Commodity Storage under Backwardation: Does the Working Curve Still Work?

Authors

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Introduction

Storage is a key aspect in many agricultural commodity markets due to the seasonal nature of production. If storage is to be considered as a rational act undertaken by profit maximizing agents, the benefits accruing from storage should be greater than its costs. In other words the difference between contemporaneous spot and futures prices should be at least equal to the cost of storage. However, the price spread between the current spot and the next to expire futures contract is sometimes negative, and the market is then said to show an inverse carrying charge, or "backwardation."

During extensive investigations of the wheat market in Chicago, Working (1933, 1948) noticed that the amount of commodity stored tends to be less when the "price of storage" (difference between contemporaneous spot and futures prices) is negative and large than when it is positive and small. The graphical representation of this storage phenomenon came to be known as the Working curve, and the explanation for its shape came to be known as the Supply of Storage Theory (Working, 1949). A key aspect of the theory is that negative carrying charges are attributed to convenience yield, i.e., the operational benefit accruing to owners of commodity stocks.

Working's argument that negative carrying charges are the result of convenience yield has been challenged by researchers, including Brennan and Williams (1989), Benirschka and Binkley (1995), and Williams and Wright (1997). These authors argue that the Working curve is an artifact of data aggregation. Specifically, stocks of commodities may be aggregated across locations and grades for market reporting purposes. Once stocks and prices are measured for the appropriate location and grade there should be no evidence of stocks being held during backwardations.

In the wake of these claims, Carter and Giha (2007) re-examine Working's original statistical data from 1921-1932. They examine stocks only for Chicago to minimize potential spatial aggregation problems and are also careful to avoid possible errors introduced by aggregating different wheat grades. The authors find that wheat stocks were carried under backwardation in a single location, lending support to the shape of the original Working curve and casting some doubt on aggregation arguments for the shape of the curve.

Carter and Giha's findings are definitive with respect to Workings original data. However, one can still be circumspect as to whether data from the 1920s and 1930s should be generalized to current commodity markets. In addition, Carter and Giha's analysis is limited to only one market—wheat. No evidence is presented whether the findings generalize to other important commodity markets. Given the central place that storage under backwardation plays in models of commodity storage, the subject warrants further academic attention.

In this paper we offer new empirical evidence on holding stocks in the presence of backwardation, and assess the existence of the Working curve with recent spot and futures prices and stock data for CBOT (Chicago Board of Trade) corn, soybeans, and wheat and KCBOT (Kansas City Board of Trade) wheat. We investigate both the conventional measure of backwardation, futures less spot prices, and the futures spread expressed as a percent of full carry against the total stock held at various delivery locations. Weekly stock data for the four commodities at deliverable locations are available for 1990-2010, which provides the most extensive data set to date for testing storage under backwardation. We further control for grade by studying the spreads using stocks of the deliverable grade, and by using maximum futures and spot spreads to reduce likelihood that observed relationships are influenced by quality differences. Following Carter and Giha's general framework, we plot both the conventional

spread and the futures spread as a percent of full carry for nearby futures contracts versus the weekly stocks at deliverable locations. The results from the analysis of commodities across different markets provide evidence for storage under backwardation at delivery locations for all four commodities. However, the exact form of the Working curve is less easy to identify.

Research Methods

The primary objective is to ascertain whether stocks certified for delivery on futures contracts at independent delivery locations are held in backwardation. The traditional method to calculate the spread is to measure the difference between contemporary spot and futures prices. However, spot prices are not available by grades and commodities certified for delivery can be of different grades which are deliverable at a premium or discount to the par grade. Hence, we follow a conservative approach by calculating the largest possible spread of the day. This spread is calculated as the difference between the contemporary low spot bid and the high (high of the day) futures price. If this spread is negative, the spread for all other bids should be negative. A second issue in the use of the traditional method is the assumption of convergence of spot and futures prices at expiration. Recent studies on CBOT corn, soybean and wheat futures markets by Irwin, Garcia, Good, and Kunda (2009) indicate that spot and futures prices do not always converge as expected, with the spot being below futures prices. Such non-convergence can bias the measurement of spreads as spot prices are used to calculate the spreads.

