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Market Inversion in Commodity Futures Prices

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In an inverted market, current prices are higher than future prices and thus the price of storage is negative. Market inversions as measured with futures spreads rarely occur during early months of the crop year. However, market inversions frequently occur across crop years and near the end of the crop year. In the last half of the crop year, market inversions clearly reflect a signal to sell stocks. Too few inversions occur early in the crop year to reach a definitive conclusion for that period. Behavioral finance offers possible explanations of why producers would hold stocks in an inverted market.

Key Words: convenience yield, cost of carry, market inversion

JEL Classification: Q13

A principal theory of futures markets tells that futures prices for storable commodities should be higher than spot prices by not more than the carrying charges. Carrying charges represent the cost of storage, primarily warehousing and insurance cost plus interest foregone. If the spot price is too low relative to the futures price, a cash-and-carry arbitrage opportunity arises and the trader who engages in arbitrage reaps a riskless profit. Thus, in a normal market, a futures price spread is limited by arbitrage to the full cost of carry.

However, this theory is not always supported by empirical evidence. A puzzling phenomenon in actual commodity markets is that processors and merchandisers routinely hold inventories in the face of inverse carrying charges. In an inverted market, a commodity's price for future delivery is below the price for immediate delivery and intertemporal arbitrage conditions fail to apply. Under market inversion, because the price spread in futures markets fails to cover commodity-holding costs, stockholders apparently gain negative returns to storage.

This aspect of commodity markets was first noticed by Working (1934) while studying the price relationships between old- and new-crop wheat futures at Chicago. He observed that nationwide wheat stocks are held even when the intertemporal spread (price of storage) is inverted and argued that the price of storage depends on the aggregate level of stocks. Later, Working's findings were represented by the supply-of-storage curve, which shows that, the farther the spot/futures spreads are below full carrying charges, the less stocks are held.

Traditionally, there were two major theories explaining the phenomenon of market inversion. The risk premium theory of Keynes holds that speculators must be compensated for taking risks in the form of a risk premium. In markets where speculators are predominantly short, the futures price is biased downward relative to the expected future spot price by the amount of a risk premium. According

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to Keynes, the futures price should rise over time to equal the expected future spot price at expiration. On the other hand, the convenience yield theory, first employed by Kaldor, maintains that, when processors and merchandisers hold stocks readily available at hand, they receive benefits that do not accrue to the holders of futures contracts.

Recently, alternative explanations for market inversions have been suggested, notably in articles by Wright and Williams; Benirschka and Binkley; and Brennan, Williams, and Wright. According to their view, the apparent relationship between market inversions and return to storage is caused by mismeasurement. Wright and Williams, and Brennan, Williams, and Wright argue that market inversions may occur when the stocks of very similar but economically distinct commodities in terms of grade or location are aggregated into a composite, while the prices for the commodities are represented by a single price. Brennan, Williams, and Wright also suggest that the market inversion may be caused by the probability of a stock out. Benirschka and Binkley argue that "storage at a loss" illusion exists because the opportunity costs of storage are overestimated by using grain prices at the central market, not at the storage locations. Frechette and Fackler examined Benirschka and Binkley's proposition, i.e., the location of stocks matters in the intertemporal price relationships of storable commodities for the U.S. corn market and found mixed empirical support.

A market inversion appears to be a situation where the market is begging producers to sell, yet many continue to store their stocks. Hurt argues that a market inversion is indeed a signal to sell. Behavioral finance (Kahneman and Riepe; Kahneman, Slovic, and Tversky) offers explanations for why producers choose to hold excess stocks when the market is inverted.

The studies cited above rationalize the market inversion well but have not provided measurements of the frequency of market inversions or evaluated marketing strategies based on market inversions. The primary objective of the study is to determine whether inverted commodity futures markets are a signal for producers to sell. First, the frequency of market inversions in corn, soybeans, and wheat markets will be determined by comparing nearby futures price spreads with the contemporaneous costs-of-carry. Then regression analysis will be used to determine the situations in which the market inversions occur. Finally, simulations will be conducted to see if inverted markets are a signal for producers to sell.

Theory

Market inversion describes a market situation in which the spot price exceeds the futures price or a nearby futures price exceeds a distant futures price. The theory of the price of storage, which explains intertemporal price relationships between spot and futures with respect to the cost of carrying a commodity, was first proposed by Kaldor. Following Kaldor, Working (1948, 1949); Brennan (1958, 1991); Telser; Fama and French (1987, 1988); Williams and Wright; and Deaton and Laroque (1992, 1996) have elaborated on the theory of storage.

The theory of the price of storage incorporates the main arguments from the convenience yield and risk premium theories. It explains the price difference between spot and futures in terms of interest foregone in storing a commodity (the opportunity cost of storage), physical storage costs, risk premium, and convenience yield for holding stocks. Let $F(t, T)$ be the futures price at time t for delivery of a commodity at time T; $S(t)$ be the spot price at time t; $S(t)R(t, T)$ be the interest foregone during storage; $W(t, T)$ be the physical storage costs; $P(t, T)$ be the risk premium; and $C(t, T)$ be the convenience yield. Then the price of storage (basis), $F(t, T) - S(t)$, is defined as

$$(1) \quad F(t, T) - S(t) = S(t)R(t, T) + W(t, T) + P(t, T) - C(t, T).$$

The price of storage or basis, $F(t, T) - S(t)$, can be interpreted as the return to storage from time period t to T $(t < T)$, i.e., the return from purchasing the commodity at t and selling it for delivery at T. The interest foregone, $S(t)R(t, T)$, is the opportunity cost of holding stocks, i.e., the opportunity cost of investing cash in the commodity stock now rather than using a futures contract. The physical cost of storage, $W(t, T)$ is the sum of rent for storage space, handling or in-and-out charges, insurance, transport, etc. The physical cost of storage increases with the quantity of stocks held by a firm. However, the marginal physical cost of storage for an additional unit of stocks is approximately constant for a wide range of stocks less than total storage capacity. Beyond the level at which the total storage capacity is almost fully utilized, the marginal physical cost of storage will rise sharply because of the large fixed costs required to construct additional storage facilities.

The risk premium is a compensation for the risk of monetary loss on the stocks held. It is often assumed to be paid in the form of a per unit insurance charge included with $W(t, T)$. Brennan incorporated the risk premium idea of Keynes into the components of the cost of storage. He argued that the market must offer a risk premium to encourage firms to hold stocks. Later, Telser found no evidence of a risk premium separate from the physical cost of storage, meaning that the physical cost of storage $W(t, T)$ also includes the risk premium.

