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**Is Storage Rational When the Price is Expected to Decline?
An Initial Study Using Data from U.S. Futures and Options Markets**

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Abstract

The expected net return to storage is conventionally calculated as the expected change in price over the storage period minus the cost of storage. However, this value is almost always negative, thus raising the question why would anyone store. Numerous explanations have been proposed, but none is widely accepted. This study initiates a new line of investigation based upon the identification of the different options embedded in the holding of stocks. Specifically, the traditional calculation of the net return to storage is shown to be equivalent to the value of a put option minus the value of a call option. Both options mature at the end of the storage period and have a strike price equal to the initial storage period price plus the cost of storage. This conceptual derivation is confirmed using data from the U.S. corn and soybean options traded on the Chicago Mercantile Exchange.

Is Storage Rational When the Price is Expected to Decline? An Initial Study Using Data from U.S. Futures and Options Markets

Introduction

Ever since Working published his seminal articles on the supply of storage (1948, 1949), debate has swirled around the apparently economically irrational empirical observation that stocks exceed zero even when price is expected to decline. Numerous explanations have been proposed, but none is widely accepted. This study initiates a new line of investigation based upon identification of the different options embedded in the holding of stocks. Specifically, this paper conceptually shows that the traditional calculation of the net return to storage is equivalent to the difference in two option values. It then confirms this conceptual derivation using data from the U.S. corn and soybean options markets.

The paper is structured as follows. It first reviews studies that have estimated the supply of storage, followed by a discussion of convenience yield. Next, the derivation of an alternative interpretation of the net return to storage using options is presented. This option measurement is then investigated using data from the corn and soybeans markets in the U.S. A summary and conclusion section ends the paper.

Literature Review

In his seminal articles, Working (1948, 1949) posited that the difference between a nearby and distant price for the same commodity was a market-determined return to storing the commodity over the time interval. This interpretation was applied whether

price was expected to increase (distant price exceeds nearby price) or decrease (distant price is less than the nearby price). Based on earlier empirical work (Hoos and Working, 1940; Working, 1933 and 1934) Working presented a stylized supply of storage curve. This stylized storage curve (see Figure 1) has been confirmed by subsequent research (Telser, 1958; Brennan, 1958; Gray and Peck, 1981; Thompson, 1986, Brennan, 1991; Milonas and Henker, 2001; Milonas and Thomadakis, 1997a; Sorensen, 2002)¹.

To explain why stocks would be held when price was expected to decline, Working borrowed the idea of convenience yield from Kaldor (1939). Kaldor defined convenience yield as the benefit that accrues from having immediate access to stocks. Working argued that this benefit should be greatest when stocks were small and smallest (even zero) when stocks were large. Working further argued that this convenience yield benefit of stocks offset the loss expected from the decline in price. By implication, the expected net return to storage was zero no matter how small or large were stocks.

Intense debate has ensued over whether or not convenience yield exists and whether or not it is necessary to explain the holding of stocks when price is expected to decline. Alternative explanations also have been proposed for this apparently irrational economic phenomena, including (1) a nonlinear cost of production (Williams, 1987; Wright and Williams, 1989); (2) a nonlinear cost of merchandising stocks, including transportation cost (Bobenrieth H., Bobenreith H., and Wright, 2004), (3) transportation cost resulting from geographically dispersed producers (Benirschka and Bindley, 1995; Brennan, Williams, and Wright, 1997; and Frechette and Fackler, 1999); (4) transaction costs of holding and handling stocks (Chavas, Despins, and Fortenbery, 2000), (5)

sufficiently risk averse competitive storage firms (Chavas, 1988); (6) asymmetric information (Khoury and Martel, 1989; Frechette, 1999 and 2001); and (7) a positive call option value to defer production (Litzenberger and Rabinowitz, 1995).

Wright and Williams (1989) observed that, if convenience yield does not exist, then stocks of a specific grade of a commodity should not be observed at local markets when the local inter-temporal price spread for the specific grade is negative. Brennan, Williams, and Wright (1997) found that wheat stocks indeed were zero when returns to storage were negative at local markets in Western Australia. Frechette and Fackler (1999) argued that Wright and Williams' observation implied that the distribution of stocks, not the level of stocks, should be the primary determinant of negative inter-temporal spreads. However, Frechette and Fackler found that the level of stocks explained more of the variation in December-March corn futures spreads than did the location of stocks.

Over approximately the same time period that alternatives to convenience yield appeared, the literature on convenience yield has moved toward conceptualizing convenience yield as the value of a call option held by the holder of the stocks. Bresnahan and Spiller (1986), followed by Milonas and Thomadakis (1997a and 1997b), argued that this call option will have value if there is a non-zero probability that a stock-out (i.e., zero stocks) can occur before the end of the expected storage period. Their argument is an update of Keynes' (1930) "liquid stocks" theory. Heinkel, Howe, and Hughes (1990) broaden this interpretation by showing that the call option will have value whenever demand shocks create a non-zero probability that current stocks may be sold at a higher price during the storage period. Both Heinkel, Howe, and Hughes (1990) and

Milonas and Thomadakis (1997a and 1997b) find that the value of the call option is negatively related to the level of stocks.