As a result, we also examine the spread between the nearby and the next nearby futures contracts. We estimate the spread between prices of expiring and next-to-expire contracts expressed as a percent of full carry, on the first delivery date of each expiring futures contract (Irwin et al (2009). The percent of full carry can be calculated as follows:

$$C_t = \left[\frac{F_{2t} - F_{1t}}{S_t + I_t} \right] \cdot 100$$

where, F_{1t}, is the settlement price of the t^{th} expiring futures contract on the first delivery date for this contract. F_{2t}, is the settlement price of the next-to-expire futures contract on the first delivery date of the t^{th} expiring futures contract. S_t, is the exchange contract storage rate per day times the number of days (n_t) between the first delivery date for the expiring and next-to-expire futures contracts and I_t, is the interest opportunity cost, computed as the settlement price of the expiring futures contract on the first day of delivery (F_{1t}) times the appropriately adjusted 3-month LIBOR interest rate $\left[I_t = F_{1t} \cdot (r_t / 365) \cdot n_t \right]$.

The percent full carry assumes that the choice to hold stocks is influenced by the futures price spread adjusted for interest rate and storage rates, which are key dimensions in the decision process. This measure allows us to overcome the issue of non-convergence by excluding the use of spot prices in calculating the spread. Since it is based only on futures prices, it measures the incentive to hold inventory independent of quality considerations. In effect, storage in the presence of backwardation and the Working curve are examined using the concept of cost of carry (Telser, 1958). For purposes of comparison, we apply the percent full carry to both the futures-futures and futures-spot spreads to assess their relationship with stocks.[1]

[1] Throughout the paper we use the backwardation and a negative percent carry interchangeably.

Data

The study uses data on CBOT corn, soybean and wheat futures prices and KCBOT wheat futures prices and weekly stock data at deliverable locations for the periods; 1990 to 2010. Spots bids at deliverable locations are also used to calculate spreads. We use the adjusted 3-month LIBOR interest rate and CBOT and KCBOT storage rates for the periods under study. A detailed description of the background and data sources is available in appendix A.

Following Wright and Williams (1989) who argue that deliverable stocks correspond more closely than the more highly aggregated U.S. stocks to the prices, we use deliverable stocks in the analysis.[2] A summary of total deliverable stocks held delivery locations by commodities are presented in table 1. Note that the deliverable wheat stocks reported in Chicago delivery locations are predominantly soft red winter (SRW) wheat stocks.

Stock data at different delivery locations are not available for the same periods. For example, data for CBOT corn at the Chicago delivery location are available from March 1990 to July 2010, whereas the data for CBOT corn at the Toledo/Maumee region are only from March 1990 to December 1999. A few delivery locations were discontinued and others were added by the CBOT during the period under study. We use all available stock data from these locations. However, we exclude through-put delivery locations (e.g. river elevators), that carry lower quantities of stocks and may represent storage dynamics different from the one that we study. Moreover, spot price data were not available at all these delivery locations. Hence, the study using both the traditional and the new spread measure is restricted to Chicago, Toledo/Maumee

[2] We also performed the analysis used total stocks including CCC and non-deliverable inventory with little change in the findings.

and St. Louis delivery locations for CBOT commodities, and the Kansas City region for KCBOT wheat.

Results

For each location, we plot the stocks and the corresponding percent of full carry measures based on the futures-futures (F-F) and futures-spot (F-S) spreads (Figures C.1.a—K.1.b). The figures contain information on the periods for which stock data were available. We also calculate the percent of the observations for which stocks were being held in the presence of negative full carry measured at each location, and the average and median magnitude of the stockholdings for these observations (Tables 2 and 3).

The results differ across locations and commodities. For the corn market, the figures for the Chicago region (C.1.a $\rightarrow$ F-F, C.1.b $\rightarrow$ F-S), the Toledo/Maumee region (C.2.a $\rightarrow$ F-F, C.2.b $\rightarrow$ F-S) and the St. Louis region (C.3.a $\rightarrow$ F-F, C.3.b $\rightarrow$ F-S) provide some evidence of storage under backwardation. Use of the maximum spread between futures and spot prices reduces the number of observations for which stocks are being held under backwardation. Strongest evidence of a convenience yield in the Working curve appears in the St. Louis and Toledo-Maumee locations which were discontinued in 1999. The Chicago region also exhibits some evidence of convenience yield. In Chicago, Toledo/Maumee and St. Louis regions, the percentage of total observations showing storage under backwardation were 15.53 %, 28% and 28 % for the F-F spread, and 8.74 %, 14 % and 42 % for the F-S spread. The magnitudes of the stocks (mean, median) carried under backwardation using the F-F and the F-S spreads were small in St. Louis, but appear to be non-trivial in the Toledo-Maumee (e.g. mean - 6. 2 million bushels, median –

4.5 million bushels using the F-F spread) and Chicago (e.g. mean – 1.9 million bushels, median – 1.5 million bushels using the F-S spread) regions.

