1.27	1.58	0.65	1.88	2.54**
6	1.10	0.82	1.51	1.25	1.31	0.51	2.21**	2.88***
7	0.90	0.67	1.48	1.20	0.99	0.52	2.00*	2.52**
8	1.02	0.63	1.28	1.03	0.94	0.49	1.71	2.86***
9	0.87	0.54	1.09	0.95	1.02	0.53	1.61	2.76***
10	0.73	0.76	0.90	0.85	0.81	0.79	1.76*	2.78***

Source: Authors' estimations.
Notes: The Schwartz Bayesian Criterion (SBC) suggests a lag structure of 3, whereas the Akaike Information Criterion (AIC) suggests a lag structure of 5.
H_0 = null hypothesis. s = semester.
*10%, **5%, ***1% significance. F-statistic reported.

Table A.6. Corn: Granger causality tests of weekly returns in spot and futures markets by Farm Bill, 1994–2009

# lags	H_0: Futures returns does not Granger-cause spot returns			
	'90 Farm Bill	'96 Farm Bill	'02 Farm Bill	'08 Farm Bill
1	13.27***	5.74**	133.52***	53.59***
2	5.13***	12.16***	74.61***	49.29***
3	5.09***	7.50***	51.40***	31.40***
4	4.13***	6.32***	39.60***	26.13***
5	3.49***	6.60***	32.40***	19.68***
6	3.27***	5.24***	27.01***	16.86***
7	2.42**	4.67***	23.90***	14.30***
8	2.11**	4.65***	21.00***	13.68***
9	2.03**	4.39***	18.48***	13.92***
10	1.77*	3.93***	16.31***	12.71***
	H_0: Spot returns does not Granger-cause futures returns			
	'90 Farm Bill	'96 Farm Bill	'02 Farm Bill	'08 Farm Bill
1	1.83	11.25***	0.01	0.42
2	1.39	4.77***	1.47	1.37
3	1.82	3.60***	1.25	0.59
4	1.37	3.46***	0.68	2.12*
5	1.06	2.90***	1.08	1.12
6	0.84	2.33**	1.16	0.91
7	0.80	2.56***	1.16	0.79
8	0.75	2.61***	0.99	0.94
9	1.27	2.07**	0.90	0.92
10	1.18	1.93**	0.85	0.74

Source: Authors' estimations.
Notes: The Schwartz Bayesian Criterion (SBC) suggests a lag structure of 2, wheras the Akaike Information Criterion (AIC) suggests a lag structure of 8. The 1990 Farm Bill corresponds to the sample period 01/07/94–04/03/96; the 1996 Farm Bill, to the sample period 04/04/96–05/12/02; the 2002 Farm Bill, to the sample period 05/13/02–06/17/08; and the 2008 Farm Bill, to the sample period 06/18/08–06/26/09. H_0 = null hypothesis.
*10%, **5%, ***1% significance. F-statistic reported.

Table A.7. Hard wheat: Granger causality tests of weekly returns in spot and futures markets by Farm Bill, 1998–2009

# lags	H_0: Futures returns does not Granger-cause spot returns		
	'96 Farm Bill	'02 Farm Bill	'08 Farm Bill
1	97.83***	121.18***	31.97***
2	77.08***	83.08***	26.39***
3	54.29***	58.71***	20.93***
4	42.47***	43.92***	23.27***
5	36.06***	34.80***	18.94***
6	29.84***	28.86***	14.33***
7	27.93***	24.64***	11.10***
8	25.78***	21.65***	11.37***
9	23.49***	19.42***	14.66***
10	20.92***	18.54***	12.48***
	H_0: Spot returns does not Granger-cause futures returns		
	'96 Farm Bill	'02 Farm Bill	'08 Farm Bill
1	1.60	2.53	0.85
2	0.62	0.76	2.08
3	0.94	0.46	1.25
4	0.54	0.52	3.17**
5	0.73	0.56	2.80**
6	0.45	0.42	2.40**
7	0.43	0.71	2.23**
8	0.54	0.56	2.59**
9	0.39	0.71	2.38**
10	0.41	1.06	2.03*

Source: Authors' estimations.
Notes: Both the Schwartz Bayesian Criterion (SBC) and the Akaike Information Criterion (AIC) suggest a lag structure of 3. The 1996 Farm Bill corresponds to the sample period 01/02/98–05/12/02; the 2002 Farm Bill, to the sample period 05/13/02–06/17/08; and the 2008 Farm Bill, to the sample period 06/18/08–06/26/09. H_0 = null hypothesis.
*10%, **5%, ***1% significance. F-statistic reported.