The convenience yield, $C(t, T)$, refers to a stream of implicit benefits that accrues to the owner of a physical stock but not to the owner of a contract for future delivery. Stockholders earn the convenience yield because stocks on hand allow them to respond more flexibly and efficiently to unexpected supply and demand shocks. Where stocks are held, regular customer demands can be met and sudden and unexpected increases in demand can be accommodated without disrupting production schedules. The convenience yield may be thought of as a negative price of storage in that it reflects the benefits rather than the cost of stockholding. These benefits are most significant when stocks are scarce. When stocks are abundant, the marginal convenience yield approaches zero because the scarcity value of stocks is minimal. Empirical evidence presented by Working (1948, 1949), Telser, Fama and French (1987, 1988), and Brennan (1991) also suggests that the convenience yield is a decreasing (convex) function of stocks. It declines with increases in stocks but at a decreasing rate, $\partial C/\partial X < 0$ and $\partial^2 C/\partial X^2 > 0$, where X is the amount of stocks held.

Although the risk premium and convenience yield are not directly observable in equation (1), we maintain them as variables separate from the cost of storage to stress the theory's argument. The theory of the price of storage also applies to the relationships between two futures contracts of different delivery months. First, notice that rational expectations implies $E_t(S(N)) = F(t, N)$; i.e., expectations at time t of the spot price in the nearby future N are given by the price of the nearby futures contract quoted at time t and maturing at time N, $F(t, N)$. Similarly, $E_t(F(N, D)) = F(t, D)$ holds. Also,

$$(1a)\quad F(N, D) - S(N) = S(N)R(N, D) + W(N, D) + P(N, D) - C(N, D)$$

follows directly from equation (1), where $t < N <$ D.

Taking expectations at time t in equation (1a), we obtain that the price of storage or spread between the nearby and distant futures contracts is

$$(2)\quad F(t, D) - F(t, N) = F(t, N)R(N, D) + W(N, D) + P(N, D) - C(N, D), \qquad D > N,$$

where $F(t, D)$ is a distant futures price quoted at time t, maturing at time D, and $F(t, N)$ is a nearby futures price quoted at time t, maturing at time N ($D > N$). Thus, $F(t, D) - F(t, N)$ is the market spread or the return to storage from time period N to D. $F(t, N)R(N, D)$ is the opportunity cost of holding stocks for the period N to D. $W(N, D)$ is the physical costs of storage from time N to D. $P(N, D)$ is the risk premium for holding stocks for the period N to D. $C(N, D)$ is the convenience yield arising from stockholding from time N to D.

When stocks are sufficiently low, the theory of the price of storage predicts a negative price of storage (negative spread) or market inversion because the convenience yield overwhelms the sum of interest foregone, storage costs, and risk premium. On the other hand, if the stock levels are sufficiently high, the convenience yield is negligible and the price of storage (spread) is essentially the sum of interest foregone, storage costs, and risk premium. Here, one testable hypothesis generated by the theory of the price of storage is that markets will be inverted when stocks are low.

When markets are inverted, a negative price of storage (negative spread) can be interpreted as a market signal that encourages firms to release their stocks into consumption channels. Under market inversion, it is best for stockholders to sell their stocks now because storage only occurs at a very high opportunity cost. Another testable hypothesis from this argument is that producers will receive the highest expected returns by selling stocks rather than storing when markets are inverted.

The theory of the price of storage can explain why processors and livestock feeders would hold stocks even when the price of storage is negative. But the theory cannot explain why grain producers would continue to hold stocks when the price of storage is negative. Behavioral finance theory (Kahneman and Riepe) offers a possible explanation. The three aspects of behavioral finance that offer possible explanations are anchoring, overconfidence, and regret.

Anchoring occurs when a producer is reluctant to revise long-held opinions in the face of new information (Brorsen and Anderson). For example, a producer may follow a strategy of storing corn on a farm and selling after the new crop is planted, regardless of market signals. In a short-crop year, even a small portion of farmers anchored to a fixed strategy could cause a market inversion.

Overconfidence refers to the natural tendency of people to overestimate their own abilities. Both Eales et al. and Kenyon have confirmed that farmers greatly overestimate the accuracy of their own price forecasts. Thus, farmers may hold stocks because they expect higher prices and incorrectly believe that their price expectations are more accurate than the market's price expectations.

The regret from having made a mistake is a dominant human emotion. The regret from an action is much greater than the regret from inaction. Selling grain in response to market signals is an action, so selling and having the price go up would generate more regret than not selling and having the price go down.

When the grain is stored on the farm, there will be a cost of delivering the grain. This cost, which may differ greatly by individual, could cause the producer to not sell in an inverted market and still remain rational. For example, scarce labor may be better allocated to other activities such as livestock enterprises, corn planting, or a vacation in Florida. There could be a physical constraint such as snow, mud, or the producer's truck needing repair. If an individual's storage cost was low, government loan programs could provide an incentive to store because, by selling, the producer would be giving up the real option value implicit in a loan program. The point is that some individuals may choose not to sell in an inverted market because of behavioral reasons, but others may have economic reasons.

Data

The agricultural commodities selected for the analysis of market inversion in futures prices are corn, soybeans, and wheat. Futures prices from the Chicago Board of Trade are obtained from the *Annual Report of the Board of Trade of the City of Chicago* and from a computer database compiled by Technical Tools, Inc. Futures price is the closing price of the corresponding contract month observed on the first trading day of each calendar month. The sample period extends from 1957 through 1999 for corn and from 1958 through 1999 for wheat and soybeans. A long time series is needed because market inversions occur infrequently. Before 1957, only nearby futures contracts were reported and a lot of observations, e.g., March futures prices, were missing. Thus, this study could not go back further in time.

For the same periods with the futures price series, monthly cash grain prices were obtained from the National Agricultural Statistics Service. The cash prices are U.S. monthly average prices received by farmers and are denoted in dollars per bushel. The average price is the open-market price resulting from dividing the total dollars received by all farmers by the total quantity sold. U.S. monthly average prices are computed by weighting monthly prices by the estimated percentage of monthly sales during the month by state. U.S. quarterly grain stocks and grain supply and demand data are also from the National Agricultural Statistics Service.

The cost-of-carry or carrying charge from the perspective of off-farm, commercial storage consists of two components: physical storage costs charged by elevators and the interest opportunity cost. Commercial grain storage rates over the 1970–1999 period, characterized as variable cost only, were obtained from the Oklahoma Cooperative Extension Service at Oklahoma State University. The prevailing commercial grain storage rates in recent years are commonly cited as 2.5–2.6 cents per bushel per month (Jackson, Irwin, and Good; Kastens and Dhuyvetter). To create an historical time series of storage costs for the period 1957–1969, the average commercial grain storage cost of 2.55 cents per bushel per month is deflated using the producer price index (PPI) from the Bureau of Labor Statistics. The U.S. prime loan rates from the Federal Reserve Bank of St. Louis are used to calculate the opportunity or interest costs for stored grain.