For soybeans, stronger evidence for stockholdings under backwardation emerges in both measures of the percent full carry. The two discounted markets (the Toledo/Maumee region (S.2.a $\rightarrow$ F-F, S.2.b $\rightarrow$ F-S), and the St. Louis region (S.3.a $\rightarrow$ F-F, S.3.b $\rightarrow$ F-S) continue to provide evidence of stockholdings under backwardation and the convenience yield component of the Working curve. Somewhat in contrast to corn, the Chicago region (S.1.a $\rightarrow$ F-F, S.1.b $\rightarrow$ F-S) provides particularly strong evidence in support of convenience yield in the Working curve. As might be expected from the figures, the percent of the observations showing storage under backwardation is high for the three locations. For the F-F spread, 29.86 %, 39.28%, and 9.30% of the observations in Chicago, Toledo/Maumee and St. Louis regions exhibited stocks under backwardation, while for the F-S spread 18.06%, 25 % and 35.34 % had a similar pattern.[3] Similar to corn, the magnitude (mean, median) of the stocks held under backwardation were smallest in St. Louis, but larger using both spread measures in Toledo/Maumee and Chicago.

For CBOT wheat, evidence of wheat stocks being held under inverse carrying charges can be seen in the figures for the Chicago region (W.1.a $\rightarrow$ F-F, W.1.b $\rightarrow$ F-S) and Toledo/Maumee region (W.2.a $\rightarrow$ F-F, W.2.b $\rightarrow$ F-S). In both these markets, we observe strong signs in support of convenience yield in the futures-futures spread measure. In the futures-spot measure, a large upward slope exists in the Working curve, particularly in Toledo/Maumee. This strong slope is likely related to poor convergence in the more recent periods and perhaps to storage capacity constraints. In Chicago, Toledo/Maumee and St. Louis regions, the percentage

[3] Recall river delivery locations were excluded because we lacked spot prices, and because they are basically thru-put operations with limited stocks. This was generally confirmed using F-F spread measure, except for soybeans where we found stockholding in the presence of backwardation and percentages of observations similar to those just discussed.

of total observations showing storage under backwardation were 13.86 %, 15.53% and 9.30 % for the F-F spread and 4.95 %, 4.85 % and 16.28 % for the S-F spread. Overall, the magnitude of the stocks carried under backwardation is again largest in Toledo/Maumee, followed by Chicago and St. Louis. In contrast to the first two markets, here the magnitudes drop sharply using the F-S spread.

For Kansas City wheat (K.1.a $\rightarrow$ F-F, K.1.b $\rightarrow$ F-S), the evidence appears to be overwhelming for stockholding under backwardation, and convenience yield in the Working curve. Regardless of which spread measure is used, more than 35% of the observations exhibit storage under backwardation, with the magnitude of stocks held under backwardation always exceeding 6.5 million bushels.

Conclusion

In this study we investigate storage in the presence of backwardation and the existence of the Working curve for CBOT corn, soybeans, and wheat markets and the KCBOT wheat market using recent data, 1990-2010. Incorporating Telser's concept of the cost of carry, we employ two measures of the spread—the percent of full carry for futures-futures and futures-spot (maximum) spreads which are adjusted for interest and storage rates. Both spreads are calculated relative to the next nearby futures contract and are matched with closest weekly deliverable stock information available at the delivery locations for the contracts.

With regards to storage at a loss and the existence of the Working curve, the evidence differs somewhat by spread measure, commodity, and delivery location. Often futures-futures spreads provide strongest evidence of storage and backwardation, except for the KCBOT wheat market. Nevertheless, the findings indicate that storage at a loss is pervasive both in terms of the

percent of observations that exhibited storage at a loss, and the magnitude of the stockholdings for those observations. The evidence for the importance of convenience yield in the Working curve is a little less systematic, with strongest support emerging in the KCBOT wheat market, CBOT wheat and corn in Toledo/Maumee, corn in Chicago, and soybeans at almost all locations. In sum, the results support Working's original analysis, and Carter and Giha's re-assessment. We provide further support that this phenomenon can occur in a number of important agricultural markets in modern times.