Table A.8. Soft wheat: Granger causality tests of weekly returns in spot and futures markets by Farm Bill, 1998–2009

# lags	H_0: Futures returns does not Granger-cause spot returns		
	'96 Farm Bill	'02 Farm Bill	'08 Farm Bill
1	33.98***	103.52***	21.63***
2	20.91***	63.78***	16.79***
3	14.55***	43.93***	12.25***
4	11.07***	33.65***	14.57***
5	9.53***	26.90***	10.69***
6	8.05***	22.34***	9.20***
7	7.87***	19.34***	6.95***
8	7.21***	17.52***	6.35***
9	6.33***	15.60***	7.67***
10	5.38***	14.39***	6.57***
	H_0: Spot returns does not Granger-cause futures returns		
	'96 Farm Bill	'02 Farm Bill	'08 Farm Bill
1	0.15	0.01	2.11
2	0.53	1.50	1.16
3	0.08	0.91	0.95
4	0.31	1.09	3.35**
5	0.33	0.99	2.62**
6	0.65	1.04	2.37**
7	0.59	1.22	2.00*
8	0.51	1.08	1.83*
9	1.20	0.98	2.07*
10	0.95	0.91	2.25**

Source: Authors' estimations.
Notes: The Schwartz Bayesian Criterion (SBC) suggests a lag structure of 2, whereas the Akaike Information Criterion (AIC) suggests a lag structure of 4. The 1996 Farm Bill corresponds to the sample period 01/02/98–05/12/02; the 2002 Farm Bill, to the sample period 05/13/02–06/17/08; and the 2008 Farm Bill, to the sample period 06/18/08–06/26/09. H_0 = null hypothesis. *10%, **5%, ***1% significance. F-statistic reported.

Table A.9. Soybeans: Granger causality tests of weekly returns in spot and futures markets by Farm Bill, 1994–2009

# lags	H_0: Futures returns does not Granger-cause spot returns			
	'90 Farm Bill	'96 Farm Bill	'02 Farm Bill	'08 Farm Bill
1	0.03	3.07*	13.08***	2.67
2	2.41*	4.12**	12.05***	2.20
3	1.77	3.96***	12.58***	1.69
4	1.31	3.34***	10.53***	1.15
5	1.07	3.65***	9.37***	0.91
6	1.20	3.02***	8.19***	0.99
7	0.97	3.11***	7.35***	1.02
8	0.94	2.82***	6.93***	1.27
9	0.79	2.91***	6.83***	1.25
10	0.66	2.78***	6.87***	1.47
	H_0: Spot returns does not Granger-cause futures returns			
	'90 Farm Bill	'96 Farm Bill	'02 Farm Bill	'08 Farm Bill
1	0.06	0.16	0.03	9.29***
2	1.39	0.14	0.51	3.93**
3	0.89	2.07	1.45	3.54**
4	1.02	1.97	1.09	2.66**
5	0.77	2.06*	0.87	2.25*
6	1.08	1.67	0.75	2.15*
7	0.89	1.63	0.72	1.97*
8	0.98	1.41	0.74	2.24**
9	0.88	1.20	0.77	2.00*
10	0.73	1.26	0.97	2.10**

Source: Authors' estimations.
Notes: The Schwartz Bayesian Criterion (SBC) suggests a lag structure of 3, whereas the Akaike Information Criterion (AIC) suggests a lag structure of 5. The 1990 Farm Bill corresponds to the sample period 01/07/94– 04/03/96; the 1996 Farm Bill, to the sample period 04/04/96–05/12/02; the 2002 Farm Bill, to the sample period 05/13/02–06/17/08; and the 2008 Farm Bill, to the sample period 06/18/08–06/26/09.
H_0 = null hypothesis.
*10%, **5%, ***1% significance. F-statistic reported

Table A.10. Corn: Granger causality tests of weekly volatility in spot and futures markets by two-year periods, 1994–2009