Procedures

The market spread, defined as the difference between two futures prices, can be constructed within and across crop years. The spread between futures prices for nearby and distant delivery dates is defined by

$$(3) \qquad Spread(t) = F(t, D) - F(t, N),$$

where $Spread(t)$ is the spread between two futures prices observed at time t, $F(t, D)$ represents the futures price of a distant delivery month at time t, and $F(t, N)$ represents the futures price of a nearby delivery month at time t. For corn, the December–March spread in December; the March–May spread in January, February, and March; the May–July spread in April and May; and the July–September spread in June and July are examined. In futures contract months for corn, December represents harvest, March represents preplanting, May represents planting, July represents the middle of the growing season, and September represents the late growing season or early harvest. For soybeans, the November–January spread in November, the January–March spread in December and January, the March–May spread in February and March, the May–July spread in April and May, the July–August spread in June and July, and the August–September spread in August are examined. For wheat, the July–September spread in July; the September–December spread in August and September; the December–March spread in October, November, and December; and the March–May spread in January, February, and March are examined.

The cost-of-carry or carrying charge necessary to carry the commodity from the nearby delivery date to the distant delivery date is

$$(4) \qquad CC(t, (N, D)) = F(t, N)[e^{r(N,D)} - 1] + W(N, D),$$

where $CC(t, (N, D))$ is the carrying charges from N to D at time t; $F(t, N)$ is a nearby futures price quoted at time t; $[e^{r(N,D)} - 1]$ is the continuously compounded rate of return for the period N to D, which is $R(N, D)$ in equation (2); and $W(N, D)$ is the physical cost of storage from time N to D.

Using equations (3) and (4), this study measures the extent to which the market spread between futures prices for nearby and distant delivery dates falls below full carrying charges. The degree of being below full carry is classified into six categories based on the percentage of market spread to the cost-of-carry or carrying charge. The frequency of market inversions is identified using information on the percentage of market spread to the cost of carry.

An empirically testable hypothesis drawn from equations (1) and (2) is that, when stocks

Table 1. Summary Statistics for Futures Price Spreads, 1957–1999

Commodity	Month	Spread	No. Observations	Mean	Standard Deviation	Minimum	Maximum
Corn	December	Dec–Mar	43	2.24	2.42	−0.75	18.25
	January	Mar–May	43	2.34	1.91	−2.00	12.25
	February	Mar–May	43	2.27	2.64	−9.88	13.00
	March	Mar–May	43	2.47	2.94	−6.50	14.75
	April	May–Jul	43	1.39	2.94	−12.75	12.25
	May	May–Jul	43	0.96	3.80	−21.75	11.50
	June	Jul–Sep	43	−2.84	10.42	−77.25	9.25
	July	Jul–Sep	43	−2.29	15.00	−122.75	31.25
Soybeans	November	Nov–Jan	42	4.10	4.77	−3.00	29.50
	December	Jan–Mar	42	3.74	4.69	−4.75	33.25
	January	Jan–Mar	42	3.79	4.48	−4.13	27.50
	February	Mar–May	42	3.15	5.52	−23.13	26.00
	March	Mar–May	42	3.37	6.38	−37.00	24.75
	April	May–Jul	42	2.50	5.40	−22.25	25.50
	May	May–Jul	42	1.42	11.14	−80.88	23.75
	June	Jul–Aug	37	−5.43	18.47	−98.50	7.25
	July	Jul–Aug	37	−1.57	11.13	−51.00	15.00
	August	Aug–Sep	37	−11.01	24.80	−128.00	10.00
Wheat	July	Jul–Sep	42	2.63	3.35	−6.00	19.50
	August	Sep–Dec	42	3.14	4.15	−14.25	31.00
	September	Sep–Dec	42	3.38	4.26	−6.00	29.50
	October	Dec–Mar	42	2.13	4.46	−15.00	25.25
	November	Dec–Mar	42	1.90	5.31	−18.50	25.25
	December	Dec–Mar	42	1.75	5.74	−16.00	30.75
	January	Mar–May	42	−2.34	7.66	−29.50	10.50
	February	Mar–May	42	−2.20	8.44	−37.50	15.25
	March	Mar–May	42	−0.99	9.07	−44.25	13.50

are low, the price of storage (basis or spread) becomes negative and markets will be inverted. To determine the relationship between the spread and the level of stocks, market spreads are regressed on the logarithm of U.S. quarterly stocks:[1]

$$(5)\quad Spread_t = \beta_0 + \beta_1 \ln(QS_t) + \beta_2 time + \varepsilon_t,$$

where $\ln(QS_t)$ is the natural logarithm of U.S. quarterly stocks, time is measured as year minus initial year in the series, and ε_t is the error term. Market spreads and stocks have time trends and show some degree of autocorrelation. Spreads tend to grow due to inflation and U.S. quarterly stocks tend to increase due to increases in crop production over the years. Regressing one trending variable against another trending variable alone may result in too high of an estimated regression coefficient. Thus, a time variable is incorporated to isolate in β_1 the effect of stocks on market spreads.

Each quarterly stock estimate is analyzed with respect to the spread corresponding to the nearest futures contract. For example, December stocks for corn are compared with December–March spreads on December 1, March

[1] Extensive literature deals with the relationship between the price of storage (spread) and the level of stocks. With the difficulty in defining and accurately measuring the relevant inventory, a major difference among the studies lies in the measurement of the level of stocks. Telser showed that the price of storage is determined by the total marketable stocks rather than the total level of existing stocks. Weymar stressed that the expected level of stocks between two futures' time periods is more important than the current level of stock for the determination of the price of storage for two distant futures contracts. Gray and Peck demonstrated that the price of storage is determined by the current stocks readily available for delivery rather than by the total level of current stocks.

Table 2. Summary Statistics for Spreads as a Percentage of Contemporaneous Costs-of-Carry, 1957–1999