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Table 1.) Deliverable Stocks on First Delivery Day by Delivery Locations (1000 bu.)

			% F.C.	*CH*	*T/M*	*ST*
CBOT	Corn	Mean	39	4569.13	8579.10	320.27
		Standard Deviation	89	4743.90	5269.91	232.98
		Min.	-733	35.00	144.00	4.00
		Max.	93	23735.00	22496.00	1041.00
	Soybean	Mean	-26	4779.50	4162.98	309.80
		Standard Deviation	229	4867.44	3674.32	232.57
		Min.	-1675	28.00	187.00	11.00
		Max.	229	20791.00	16197.00	1443.00
	Wheat	Mean	43	3477.57	17178.60	1050.01
		Standard Deviation	95	3556.68	9566.29	663.26
		Min.	-448	1.00	40.00	61.00
		Max.	122	12477.00	32462.00	3234.00
			% F.C.	*KC*		
KCBOT	Wheat	Mean	-284	706.00		
		Standard Deviation	122	27477.00		
		Min.	3	11216.38		
		Max.	94	7729.16		

% F.C: Futures-futures spread expressed as a percent of full carry at: CH: Chicago, LS: Lockport-Seneca, OC: Ottawa-Chillecothe, CCP: Creve Coeur-Pekin, HG: Havana Grafton, T/M: Toledo/Maumee, ST: St. Louis, NO: Northwest Ohio, OR: Ohio River, MR: Mississippi River, KC: Kansas City, H: Hutchinson, S: Salina, W: Wichita.

Table 2.) Percent of the Observations on First Delivery Day with Deliverable Stocks and Backwardation (F-F Spread)

			CH	T/M	ST
CBOT	Corn	% with storage under loss	15.53	28.00	28.00
		No. of observations	103.00	50.00	50.00
		Mean (1000 bu.)	1624.50	6232.00	230.21
		Median (1000 bu.)	1108.50	4503.00	173.50
	Soybean	% with storage under loss	29.86	39.28	34.48
		No. of observations	144.00	84.00	117.00
		Mean (1000 bu.)	1899.56	2082.26	191.07
		Median (1000 bu.)	865.00	1110.00	180.00
	Wheat	% with storage under loss	13.86	15.53	9.30
		No. of observations	103.00	103.00	86.00
		Mean (1000 bu.)	1357.00	7890.94	1203.75
		Median (1000 bu.)	401.00	6084.50	1092.50
			KC		
KCBOT	Wheat	% with storage under loss	37.86		
		No. of observations	103.00		
		Mean (1000 bu.)	7010.38		
		Median (1000 bu.)	6692.00		

Table 3.) Percent of the Observations on First Delivery Day with Deliverable Stocks and Backwardation (F-S Spread)

			CH	T/M	ST
CBOT	Corn	% with storage under loss	8.74	14.00	42.00
		No. of observations	103.00	50.00	50.00
		Mean (1000 bu.)	1895.78	4245.71	294.90
		Median (1000 bu.)	1505.00	3604.00	184.00
	Soybean	% with storage under loss	18.06	25.00	35.34
		No. of observations	144.00	84.00	117.00
		Mean (1000 bu.)	1617.69	657.57	208.12
		Median (1000 bu.)	557.50	655.00	199.50
	Wheat	% with storage under loss	4.95	4.85	16.28
		No. of observations	103.00	103.00	86.00
		Mean (1000 bu.)	406.43	2270.80	596.00
		Median (1000 bu.)	63.00	1802.00	540.00
			KC		
KCBOT	Wheat	% with storage under loss	39.81		
		No. of observations	103.00		
		Mean (1000 bu.)	8113.00		
		Median (1000 bu.)	7819.00		

Figure C.1.a.) Backwardation: Corn, Chicago Region (F-F)

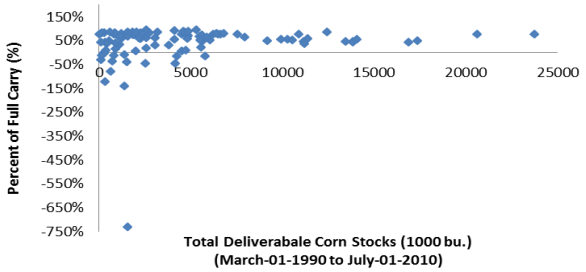


Figure C.1.b.) Backwardation: Corn, Chicago Region (F-S)