# lags	'94–'95	'96–'97	'98–'99	'00–'01	'02–'03	'04–'05	'06–'07	'08–'09s1
	H_0: Futures volatility does not Granger-cause spot volatility							
1	10.72***	2.86*	0.01	0.98	20.62***	6.47***	17.63***	21.35***
2	6.06***	6.65***	3.15**	0.66	10.00***	4.28**	9.35***	11.15***
3	4.60***	4.93***	1.98	0.91	7.09***	3.40**	6.61***	7.30***
4	2.64**	3.94***	1.52	0.71	7.09***	2.30*	5.57***	5.60***
5	1.99*	2.93**	1.33	0.94	5.96***	2.19*	4.62***	3.70***
6	1.42	3.97***	1.10	0.79	4.34***	3.40***	4.47***	3.87***
7	1.33	3.54***	1.43	0.73	3.71***	3.29***	3.75***	3.26***
8	1.26	4.25***	1.37	0.71	3.28***	2.79***	3.45***	3.48***
9	1.20	4.10***	1.32	1.01	2.53***	2.52***	3.05***	3.60***
10	1.11	4.28***	1.20	1.03	2.77***	2.24**	3.66***	3.11***
	H_0: Spot volatility does not Granger-cause futures volatility							
	'94–'95	'96–'97	'98–'99	'00–'01	'02–'03	'04–'05	'06–'07	'08–'09s1
1	1.09	1.29	7.61***	0.28	1.12	0.37	0.46	0.35
2	2.55*	0.75	3.31**	0.18	0.04	0.39	0.30	0.25
3	4.36***	1.09	1.88	0.62	0.13	0.46	0.45	0.42
4	4.70***	0.84	2.48**	1.02	0.22	0.23	0.24	1.79
5	3.56***	0.75	2.52**	0.83	0.10	0.24	0.22	1.63
6	3.10***	0.92	2.66**	0.82	0.14	0.28	0.35	1.58
7	2.46**	1.33	2.36**	0.89	0.72	0.25	0.28	1.78
8	2.05**	1.38	2.03**	0.88	1.05	0.35	0.22	1.78*
9	1.97**	1.34	1.71*	1.02	1.00	0.77	0.31	1.78*
10	2.08**	1.33	1.52	0.89	1.05	0.74	0.36	1.51

Source: Authors' estimations.
Notes: Volatility measured as absolute deviations of weekly spot and futures returns from the sample average. The Schwartz Bayesian Criterion (SBC) suggests a lag structure of 2, whereas the Akaike Information Criterion (AIC) suggests a lag structure of 10. H_0 = null hypothesis. s = semester.
*10%, **5%, ***1% significance. F-statistic reported.

Table A.11. Hard wheat: Granger causality tests of weekly volatility in spot and futures markets by two-year periods, 1998–2009

# lags	H0: Futures volatility does not Granger-cause spot volatility					
	'98–'99	'00–'01	'02–'03	'04–'05	'06–'07	'08–'09s1
1	6.00**	0.78	22.53***	0.02	9.37***	0.29
2	2.98*	0.81	13.79***	0.07	6.66***	2.01
3	2.13*	1.85	8.93***	0.13	4.83***	2.92**
4	2.04*	1.98*	7.23***	1.49	3.72***	2.12*
5	3.89***	1.57	6.09***	1.27	3.51***	1.64
6	3.37***	1.65	4.92***	1.09	2.97***	1.35
7	2.68***	1.54	3.81***	0.95	2.42**	0.95
8	2.44**	1.32	3.29***	0.77	2.13**	1.15
9	2.26**	1.28	2.49***	1.06	2.29**	1.10
10	1.96**	1.17	2.51***	1.08	2.09**	1.51
	H0: Spot volatility does not Granger-cause futures volatility					
	'98–'99	'00–'01	'02–'03	'04–'05	'06–'07	'08–'09s1
1	0.17	0.85	0.15	0.13	1.45	0.14
2	0.11	0.50	0.15	0.08	1.03	0.21
3	0.70	0.47	1.93	0.09	5.02***	1.63
4	0.63	0.60	2.55**	0.40	3.04**	2.02*
5	0.52	0.47	2.97**	0.84	3.00***	1.62
6	0.96	0.88	2.44**	0.69	2.78**	1.38
7	0.74	0.96	2.17**	1.09	2.67***	1.33
8	0.64	0.66	3.30***	0.96	2.57***	1.12
9	0.66	0.79	2.47***	0.76	2.70***	1.02
10	0.58	0.78	2.50***	0.70	2.68***	1.46

Source: Authors' estimations.
Notes: Volatility measured as absolute deviations of weekly spot and futures returns from the sample average. The Schwartz Bayesian Criterion (SBC) suggests a lag structure of 1, whereas the Akaike Information Criterion (AIC) suggests a lag structure of 10. H_0 = null hypothesis. s = semester.
*10%, **5%, ***1% significance. F-statistic reported.