Commodity	Month	Spread	No. Observations	Mean	Standard Deviation	Minimum	Maximum
Corn	December	Dec–Mar	43	0.77	0.32	−0.06	1.60
	January	Mar–May	43	0.79	0.38	−0.51	1.54
	February	Mar–May	43	0.76	0.64	−2.46	1.73
	March	Mar–May	43	0.86	0.58	−0.96	1.91
	April	May–Jul	43	0.53	0.57	−1.17	1.71
	May	May–Jul	43	0.40	0.72	−1.83	1.80
	June	Jul–Sep	43	−0.71	1.55	−6.69	1.10
	July	Jul–Sep	43	−0.53	2.02	−9.78	3.72
Soybeans	November	Nov–Jan	42	0.81	0.43	−0.26	1.66
	December	Jan–Mar	42	0.71	0.39	−0.38	1.44
	January	Jan–Mar	42	0.70	0.41	−0.90	1.41
	February	Mar–May	42	0.54	0.68	−3.12	1.14
	March	Mar–May	42	0.64	0.81	−3.97	1.47
	April	May–Jul	42	0.39	0.63	−2.64	1.08
	May	May–Jul	42	0.23	1.34	−7.25	1.10
	June	Jul–Aug	37	−0.87	2.31	−12.22	0.77
	July	Jul–Aug	37	−0.45	1.73	−6.58	2.04
	August	Aug–Sep	37	−2.22	3.65	−15.03	1.05
Wheat	July	Jul–Sep	42	0.73	0.49	−0.70	1.45
	August	Sep–Dec	42	0.91	0.48	−1.16	1.47
	September	Sep–Dec	42	0.96	0.47	−0.42	1.54
	October	Dec–Mar	42	0.61	0.52	−0.90	1.32
	November	Dec–Mar	42	0.53	0.66	−1.41	1.27
	December	Dec–Mar	42	0.47	0.74	−1.97	1.37
	January	Mar–May	42	−0.57	1.19	−2.60	1.20
	February	Mar–May	42	−0.51	1.34	−3.66	1.27
	March	Mar–May	42	−0.17	1.42	−4.35	1.86

stocks are compared with March–May spreads on March 1, and June stocks are compared with July–September spreads on June 1. Because the quarterly grain stocks estimates are based on the stock levels as of the first day of December, March, June, and September, the spread–stock relationships are synchronous. A similar regression was also used in coffee and cocoa futures markets (Thompson) and energy futures markets (Cho and McDougall).

When markets are inverted, stockholders apparently gain negative returns to storage due to inverse carrying charges. Thus, the recommended strategy is 'sell the stocks.' To determine whether a market inversion is a signal to sell stocks, simulations are conducted.[2]

Simulation strategies considered are cash sale, unhedged storage, and hedged storage. To compare the results of three strategies, net returns to each strategy are evaluated at a future date, i.e., when the hedge for a hedged storage is lifted. The hedge is lifted on the first trading day of the delivery month for the distant futures contract. For example, in the December-March spread for corn observed on December 1, the hedge initiated on December 1 is finally lifted on March 1. For this study, the producer is assumed to produce 5,000 bushels of corn, soybeans, or wheat.

[2] Besides true market inversions, we consider the situation where the nearby spread to the cost-of-carry falls below 0.25%. Although this relaxes the market inversion definition somewhat, it allows for slightly larger data sets. Results are similar in both circumstances.

Table 3. Occurrences of Spreads as a Percentage of Contemporaneous Costs-of-Carry, 1957–1999

Month	Spread	No. Observations	Percentage (%) of Market Spread to Cost-of-Carry					
			0 < %	0 < % < 0.25	0.25 < % < 0.50	0.50 < % < 0.75	0.75 < % < 1.0	% > 1.0
Corn								
Dec	Dec–Mar	43	2	1	3	13	14	10
Jan	Mar–May	43	1	1	8	6	17	10
Feb	Mar–May	43	2	1	6	11	12	11
Mar	Mar–May	43	4	1	2	8	6	22
Apr	May–Jul	43	7	4	8	9	9	6
May	May–Jul	43	10	7	8	6	5	7
Jun	Jul–Sep	43	25	2	7	5	3	1
Jul	Jul-Sep	43	21	4	2	9	5	2
Soybeans								
Nov	Nov–Jan	42	2	3	5	10	9	13
Dec	Jan–Mar	42	2	2	6	13	12	7
Jan	Jan–Mar	42	3	2	4	10	14	9
Feb	Mar–May	42	4	2	6	14	12	4
Mar	Mar–May	42	3	3	3	10	13	10
Apr	May–Jul	42	3	9	9	10	9	2
May	May–Jul	42	8	4	7	8	11	4
Jun	Jul–Aug	37	21	4	4	7	1	0
Jul	Jul–Aug	37	17	3	6	3	7	1
Aug	Aug–Sep	37	24	4	2	5	1	1
Wheat								
Jul	Jul–Sep	42	3	4	6	5	9	15
Aug	Sep–Dec	42	1	3	1	6	9	22
Sep	Sep–Dec	42	3	0	3	4	11	21
Oct	Dec–Mar	42	5	2	9	5	11	10
Nov	Dec–Mar	42	8	4	4	5	10	11
Dec	Dec–Mar	42	10	6	2	3	8	13
Jan	Mar–May	42	26	2	1	6	5	2
Feb	Mar–May	42	23	2	5	2	4	6
Mar	Mar–May	42	19	1	5	2	6	9

The simulation strategies are summarized as follows:

1. Cash sale: At the beginning of each calendar month, if faced with a market inversion, the producer will sell 5,000 bushels of grain. The cash price examined in this study is U.S. average prices received by farmers during the month the cash commodity is sold. Interest is accrued to the proceeds from the cash sale at a continuously compounding rate. Thus, net returns to cash sale is calculated as the sum of cash price sold and the accrued interest.

2. Unhedged storage: This strategy involves storing the cash commodity without using any hedging instrument. Returns to unhedged storage are determined by the levels of cash prices. This strategy is used as the benchmark against which cash sale and hedged storage are evaluated.

3. Hedged storage: At the beginning of each calendar month, if faced with a market inversion, the producer will sell one lot (5,000 bushels) of distant futures contract. On the first trading day of the delivery month for the distant futures contract, the hedge is lifted and the cash commodity is sold. Returns to hedged storage are dependent on changes in the cash price relative to changes in the futures price.

Table 4. Regressions of Spreads on U.S. Quarterly Grain Stocks, 1957–1999

Commodity	Date	Spread	Quarterly Stocks	No. Observations	β_0	β_1	Time	R^2
Corn	December 1	Dec–Mar	December	43	−31.32 (−1.04)	4.34 (1.17)	0.03 (0.40)	0.16
	March 1	Mar–May	March	43	−36.82 (−1.65)	5.06 (1.79)*	−0.003 (−0.05)	0.14
	June 1	Jul–Sep	June	43	−123.61 (−2.48)**	16.43 (2.50)**	−0.53 (2.79)**	0.19
Soybeans	December 1	Nov–Jan	December	42	−84.97 (−2.64)**	14.40 (2.78)**	−4.42 (−1.92)*	0.23
	March 1	Mar–May	March	42	−83.05 (−2.19)**	14.80 (2.27)**	−0.39 (−1.39)	0.18
	June 1	Jul–Aug	June	37	−140.92 (−3.16)**	25.26 (3.04)**	−1.02 (−2.34)**	0.21
Wheat	September 1	Sep–Dec	September	42	−90.18 (−2.22)**	12.70 (2.35)**	0.15 (1.73)*	0.25
	December 1	Dec–Mar	December	42	−75.00 (−1.60)	10.86 (1.71)*	−0.008 (−0.06)	0.07
	March 1	Mar–May	March	42	−23.06 (−0.51)	3.36 (0.53)	−0.13 (−0.81)	0.02

Note: The estimated regression equation is $Spread_t = \beta_0 + \beta_1 \ln(QS_t) + \beta_2 time + \varepsilon_t$, where $\ln(QS_t)$ is the natural logarithm of U.S. quarterly stocks; time is $t - t_0$, where t is in years and t_0 is the initial year; and ε_t is the error term. The figures in parentheses are t-statistics, with ** indicating statistical significance at the 5% level and * statistical significance at the 10% level.