From the theory of options, if convenience yield is a call option on current stock holdings, the value of the call option should be positively related to the variability of the relevant cash price and to the exercise price of the option (Milonas and Thomadakis, 1997a). Empirical support has been found for the hypothesized relationship involving exercise price (Milonas and Thomadakis, 1997a) but not price variability (Milonas and Thomadakis, 1997a; Sorensen, 2002). Furthermore, Zulauf, Zhou, and Roberts finds that Heaney's (2002) metric for estimating the call option² value of convenience yields explains only 60 percent of the variation in the storage adjusted old crop – new crop futures price spread in the U.S. soybean market between 1988 and 2004. While a 60 percent explanation share is large for a single variable, this finding also suggests that either other variables are needed to explain the storage cost adjusted spread or that Heaney's estimate of the value of the call option associated with stocks can be improved.

In conclusion, many explanations have been proposed for why stocks are held even when price is expected to decline. However, empirical studies have not found uniform support for any of the proposed explanations. Thus, no alternative is widely accepted as the likely explanation for why stocks are held when price is expected to decline.

Model

For the sake of simplicity, assume a risk neutral storage agent in a two period world with uncertainty. The agent has two alternatives: (1) sell now at time t for the certain cash price, or (2) store to sell at future time $t + 1$ for an uncertain price. Also assume a futures market exists for time $t + 1$. The returns to storing until time $t + 1$ as of time t is conventionally stated as:

$$SR_{t,t+1} = \bar{P}_{t+1,t} - P_t^* \quad (1)$$

where: (1) $SR_{t,t+1}$ is the expected net return when storing from time t to time $t + 1$; (2) $\bar{P}_{t+1,t}$ is the futures price expected for time $t + 1$ at time t --- if the futures market is assumed to be efficient and to provide an unbiased forecast, $\bar{P}_{t+1,t}$ is the mean price of the expected price distribution for time $t + 1$ at time t ; and (3) P_t^* is the cash price at time t plus storage cost from time t to $t + 1$ (physical storage cost, interest opportunity cost, and insurance).

Because storage arbitrage will move stocks from time t to $t + 1$ if expected net returns to storage exceeds zero, P_t^* is bound on the lower side by $\bar{P}_{t+1,t}$. However, P_t^* is not bound on the upper side because supply cannot be moved backward in time. Thus, $SR_{t,t+1}$ will be less than or equal to zero. A negative $SR_{t,t+1}$ is the Kaldor-Working measure of convenience yield.

However, Equation 1 can be restated as follows using the rules of integration:

$$P_{t+1,t} - P_t^* = \int_{P^*}^{\infty} (P - P^*) f(P) dP - \int_0^{P^*} (P^* - P) f(P) dP \quad (2)$$

where (1) P is an expected price at time $t + 1$ and (2) $f(P)$ is the probability of observing

that price at time $t+1$ as of time t^4 . The first right-hand term is the value of a European call with a strike price of P^* , which is illustrated as $Call_A$ in Figure 1. The second right-hand term is the value of a European put with a strike price of P^* , which is illustrated as Put_B in figure 1. Thus, the traditional net storage return equation also equals:

$$P_{t+1,t} - P_t^* = \text{European Call}_{t+1,t}[P_t^*] - \text{European Put}_{t+1,t}[P_t^*] \quad (3)$$

The value of the European call at strike price, P_t^* , with maturity at $t+1$ is the expected net storage return at t that is earned when price increases by more than the cost of storage between time t and $t+1$. The value of the European put at strike price, P_t^* , with maturity at $t+1$ is the expected net storage return at t that is earned when price increases by less than the storage cost between time t and time $t+1$.

Data and Variable Measurement

The different measures of net storage returns are evaluated for corn and soybean stocks carried from one crop year to the next. Carryout stocks are chosen for analysis because they have been commonly evaluated in the storage literature. Moreover, each month the U.S Department of Agriculture (USDA) issues an estimate of stocks carried out of the current crop year, as well as other supply and demand information, for corn and soybeans in its *World Agricultural Supply and Demand Estimates (WASDE)* report. These reports are widely-followed, key market events.

Contemporaneous data exists for corn and soybean stocks, futures prices, option prices, and storage costs are collected as of the first non-limit close of corn and soybean futures prices after the release of *WASDE*. Contemporaneous data minimizes

measurement error by aligning prices with the information set used by the market to determine them. Waiting to collect the data at the first non-limit close allows the market time to incorporate new supply and demand information contained in *WASDE* into futures and options prices.