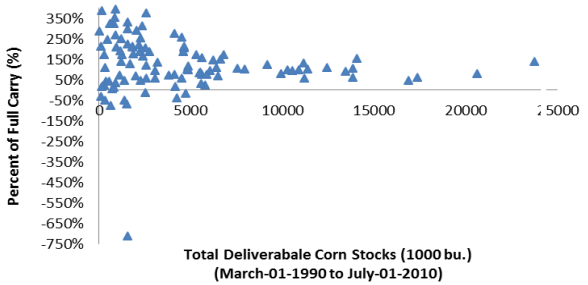


Figure C.2.a) Backwardation: Corn, Toledo-Maumee Region (F-F)

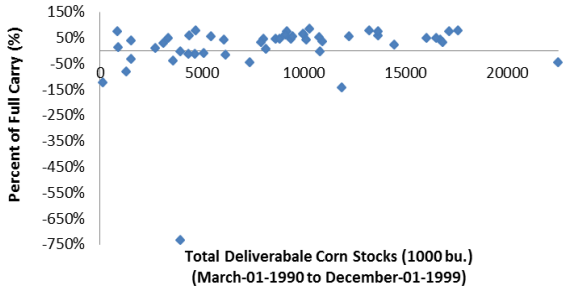


Figure C.2.b) Backwardation: Corn, Toledo-Maumee Region (F-S)

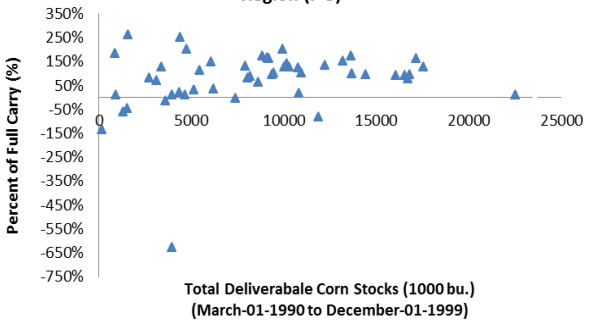


Figure C.3.a) Backwardation: Corn, St. Louis Regio (F-F)

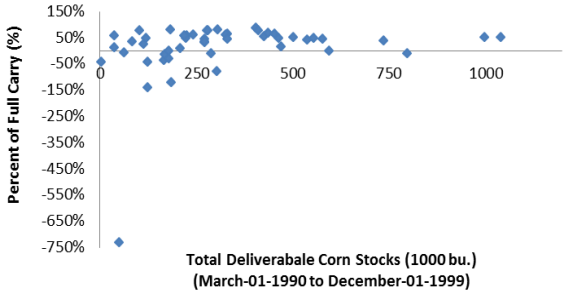


Figure C.3.b.) Backwardation: Corn, St. Louis Region (F-S)

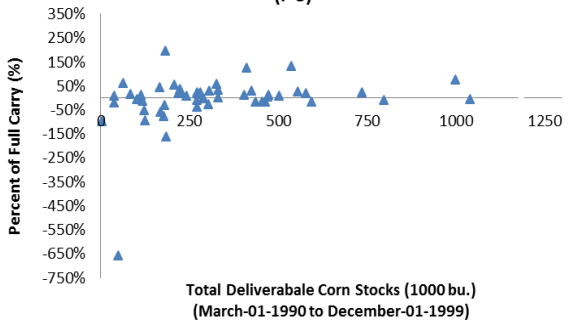


Figure S.1.a) Backwardation: Soybean, Chicago Region (F-F)

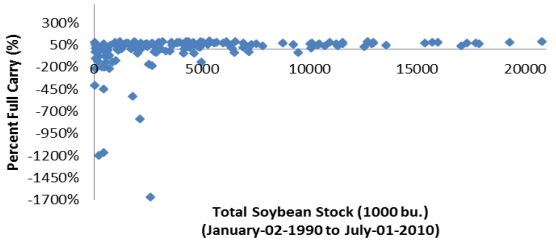


Figure S.1.b.) Backwardation: Soybean, Chicago Region (F-S)