Futures transaction costs, including brokerage fees and liquidity costs, are assumed to be 1.5 cents per bushel, or 75 dollars per contract.

To compare the net returns to the three marketing strategies, paired-differences tests are conducted. The paired t-tests are based on the following three pairs of strategies: (1) cash sale versus unhedged storage (CS-US), (2) cash sale versus hedged storage (CS-HS), and (3) unhedged storage versus hedged storage (US-HS).

As with all simulations, an adequate number of observations to fully specify the distribution of net returns to each strategy are a real matter of concern. Because the true market inversions with negative spreads are expected to rarely occur during early months of the crop year, the number of observations in this study may not be large enough to meet the desired number of observations from statistical sampling theory. Thus, besides running simulations under a true market inversion, this study repeats the analysis under conditions where the market spread as a percent of the cost-of-carry is below 0.25. Simulations were conducted with Oklahoma wheat cash prices to see if the aggregation of prices mattered. Results were qualitatively no different (a little more statistical significance), and thus the Oklahoma wheat results are not included.

With the aggregated data, this study regresses the actual returns to storage (unhedged and hedged) on the predicted returns to storage and a set of dummies representing the distance to harvest. The actual returns to unhedged (hedged) storage are computed by subtracting the returns to cash sale from the returns to unhedged (hedged) storage, and the predicted returns to storage are the corresponding futures price spreads.

Results

Table 1 reports summary statistics for the market spreads of soybeans, corn, and wheat. Because the length of spreads is not of equal time intervals, they are standardized to reflect equal spread length of 1 month. To calculate the mean value of spreads per month, spreads are adjusted by dividing by the number of months

Table 5. Regressions of Percent of Spreads to Costs-of-Carry on Stocks-to-Use Ratio, 1957–1999

Commodity	Month	Spread	No. Observations	β_0		β_1		R^2
Corn	December	Dec–Mar	43	0.654	(6.93)*	0.004	(1.41)	0.05
	March	Mar–May	43	0.640	(3.72)*	0.008	(1.48)	0.05
	May	May–Jul	43	0.230	(1.05)	0.006	(0.88)	0.02
	July	Jul–Sep	43	−0.660	(−1.07)	0.005	(0.25)	0.00
Soybeans	November	Nov–Jan	42	0.860	(5.73)*	−0.004	(−0.41)	0.00
	March	Mar–May	42	0.667	(2.36)*	−0.002	(−0.10)	0.00
	May	May–Jul	42	0.158	(0.34)	0.005	(0.18)	0.00
	July	Jul–Aug	37	−0.869	(−1.33)	0.029	(0.72)	0.01
Wheat	July	Jul–Sep	42	0.407	(2.95)*	0.006	(2.74)*	0.16
	September	Sep–Dec	42	0.620	(4.78)*	0.006	(3.04)*	0.19
	December	Dec–Mar	42	0.050	(0.23)	0.007	(2.28)*	0.11
	March	Mar–May	42	−0.342	(−0.78)	0.003	(0.46)	0.01

Note: The estimated regression equation is $\%carry_t = \beta_0 + \beta_1 SUR_t + \varepsilon_t$, where $\%carry_t$ is the percentage of market spread to the cost-of-carry, SUR_t is the stocks-to-use ratio, and ε_t is the error term. The stocks-to-use ratio is calculated as the ratio of end-of-crop-year stocks (ending stocks) to the 5-year moving average of total use. The figures in parentheses are t-statistics, with * indicating statistical significance at the 5% level.

Table 6. Simulation Results for Corn, 1957–1999

			Percent Carry < 0.25			Percent Carry < 0		
Month	Spread	Strategy	Observations	Mean	SD	Observations	Mean	SD
December	Dec–Mar	Cash sale	3	275.59	45.06	2	251.49	24.03
		Unhedged storage	3	276.33	46.06	2	254.00	35.36
		Hedged storage	3	271.08	51.25	2	241.50	1.41
January	Mar–May	Cash sale	2	229.87	124.53	1	141.81	—
		Unhedged storage	2	213.50	74.25	1	161.00	—
		Hedged storage	2	236.38	142.31	1	135.75	—
February	Mar–May	Cash sale	3	215.05	69.53	2	203.78	94.39
		Unhedged storage	3	223.00	55.75	2	215.00	76.37
		Hedged storage	3	206.33	60.91	2	186.25	70.71
March	Mar–May	Cash sale	5	267.35	85.80	4	252.45	91.31
		Unhedged storage	5	283.40	95.89	4	270.75	105.79
		Hedged storage	5	256.83	70.23	4	240.34	69.03
April	May–Jul	Cash sale	11	242.20	87.67	7	270.44	80.68
		Unhedged storage	11	244.73	93.11	7	274.86	87.34
		Hedged storage	11	235.22	80.00	7	256.23	66.58
May	May–Jul	Cash sale	17	228.93	89.91	10	235.37	89.35
		Unhedged storage	17	227.82	91.46	10	235.80	94.06
		Hedged storage	17	219.55	85.63	10	225.85	84.00
June	Jul–Sep	Cash sale	27	214.76	85.15	25	211.92	87.84
		Unhedged storage	27	197.89	77.64	25	197.20	80.73
		Hedged storage	27	209.05	90.97	25	205.46	93.72
July	Jul–Sep	Cash sale	25	207.83	92.70	21	219.09	93.22
		Unhedged storage	25	193.76	82.89	21	205.10	83.46
		Hedged storage	25	197.11	84.32	21	206.76	84.71