Table A.12. Soft wheat: Granger causality tests of weekly volatility in spot and futures markets by two-year periods, 1998–2009

# lags	H0: Futures volatility does not Granger-cause spot volatility					
	'98–'99	'00–'01	'02–'03	'04–'05	'06–'07	'08–'09s1
1	3.81**	6.73***	6.02**	2.15	3.93**	0.19
2	2.01	4.66***	3.07**	0.88	2.28	0.43
3	1.39	3.80***	2.38*	1.07	1.62	0.42
4	0.97	2.93**	1.80	2.65**	1.30	0.32
5	2.40**	2.17*	1.78	1.94*	1.01	0.44
6	2.05*	1.86*	1.47	1.76	0.83	0.81
7	1.74	1.38	1.27	1.60	0.80	1.35
8	1.39	1.30	1.17	1.29	0.83	1.47
9	1.22	1.61	1.07	1.25	1.31	1.58
10	1.11	1.52	0.89	1.60	1.33	1.78*
	H0: Spot volatility does not Granger-cause futures volatility					
	'98–'99	'00–'01	'02–'03	'04–'05	'06–'07	'08–'09s1
1	0.00	0.14	1.13	3.54*	1.06	1.24
2	0.60	0.43	0.40	1.75	0.78	0.61
3	0.75	0.56	0.50	1.15	1.34	0.58
4	0.62	0.97	0.48	0.90	0.79	1.18
5	0.62	1.21	0.41	1.55	0.65	0.86
6	0.71	0.99	0.68	1.28	0.54	0.77
7	0.78	0.84	0.52	1.14	0.47	0.80
8	0.83	0.89	0.71	1.12	0.44	0.96
9	1.42	0.78	0.91	1.01	0.45	0.89
10	1.30	0.69	0.69	1.12	0.42	1.29

Source: Authors' estimations.
Notes: Volatility measured as absolute deviations of weekly spot and futures returns from the sample average. The Schwartz Bayesian Criterion (SBC) suggests a lag structure of 1, whereas the Akaike Information Criterion (AIC) suggests a lag structure of 2. H_0 = null hypothesis. s = semester.
*10%, **5%, ***1% significance. F-statistic reported.

Table A.13. Soybeans: Granger causality tests of weekly volatility in spot and futures markets by 2-year periods, 1994–2009

# lags	H0: Futures volatility does not Granger-cause spot volatility							
	'94–'95	'96–'97	'98–'99	'00–'01	'02–'03	'04–'05	'06–'07	'08–'09s1
1	0.66	5.27**	1.15	6.88***	0.03	5.66**	0.03	0.29
2	3.00**	5.91***	1.96	5.63***	1.27	4.66***	0.19	0.65
3	1.91	4.09***	1.24	4.74***	1.24	4.43***	0.39	0.38
4	2.79**	2.79**	1.27	3.49***	0.70	3.28***	0.55	0.26
5	2.56**	2.31**	1.17	3.53***	0.42	3.58***	0.43	0.26
6	2.22**	4.39***	1.10	2.84***	0.35	2.93***	0.39	0.27
7	1.91*	3.78***	0.97	2.80***	0.66	2.51**	0.41	0.23
8	1.71	3.28***	1.25	2.42**	1.08	2.25**	0.34	0.19
9	1.48	2.84***	1.12	2.28**	0.92	2.98***	0.31	0.28
10	1.29	2.89***	0.96	2.10**	0.87	3.84***	0.34	0.30
	H0: Spot volatility does not Granger-cause futures volatility							
	'94–'95	'96–'97	'98–'99	'00–'01	'02–'03	'04–'05	'06–'07	'08–'09s1
1	0.01	0.51	0.22	1.64	0.38	0.13	0.52	0.18
2	4.90***	0.68	0.72	1.30	1.71	0.40	0.30	0.07
3	3.18**	0.34	0.42	1.80	1.21	0.23	0.49	0.39
4	3.55***	1.05	0.43	1.42	1.16	0.24	0.59	0.38
5	3.37***	0.82	0.46	1.47	1.08	0.46	0.70	0.30
6	3.21***	0.85	0.39	1.18	0.96	0.48	0.64	0.44
7	2.77***	0.80	0.33	1.57	1.11	0.51	0.56	0.38
8	2.39**	0.85	0.58	1.46	1.07	0.56	0.61	0.33
9	2.03**	0.82	0.62	1.51	0.96	1.00	0.54	0.51
10	1.75*	0.78	0.73	1.30	0.95	0.97	0.51	0.48