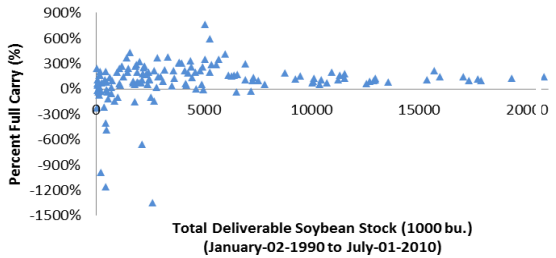


Figure S.2.a.) Backwardation: Soybean, Toledo-Maumee Region (F-F)

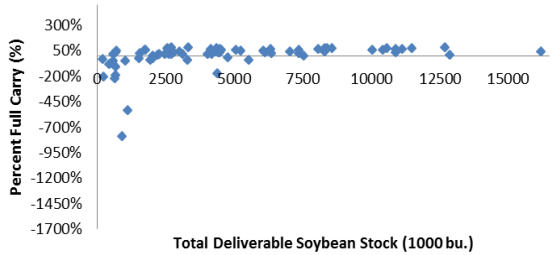
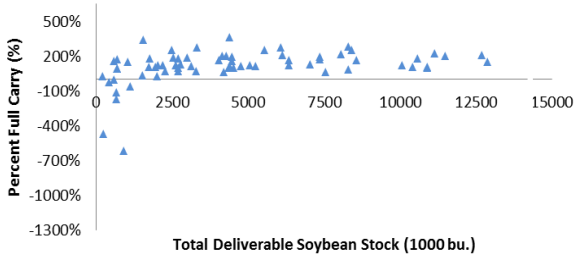


Figure S.2.b.) Backwardation: Soybean, Toledo Region (F-S)



Figuret S.3.a.) Backwardation: Soybean, St. Louis Region (F-F)

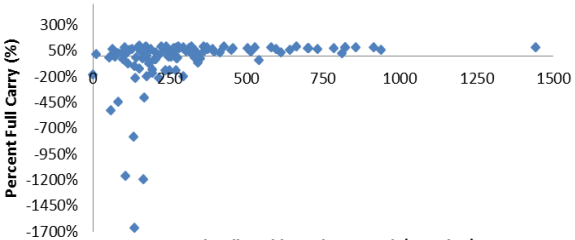


Figure S.3.b.) Backwardation: Soybean, St. Louis Region (F-S)

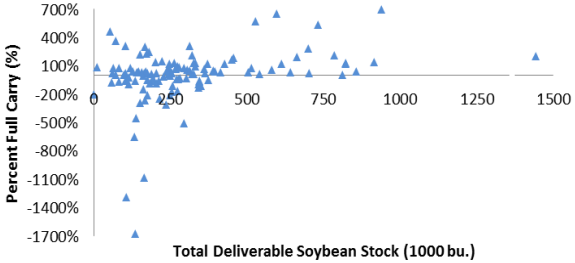


Figure W.1.a.) Backwardation: Wheat, Chicago Region (F-F)

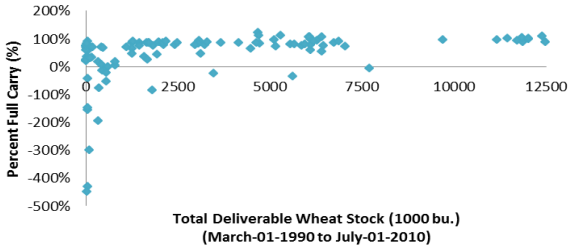


Figure W.1.b.) Backwardation: Wheat, Chicago Region (F-S)

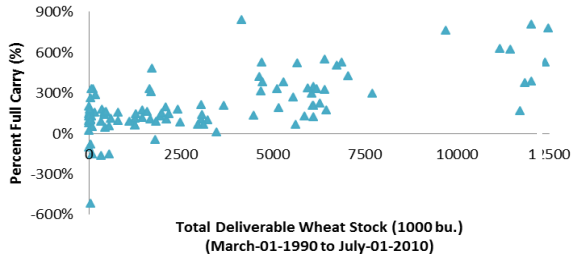


Figure W.1.a.) Backwardation: Wheat, Toledo/Maumee Region (F-F)