Table 7. Simulation Results for Soybeans, 1958–1999

			Percent Carry < 0.25			Percent Carry < 0		
Month	Spread	Strategy	Observations	Mean	SD	Observations	Mean	SD
November	Nov–Jan	Cash sale	5	514.89	129.46	2	496.13	37.18
		Unhedged storage	5	547.80	115.87	2	528.50	82.73
		Hedged storage	5	519.15	121.66	2	511.63	43.66
December	Jan–Mar	Cash sale	4	586.21	200.59	2	495.83	296.38
		Unhedged storage	4	623.50	243.56	2	535.50	369.82
		Hedged storage	4	588.75	206.93	2	484.13	290.09
January	Jan–Mar	Cash sale	5	503.35	166.16	3	472.60	227.06
		Unhedged storage	5	540.60	192.27	3	558.33	264.47
		Hedged storage	5	481.88	164.27	3	442.04	218.94
February	Mar–May	Cash sale	6	549.83	165.63	4	515.87	198.01
		Unhedged storage	6	610.50	212.35	4	614.00	273.44
		Hedged storage	6	532.67	148.87	4	493.88	171.59
March	Mar–May	Cash sale	6	493.70	208.43	3	455.30	168.10
		Unhedged storage	6	536.17	260.29	3	538.67	279.47
		Hedged storage	6	492.65	208.03	3	473.79	199.24
April	May–Jul	Cash sale	12	496.85	192.72	3	466.29	195.36
		Unhedged storage	12	484.58	183.14	3	504.67	236.19
		Hedged storage	12	471.72	215.97	3	367.63	212.98
May	May–Jul	Cash sale	12	578.15	246.08	8	615.61	296.54
		Unhedged storage	12	525.17	191.26	8	540.50	198.71
		Hedged storage	12	542.22	241.05	8	570.36	270.84
June	Jul–Aug	Cash sale	25	525.91	235.37	21	539.25	240.53
		Unhedged storage	25	484.04	195.83	21	494.00	199.40
		Hedged storage	25	516.69	238.28	21	530.62	244.48
July	Jul–Aug	Cash sale	20	474.75	197.56	17	492.95	202.95
		Unhedged storage	20	453.20	182.62	17	469.00	188.60
		Hedged storage	20	472.86	199.06	17	489.99	206.33
August	Aug–Sep	Cash sale	28	518.66	199.82	24	488.73	200.00
		Unhedged storage	28	486.32	177.21	24	457.25	173.97
		Hedged storage	28	498.29	193.56	24	461.82	179.77

between the near and distant futures. For example, the mean of the December–March spread for corn is adjusted by dividing by the spread interval of 3 months. To measure the volatility of the spreads per month, spreads are adjusted by dividing by the square root of the spread length and subsequently computing the standard deviation of the adjusted spreads.

From Table 1, it can be observed that there is a seasonal pattern in the mean of spreads for all three commodities. In general, the mean value of the spreads declines from the beginning of the crop year to the end of the crop year. Mean spreads are greatest after harvest or during early months of the crop year, then decrease to minimums and even go negative on average during the growing season or just before the new harvest. Negative spreads, or inverse carrying charges, are consistently observed in the July–September spread for corn, the July–August and August–September spreads for soybeans, and the March–May spread for wheat. For corn and soybeans, the July futures contract is the last consistently old-crop contract. The September futures contract may be a new-crop contract if harvest starts early enough and thus is often treated as a transitional contract between old and new crop. The results confirm that, in grain markets, market inversions are most frequent be-

Table 8. Simulation Results for Wheat, 1958–1999

			Percent Carry < 0.25			Percent Carry < 0		
Month	Spread	Strategy	Observations	Mean	SD	Observations	Mean	SD
July	Jul–Sep	Cash sale	7	249.79	98.85	3	204.55	61.03
		Unhedged storage	7	293.29	129.76	3	272.00	172.27
		Hedged storage	7	259.20	112.44	3	201.79	62.26
August	Sep–Dec	Cash sale	4	364.20	118.27	1	458.17	—
		Unhedged storage	4	358.50	103.01	1	478.00	—
		Hedged storage	4	316.25	111.83	1	346.75	—
September	Sep–Dec	Cash sale	3	406.11	93.91	3	406.11	93.91
		Unhedged storage	3	395.00	89.01	3	395.00	89.01
		Hedged storage	3	395.50	118.65	3	395.50	118.65
October	Dec–Mar	Cash sale	7	325.06	110.82	5	362.40	86.48
		Unhedged storage	7	322.14	112.73	5	358.20	92.59
		Hedged storage	7	296.84	104.53	5	330.10	85.65
November	Dec–Mar	Cash sale	12	305.60	101.00	8	322.03	96.09
		Unhedged storage	12	304.92	108.74	8	331.13	106.71
		Hedged storage	12	282.49	87.54	8	291.72	81.21
December	Dec–Mar	Cash sale	16	321.82	114.55	10	336.32	112.05
		Unhedged storage	16	315.63	117.40	10	332.00	117.75
		Hedged storage	16	302.80	106.28	10	311.10	100.69
January	Mar–May	Cash sale	28	289.38	118.43	26	300.74	115.19
		Unhedged storage	28	275.43	109.04	26	285.96	105.94
		Hedged storage	28	277.84	110.42	26	288.14	107.79
February	Mar–May	Cash sale	25	294.04	120.00	23	304.47	119.20
		Unhedged storage	25	281.24	108.58	23	290.57	107.90
		Hedged storage	25	281.46	108.15	23	290.84	107.47
March	Mar–May	Cash sale	20	291.41	116.34	19	288.04	118.52
		Unhedged storage	20	284.10	111.36	19	279.79	112.68
		Hedged storage	20	283.12	112.72	19	279.73	114.76

tween the last of the old-crop delivery months and the first of the new-crop delivery months, i.e., across crop years. Contrary to the behavior of mean spreads, the volatility of the spreads has a tendency to increase from harvest to the end of the crop year. For example, the standard deviation of the December–March spread for corn in December is 2.42 while the standard deviation of the July–September spread for corn in July is 15.00.

Table 2 presents summary statistics for spreads as percentage of contemporaneous costs-of-carry. The mean of the spread to cost-of-carry ratio falls below one for all spreads, indicating that grain markets on average are below full carry. The highest ratio is 0.96 in the September–December wheat futures spread observed in September.

Table 3 exhibits the occurrences of spreads as a percent of contemporaneous costs-of-carry at various levels. Market inversions in nearby spreads rarely occur during early months of the crop year. The theory of the price of storage also predicts that negative spreads between two new crop futures contracts are less likely to occur because stocks are usually plentiful after harvest, and thus convenience yields are small. On the contrary, the number of observations with the percent of cost-of-carry greater than one, i.e., above full carry, is relatively large. This implies that there exist substantial cash-and-carry arbitrage opportunities because the cost-of-carry is too low relative to the market spread. One reason for being above full carry is that the fixed cost component of grain storage costs is missed in