Source: Authors' estimations.
Notes: Volatility measured as absolute deviations of weekly spot and futures returns from the sample average. The Schwartz Bayesian Criterion (SBC) suggests a lag structure of 2, whereas the Akaike Information Criterion(AIC) suggests a lag structure of 5. H_0 = null hypothesis. s = semester.
*10%, **5%, ***1% significance. F-statistic reported.

Table A.14. Corn: Granger causality tests of weekly volatility in spot and futures markets by Farm Bill, 1994–2009

# lags	H₀: Futures volatility does not Granger-cause spot volatility			
	'90 Farm Bill	'96 Farm Bill	'02 Farm Bill	'08 Farm Bill
1	8.47***	5.58**	44.60***	16.94***
2	4.89***	8.73***	23.17***	9.22***
3	3.93***	6.15***	15.30***	5.89***
4	2.32*	4.50***	12.18***	4.47***
5	1.75	3.45***	10.48***	3.17**
6	1.34	4.38***	10.30***	3.10***
7	1.15	3.75***	8.95***	2.85**
8	1.04	3.52***	7.79***	3.01***
9	1.05	3.30***	6.87***	2.84***
10	1.13	3.39***	7.76***	2.49**
	H_0: Spot volatility does not Granger-cause futures volatility			
	'90 Farm Bill	'96 Farm Bill	'02 Farm Bill	'08 Farm Bill
1	1.85	1.01	0.13	0.00
2	2.76*	0.36	0.30	0.08
3	3.76***	0.22	0.15	0.68
4	3.97***	1.46	0.13	1.19
5	2.99***	1.12	0.14	1.33
6	2.48**	1.39	0.23	1.20
7	2.20**	1.47	0.25	1.06
8	1.95*	1.31	0.33	1.06
9	1.86*	1.18	0.78	1.17
10	2.04**	1.03	0.87	0.97

Source: Authors' estimations.
Notes: Volatility measured as absolute deviations of weekly spot and futures returns from the sample average. The Schwartz Bayesian Criterion (SBC) suggests a lag structure of 2, whereas the Akaike Information Criterion (AIC) suggests a lag structure of 10. The 1990 Farm Bill corresponds to the sample period 01/07/94–04/03/96; the 1996 Farm Bill, to the sample period 04/04/96–05/12/02; the 2002 Farm Bill, to the sample period 05/13/02–06/17/08; and the 2008 Farm Bill, to the sample period 06/18/08–06/26/09. H_0 = null hypothesis.
*10%, **5%, ***1% significance. F-statistic reported.

Table A.15. Hard wheat: Granger causality tests of weekly volatility in spot and futures markets by Farm Bill, 1998–2009

# lags	H_0: Futures volatility does not Granger-cause spot volatility		
	'96 Farm Bill	'02 Farm Bill	'08 Farm Bill
1	6.14***	16.55***	1.51
2	3.21**	13.96***	0.78
3	2.71**	11.47***	0.51
4	2.68**	8.18***	0.74
5	3.59***	6.41***	0.68
6	3.03***	5.55***	0.63
7	2.77***	4.22***	0.62
8	2.48***	4.00***	0.71
9	2.42***	3.53***	0.74
10	2.13**	3.40***	1.51
	H_0: Spot volatility does not Granger-cause futures volatility		
	'96 Farm Bill	'02 Farm Bill	'08 Farm Bill
1	0.31	2.22	0.11
2	0.58	1.30	0.19
3	0.74	8.63***	0.21
4	0.93	7.13***	0.24
5	0.88	7.25***	0.61
6	1.10	6.19***	0.54
7	1.03	5.36***	0.49
8	1.05	4.77***	0.42
9	1.13	4.18***	0.4
10	1.10	4.31***	1.07

Source: Authors' estimations.
Notes: Volatility measured as absolute deviations of weekly spot and futures returns from the sample average. The Schwartz Bayesian Criterion (SBC) suggests a lag structure of 1, whereas the Akaike Information Criterion (AIC) suggests a lag structure of 10. The 1996 Farm Bill corresponds to the sample period 01/02/98–05/12/02; the 2002 Farm Bill to the sample period 05/13/02–06/17/08; and the 2008 Farm Bill to the sample period 06/18/08–06/26/09. H_0 = null hypothesis.
*10%, **5%, ***1% significance. F-statistic reported.