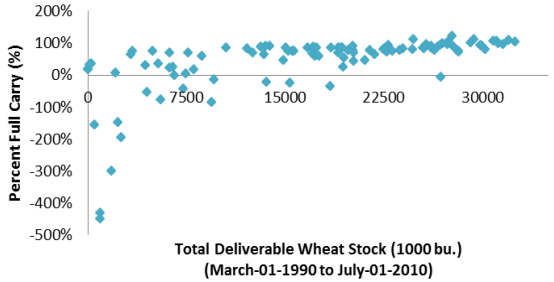


Figure W.2.b.) Backwardation: Wheat, Toledo/Maumee Region (F-S)

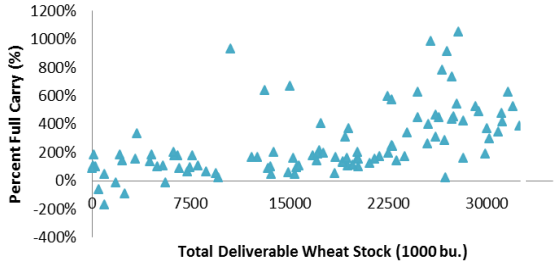


Figure W.3.a.) Backwardation: Wheat, St. Louis Region (F-F)

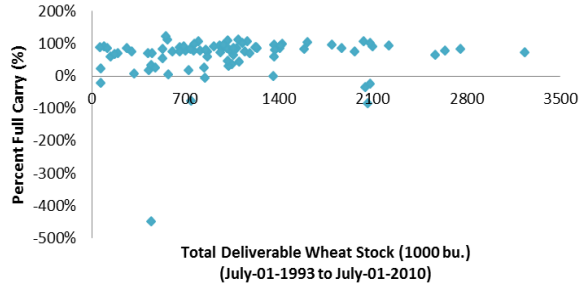


Figure W.3.b.) Backwardation: Wheat, St. Louis Region (F-S)

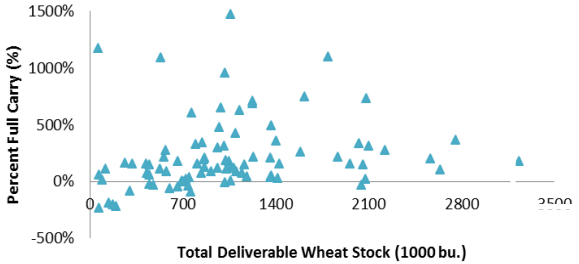


Figure K.1.a.) Backwardation: Wheat, Kansas Region (F-F)

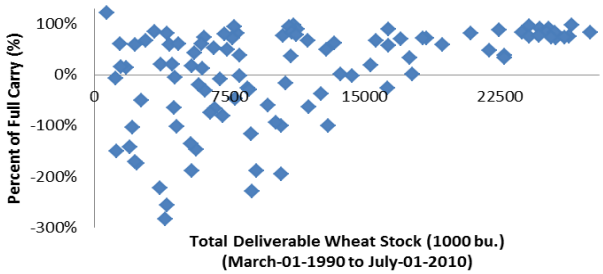
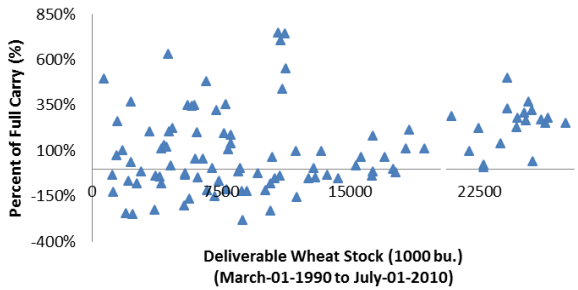


Figure K.1.b.) Backwardation: Wheat, Kansas City Region (F-S)



Appendix A: Data Sources and Background

(a) Futures prices.

Futures prices are from Barchart. Futures contract trading at CBOT stops daily at 1:15 p.m. CST, except on holidays and on the last trading day, trading stops at noon CST. Trading at KCBT takes place between 9:30 a.m. and 1:15 p.m., Monday through Friday and trading stops at 1:15 p.m. on the last trading day.

http://www.barchart.com/

(b) The CBOT delivery locations and deliverable grades: Corn, Soybean and Wheat.