Table 9. Results of the Paired-Differences Tests for Corn, 1957–1999

			Percent Carry < 0.25			Percent Carry < 0		
Month	Spread	Paired Difference	Observations	Mean	t-Ratio	Observations	Mean	t-Ratio
December	Dec–Mar	CS-US	3	−0.74	−0.15	2	−2.51	−0.31
		CS-HS	3	4.51	0.38	2	9.99	0.56
		US-HS	3	5.25	0.31	2	12.50	0.48
January	Mar–May	CS-US	2	16.37	0.46	1	−19.19	—
		CS-HS	2	−6.50	−0.52	1	6.06	—
		US-HS	2	−22.88	−0.48	1	25.25	—
February	Mar–May	CS-US	3	−7.95	−0.99	2	−11.22	−0.88
		CS-HS	3	8.71	0.67	2	17.53	1.05
		US-HS	3	16.67	1.35	2	28.75	7.19*
March	Mar–May	CS-US	5	−16.05	−1.34	4	−18.30	−1.20
		CS-HS	5	10.53	1.13	4	12.11	1.02
		US-HS	5	26.58	1.39	4	30.41	1.25
April	May–Jul	CS-US	11	−2.53	−0.25	7	−4.42	−0.33
		CS-HS	11	6.99	0.79	7	14.20	1.10
		US-HS	11	9.51	0.58	7	18.63	0.81
May	May–Jul	CS-US	17	1.11	0.21	10	−0.43	−0.05
		CS-HS	17	9.38	2.54*	10	9.52	1.57
		US-HS	17	8.27	1.22	10	9.95	0.85
June	Jul–Sep	CS-US	27	16.87	2.71*	25	14.72	2.26*
		CS-HS	27	5.72	0.61	25	6.46	0.64
		US-HS	27	−11.16	−1.05	25	−8.26	−0.73
July	Jul–Sep	CS-US	25	14.07	2.62*	21	14.00	2.25*
		CS-HS	25	10.72	3.23*	21	12.34	3.19*
		US-HS	25	−3.35	−0.58	21	−1.66	−0.25

Notes: CS-US denotes the paired difference of net returns between the cash sale (CS) and unhedged storage (US). CS-HS denotes the paired difference of net returns between the cash sale (CS) and hedged storage (HS), and US-HS denotes the paired difference of net returns between the unhedged storage (US) and hedged storage (HS). The t-ratio is $t = (\bar{d} - 0)/(s_D^2/n)^{1/2}$, where $\bar{d}$ is the average of the paired differences (d_i) of the net returns between two marketing strategies, n is the number of paired differences, and

$$s_D^2 = \frac{\sum_{i=1}^{n} d_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} d_i\right)^2}{n-1}.$$

Asterisks denote rejection of the null hypothesis of no difference at the 5% significance level.

calculating the cost-of-carry, and thus the cost-of-carry is underestimated. Another possible reason is that market spreads may reflect risk premia with buildup in stocks after new-crop harvest or during early months of the crop year.

Table 4 reports the regression results for spreads against U.S. quarterly grain stocks. The R^2 values are very low, ranging from .02 in the March–May spread for wheat to .25 in the September–December spread for wheat. The slope terms are almost always statistically significant. There is a tendency for regressions during early months of the crop year to fit better than the regressions toward the end of the crop year, suggesting that the spread–stock relationship is more pronounced when stocks are abundant. Overall, the results support that there is a positive relationship between the spread and the level of stocks, and thus when the stocks are scarce, the spread becomes negative and markets are inverted.

Table 5 summarizes the regressions of the spread percentage of cost-of-carry on the

Table 10. Results of the Paired-Differences Tests for Soybeans, 1958–1999

			Percent Carry < 0.25			Percent Carry < 0		
Month	Spread	Paired Difference	Observations	Mean	t-Ratio	Observations	Mean	t-Ratio
November	Nov–Jan	CS-US	5	−32.91	−2.31*	2	−32.37	−1.01
		CS-HS	5	−4.26	−0.62	2	−15.50	−3.38*
		US-HS	5	28.65	2.09*	2	16.88	0.61
December	Jan–Mar	CS-US	4	−37.29	−0.95	2	−39.67	−0.76
		CS-HS	4	−2.54	−0.29	2	11.71	2.63*
		US-HS	4	34.75	0.80	2	51.38	0.91
January	Jan–Mar	CS-US	5	−37.25	−0.83	3	−85.74	−1.52
		CS-HS	5	21.47	1.97*	3	30.55	2.40*
		US-HS	5	58.73	1.06	3	116.29	1.69
February	Mar–May	CS-US	6	−60.67	−1.33	4	−98.13	−1.63
		CS-HS	6	17.17	1.69	4	21.99	1.46
		US-HS	6	77.83	1.52	4	120.13	1.76
March	Mar–May	CS-US	6	−42.46	−1.17	3	−83.36	−1.22
		CS-HS	6	1.06	0.07	3	−18.49	−0.78
		US-HS	6	43.52	1.69	3	64.88	1.39
April	May–Jul	CS-US	12	12.27	0.89	3	−38.37	−1.35
		CS-HS	12	25.13	0.74	3	98.67	0.70
		US-HS	12	12.86	0.32	3	137.04	0.97
May	May–Jul	CS-US	12	52.98	1.92	8	75.11	2.05*
		CS-HS	12	35.93	0.99	8	45.25	0.82
		US-HS	12	−17.05	−0.46	8	−29.86	−0.54
June	Jul–Aug	CS-US	25	41.87	2.71*	21	45.25	2.49*
		CS-HS	25	9.23	1.19	21	8.63	0.94
		US-HS	25	−32.65	−1.64	21	−36.62	−1.55
July	Jul–Aug	CS-US	20	21.55	2.64*	17	23.26	2.47*
		CS-HS	20	1.89	0.23	17	2.26	0.23
		US-HS	20	−19.66	−1.50	17	−20.99	−1.36
August	Aug–Sep	CS-US	28	32.34	2.83*	24	31.48	2.36*
		CS-HS	28	20.38	2.37*	24	26.91	3.59*
		US-HS	28	−11.96	−1.25	24	−4.57	−0.51

Notes: CS-US denotes the paired difference of net returns between the cash sale (CS) and unhedged storage (US), CS-HS denotes the paired difference of net returns between the cash sale (CS) and hedged storage (HS), and US-HS denotes the paired difference of net returns between the unhedged storage (US) and hedged storage (HS). The t-ratio is $t = (\bar{d} - 0)/(s_D^2/n)^{1/2}$, where $\bar{d}$ is the average of the paired differences (d_i) of the net returns between two marketing strategies, n is the number of paired differences, and

$$s_D^2 = \frac{\sum_{i=1}^{n} d_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} d_i\right)^2}{n - 1}.$$

Asterisks denote rejection of the null hypothesis of no difference at the 5% significance level.

stocks-to-use ratio. The results show that none of the regressions for corn and soybeans are statistically significant at the 5% level. Three regressions for wheat are statistically significant at the 5% level, yet their overall explanatory power is low because R^2 values are extremely small. The findings suggest that the market spreads do not closely approximate the price of storage relationships when regressed on the ending stocks.