Table A.16. Soft wheat: Granger causality tests of weekly volatility in spot and futures markets by Farm Bill, 1998–2009

# lags	H_0: Futures volatility does not Granger-cause spot volatility		
	'96 Farm Bill	'02 Farm Bill	'08 Farm Bill
1	10.58***	3.19*	0.39
2	5.84***	1.12	0.22
3	5.12***	0.86	0.15
4	3.70***	0.60	0.79
5	3.64***	0.57	1.36
6	3.27***	0.84	1.19
7	2.63***	0.81	1.28
8	2.41**	0.83	1.61
9	2.22**	0.77	1.45
10	1.88**	0.72	1.59
	H_0: Spot volatility does not Granger-cause futures volatility		
	'96 Farm Bill	'02 Farm Bill	'08 Farm Bill
1	0.07	10.52***	0.45
2	1.00	6.07***	0.34
3	0.91	5.70***	0.23
4	0.97	4.66***	0.16
5	0.92	3.91***	0.14
6	1.30	3.25***	0.36
7	1.38	2.89***	0.33
8	1.26	2.52***	0.27
9	1.50	2.11**	0.39
10	1.40	2.03**	0.95

Source: Authors' estimations.
Notes: Volatility measured as absolute deviations of weekly spot and futures returns from the sample average. The Schwartz Bayesian Criterion (SBC) suggests a lag structure of 1, whereas the Akaike Information Criterion (AIC) suggests a lag structure of 2. The 1996 Farm Bill corresponds to the sample period 01/02/98–05/12/02; the 2002 Farm Bill, to the sample period 05/13/02–06/17/08; and the 2008 Farm Bill, to the sample period 06/18/08–06/26/09. H_0 = null hypothesis.
*10%, **5%, ***1% significance. F-statistic reported.

Table A.17. Soybeans: Granger causality tests of weekly volatility in spot and futures markets by Farm Bill, 1994–2009

# lags	H0: Futures volatility does not Granger-cause spot volatility			
	'90 Farm Bill	'96 Farm Bill	'02 Farm Bill	'08 Farm Bill
1	0.65	1.19	4.48**	0.05
2	2.31*	0.73	5.96***	1.72
3	1.48	0.75	4.95***	1.15
4	2.16*	0.51	4.00***	0.89
5	1.95*	0.56	3.65***	0.69
6	1.69	1.28	3.01***	0.78
7	1.45	1.44	2.58***	0.75
8	1.36	1.39	2.52***	0.67
9	1.17	1.32	2.71***	0.70
10	1.00	1.44	3.32***	0.66
	H0: Spot volatility does not Granger-cause futures volatility			
	'90 Farm Bill	'96 Farm Bill	'02 Farm Bill	'08 Farm Bill
1	0.00	0.05	0.00	1.88
2	4.21**	2.45*	0.12	1.70
3	2.80**	1.85	0.05	2.20*
4	3.16**	1.40	0.09	1.64
5	2.83**	1.13	0.37	1.28
6	2.73**	1.01	0.41	1.41
7	2.33**	1.09	0.50	1.48
8	2.10**	1.30	0.61	1.28
9	1.87*	1.18	1.73*	1.33
10	1.61	1.32	1.56	1.38

Source: Authors' estimations.
Notes: Volatility measured as absolute deviations of weekly spot and futures returns from the sample average. The Schwartz Bayesian Criterion (SBC) suggests a lag structure of 2, whereas the Akaike Information Criterion (AIC) suggests a lag structure of 5. The 1990 Farm Bill corresponds to the sample period 01/07/94–04/03/96; the 1996 Farm Bill, to the sample period 04/04/96–05/12/02; the 2002 Farm Bill, to the sample period 05/13/02–06/17/08; and the 2008 Farm Bill, to the sample period 06/18/08–06/26/09.
*10%, **5%, ***1% significance. F-statistic reported.

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