The deliverable grades for CBOT corn are U.S. #2 yellow at contract Price, U.S. #1 yellow at a 1.5 cent/bu. premium and U.S. #3 yellow at a 1.5 cent/bu. discount. Delivery rate at delivery locations are subject to class and grade differentials as mentioned above. The delivery location and rate for CBOT corn contract are Chicago switching district or the Burns harbor, Indiana switching district at par, Lockport-Seneca switching district at a premium of 2 cents/bu., Ottawa-Chillicothe switching district at a premium of 2.5 cents/bu., Creve Coeur-Pekin at a premium of 3 cents/bu., Toledo/Maumee area from 1989 to September 1993 at 4 cents/bu. discount and from December 1993 to December 1999 at a discount of 3 cents/bu. The rate at St. Louis area was at a discount of 4 cents/bu. from 1989 to September 1993 and a premium of 7 cents/bu. from December 1993 to December 1999.
http://www.cmegroup.com/rulebook/CBOT/II/10/

The deliverable grades for CBOT soybean contract are U.S. #2 yellow soybeans (maximum 14% moisture) at par, U.S. #1 yellow soybeans (maximum 13% moisture) at 6 cents/bu. premium, and U.S. #3 yellow soybeans (maximum 14% moisture) at 6 cents/bu. discount. Delivery rate at delivery locations are subject to class and grade differentials as mentioned above. The delivery location and rate for CBOT soybean contract are Chicago switching district or the Burns harbor, Indiana switching district at par, Lockport-Seneca switching district at a premium of 2 cents/bu., Ottawa-Chillicothe switching district at a premium of 2.5 cents/bu., Creve Coeur-Pekin at a premium of 3 cents/bu., and Havana-Grafton shipping district at a 3.5 cents/bu. premium. Toledo/Maumee area was also a delivery location during the earlier period of the analysis. The rate at the Toledo/Maumee area from 1979 November to December 1993 was at a 4 cents/bu. discount and a discount of 3 cents/bu. from November 1993 to November 1999. St. Louis area was at a premium of 8 cents/bu. from November 1993 to November 1999 and present delivery at St. Louis, St. Louis East and Alton switching district is at a 6 cents/bu. premium.
http://www.cmegroup.com/rulebook/CBOT/II/11/

The deliverable grades for CBOT wheat contract are U.S. #2 Soft Red Winter, U.S. #2 Hard Red Winter, U.S. #2 Dark Northern Spring, and U.S. #2 Northern Spring at contract Price. U.S. #1 Soft Red Winter, U.S. #1 Hard Red Winter, U.S. #1 Dark Northern Spring, and U.S. #1 Northern Spring are deliverable at a 3 cents/bu. premium. Delivery rate at delivery locations are subject to class and grade differentials as mentioned above. The delivery location and rate for

CBOT corn contract are Chicago delivered at par, Toledo at par, St. Louis at a 10 cents/bu. premium, Ohio River at par, Northwest Ohio at a 20 cents/bu. discount and the Mississippi river at a 20 cents/bu. premium.
http://www.cmegroup.com/rulebook/CBOT/II/14/

From 12/01/1981 through 11/30/1990 the CBOT storage rate was 16/100 cents/bu./day. From 12/01/1990 through 12/31/1999 the storage rate was 15/100 cents/bum/day. From 5/15/2008 onwards the storage rate used is 16.5/100 cents/bu./day. The variable storage rate system was introduced from the July 2010 contract and data since this period has not used in this study.
http://www.cmegroup.com/rulebook/CBOT/

Deliverable stocks of grains are available from the registrar reports of CME group. Deliverable Stocks of Grain, as of Fridays for the agricultural complex are released the following Tuesday by 1:00 p.m. Central Time.
http://www.cmegroup.com/market-data/reports/registrar-reports

(c) KCBOT delivery locations and deliverable grades: Wheat

The deliverable grade is #2 HRW wheat, #1 is deliverable at a 1.5 cent/bu. premium deliverable at Kansas City, Missouri/Kansas at par, Hutchinson, Kansas at 9 cents/bu. under contract price, Salina/Abilene, Kansas 12 cents/bu. under contract price or Wichita, Kansas at 6 cents/bu. under contract price. The storage rates for KCBT HRW wheat contract is 14.8/100 cents/bu./day.
http://www.kcbt.com/histdata/rule_book/CH20.pdf

Deliverable wheat stocks at Kansas City are from the KCBT deliverable stocks report.
http://www.kcbt.com/deliverable_stocks.asp

(d) Interest rates:

Interest rates are from the British Bankers' Association (BBA): 3-month LIBOR. The LIBOR+200 basis points is used as the interest rate for this study.
http://www.bba.org.uk/media/article/daily-bba-libor-rate.