Tables 6, 7, and 8 report the results of simulations when markets are inverted, and Tables 9, 10, and 11 report the results for the corresponding paired-differences tests. Across three

Table 11. Results of the Paired-Differences Tests for Wheat, 1958–1999

			Percent Carry < 0.25			Percent Carry < 0		
Month	Spread	Paired Difference	Observations	Mean	t-Ratio	Observations	Mean	t-Ratio
July	Jul–Sep	CS-US	7	−43.49	−1.50	3	−67.45	−0.93
		CS-HS	7	−9.40	−1.21	3	2.76	0.40
		US-HS	7	34.09	1.13	3	70.21	1.04
August	Sep–Dec	CS-US	4	5.70	0.29	1	−19.83	—
		CS-HS	4	47.95	1.99*	1	111.42	—
		US-HS	4	42.25	1.09	1	131.25	—
September	Sep–Dec	CS-US	3	11.11	0.77	3	11.11	0.77
		CS-HS	3	10.61	0.64	3	10.61	0.64
		US-HS	3	−0.50	−0.02	3	−0.50	−0.02
October	Dec–Mar	CS-US	7	2.92	0.22	5	4.20	0.22
		CS-HS	7	28.22	2.62*	5	32.30	2.16*
		US-HS	7	25.30	1.23	5	28.10	0.95
November	Dec–Mar	CS-US	12	0.68	0.08	8	−9.09	−0.87
		CS-HS	12	23.11	2.38*	8	30.31	2.19*
		US-HS	12	22.43	1.48	8	39.41	1.92
December	Dec–Mar	CS-US	16	6.20	1.57	10	4.32	0.85
		CS-HS	16	19.02	2.91*	10	25.22	2.62*
		US-HS	16	12.82	1.71	10	20.90	1.92
January	Mar–May	CS-US	28	13.95	1.69	26	14.78	1.67
		CS-HS	28	11.54	2.05*	26	12.60	2.10*
		US-HS	28	−2.41	−0.22	26	−2.18	−0.18
February	Mar–May	CS-US	25	12.80	1.36	23	13.91	1.36
		CS-HS	25	12.58	2.00*	23	13.64	2.01*
		US-HS	25	−0.22	−0.02	23	−0.27	−0.02
March	Mar–May	CS-US	20	7.31	0.85	19	8.25	0.91
		CS-HS	20	8.30	1.98*	19	8.31	1.93
		US-HS	20	0.98	0.07	19	0.06	0.00

Notes: CS-US denotes the paired difference of net returns between the cash sale (CS) and unhedged storage (US), CS-HS denotes the paired difference of net returns between the cash sale (CS) and hedged storage (HS), and US-HS denotes the paired difference of net returns between the unhedged storage (US) and hedged storage (HS). The t-ratio is $t = (\bar{d} - 0)/(s_D^2/n)^{1/2}$, where $\bar{d}$ is the average of the paired differences (d_i) of the net returns between two marketing strategies, n is the number of paired differences, and

$$s_D^2 = \frac{\sum_{i=1}^{n} d_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} d_i\right)^2}{n - 1}.$$

Asterisks denote rejection of the null hypothesis of no difference at the 5% significance level.

commodities, net returns to cash sale become higher than net returns to unhedged storage and hedged storage with the approach of a new harvest.

The results of paired-differences tests for corn (Table 9) show that net returns to cash sale are greater than those of unhedged storage or hedged storage after May. The results of paired-differences tests for soybeans (Table 10) show that returns to cash sale are consistently higher than returns to unhedged storage after April. The results of paired-differences tests for wheat (Table 11) show that returns to cash sale are consistently higher than returns to storage after November. One reason that net returns to hedged storage should be lower than the returns to cash sale is the costs associated with trading futures contracts.

Table 12. Regressions of Actual Returns to Storage on the Predicted Returns to Storage Under a Market Inversion, 1957–1999

Commodity	Returns to Storage	No. Observations	β_0	β_1	R^2
Corn	Unhedged (US-CS)	72	1.74 (0.48)	0.87 (4.83)*	0.25
	Hedged (HS-CS)	72	−5.53 (−1.23)	0.45 (2.02)*	0.06
Soybeans	Unhedged (US-CS)	87	1.66 (0.17)	1.52 (3.81)*	0.16
	Hedged (HS-CS)	87	1.85 (0.24)	1.63 (5.22)*	0.24
Wheat	Unhedged (US-CS)	98	1.45 (0.22)	0.82 (0.91)	0.03
	Hedged (HS-CS)	98	−2.46 (1.42)	1.39 (4.24)*	0.16

Notes: US-CS denotes the difference of net returns between unhedged storage (US) and cash sale (CS), i.e., actual returns to unhedged storage, and HS-CS denotes the difference of net returns between hedged storage (HS) and cash sale (CS), i.e., actual returns to hedged storage. Asterisks denote rejection of the null hypothesis of no difference at the 5% significance level.

The results from simulations when markets are inverted show that, as the end of the crop year approaches, a market inversion is clearly the market's signal to release stocks in anticipation of new crop supplies. However, it is not conclusive whether a market inversion is a signal to sell during early months of the crop year due to the low frequency of market inversions.

Table 12 presents the regression results for actual returns to storage against predicted returns to storage. There exists a positive relationship between actual returns to storage and predicted returns to storage except for the unhedged storage for wheat. The result for wheat may come from the difference in crop variety. While the wheat futures contract traded on the Chicago Board of Trade is based on soft red winter wheat, U.S. monthly cash prices aggregate all varieties and qualities. The results suggest that as predicted returns to storage, i.e., spreads, get smaller or even go negative, the actual returns to storage decreases and thus support the argument that a market inversion is a signal to sell.

Conclusions

As opposed to a normal market, an inverted market has a negative price of storage or spread. Futures price spreads for corn, soybeans, and wheat exhibit a seasonal pattern. In general, spreads gradually decline from the start of the crop year and even go negative on average at the end of the crop year or just before the new harvest. In contrast, the volatility of spreads measured by the standard deviation of spreads has a tendency to increase from harvest to the end of the crop year. The spreads as a percentage of contemporaneous costs-of-carry are less than one on average, indicating that grain markets on average are below full carry.

Market inversions in nearby spreads rarely occur during early months of the crop year. However, market inversions become pronounced when the spreads are observed across crop years at the end of the crop year or just before the new harvest. The regressions of spreads on the logarithm of U.S. quarterly stocks show that market inversions are more likely when stocks are low.

A market inversion appears to be a situation where the market encourages producers to release their stocks, yet many continue to store their grain. The simulations were conducted to determine whether a market inversion is a signal to sell the stocks. The results of the paired-differences tests reveal that in at least the last half of the crop year, market inversions are the market's signal for producers to sell their grain. While some farmers may choose not to sell for economic reasons, the behavioral finance aspects of overconfidence, anchoring, and regret also offer explanations of why some farmers do not respond to these signals.

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