Corn and soybeans are chosen for analysis because they are the largest acreage field crops in the U.S. They also have liquid markets for futures and options contracts. Soybean is also chosen for analysis because public stocks of soybean have been minimal⁴. Public stocks can displace privately held stocks, thus affecting private storage relationships (Sharpley and Holland, 1981). The 1986/87 crop year was the last time that public stocks of soybeans were held.

The spread between old crop and new crop prices is measured using the July and November futures for soybeans and July and December futures for corn. July is the old crop futures contract while November soybeans and December corn are the new crop futures contract. Soybeans futures and options are traded for August and September delivery while corn futures and options are traded for the September delivery. September can trade as a new crop or an old crop contract depending on how early harvest is. Hence, it was not used in this analysis. The August soybean contract is generally lightly traded and thus was not chosen over the more heavily traded July soybean contract.

To avoid statistical problems associated with overlapping samples as well as the potential for seasonal effects resulting from a crop with a harvest, annual data are used. Trading of options began in 1984 and 1985 for soybeans and corn, respectively (Board of Trade of the City of Chicago, 1989). Due to low trading volume during the early years of

options trading for corn and soybeans, this study begins with stocks carried out of the 1989/90 crop year. It ends with stocks carried out of the 2012/13 crop year. Thus, the sample size is 24.

Corn and soybeans stocks carried out of a crop year are measured as of September 1. Thus, the observations months were later in the crop year because more accurate information should exist regarding carryout stocks. However, the observation months could not be later than June since option trading on the July corn and soybean contracts ends around the 20th of June, with the specific date varying by year. As a result of these two considerations, this study uses the WASDE reporting dates for April, May, and June.

Calculation of the storage cost adjusted July futures price for storage is illustrated for soybeans from July through November as of *WASDE* release date t :

$$SCS_t = \text{July Futures}_t + \text{IntCost}_{tN} + \text{PSC}_{tN} \quad (5)$$

where

$$\begin{aligned} \text{IntCost}_{tN} &= \text{interest cost between July and November, calculated as:} \\ &= r_t \bullet (\text{July Futures}_t) \bullet 0.3335 \end{aligned} \quad (6)$$

r_t = six month U.S. Treasury Bill Rate

0.3335 = proportion of year between July and November

$$\begin{aligned} \text{PSC}_{tN} &= \text{physical storage cost between July and November, calculated as:} \\ &= SC_t \bullet 0.3335 \end{aligned} \quad (7)$$

SC_t = annual storage charge

Interest and physical storage cost are estimated using discrete rather than continuous time methods because physical storage cost is reported in discrete time intervals, either per month or per year.

Futures and options prices are for contracts traded on the Chicago Mercantile Exchange and obtained from Barchart.com. Interest rates are six month U.S. Treasury Bill rates from the Federal Reserve Economic Data maintained by the Federal Reserve Bank of St. Louis. Physical storage costs are from the USDA, Commodity Credit Corporation (CCC) through the 2008 crop year. However, CCC changed the method used to report storage rates by commodity, resulting in a substantial change in storage rates. Thus, for the more recent years, physical storage rates were collected from an Ohio country elevator and then cross checked with another Ohio elevator. This storage rate is more consistent with the storage rates previously reported by CCC.

Estimation Issues

Options for corn and soybeans at the Chicago Mercantile Exchange are traded at discrete strike prices. The interval between strike prices was 25 cents per bushel for soybeans until 2000 and then became 20 cents per bushel. For corn, the strike price has been 10 cents per bushel over the study period. It is unlikely that the strike prices identified by the option valuation of storage will match one of the discretely traded strike prices. Therefore, the option value of a strike price associated with the option valuation of storage is calculated using linear interpolation of the two traded strike prices that bracket it. More sophisticated estimation procedures can be used. For example, the

traded option premiums can be used to estimate the curvature of the price distribution. However, because adjacent traded strike prices are being used, linear interpolation should provide a relatively accurate approximation of the option premiums associated with the option valuation of storage model.

To illustrate the linear interpolation, consider the observation for February 2000. The September 2000 futures price plus storage cost equals \$5.38 cents per bushel. The two November 2000 option strike prices that bracket \$5.38 are \$5.25 and \$5.50. Premium for the \$5.25 and \$5.50 November 2000 call is \$0.48 and \$0.395 per bushel, respectively, on February 12, 2000, the first non-limit close after the release of the February 2000 WASDE. A \$0.44 premium is calculated for the \$5.38 strike price as follows:

$$[(\$0.48 * ((\$5.38 - \$5.25) / \$0.25)) + (\$0.395 * ((\$5.50 - \$5.38) / \$0.25))] = \$0.44 \quad (8)$$

Option premium are missing for four dates: corn on April 11 and May 10, 1996, and soybeans on June 12, 1997 and May 12, 2004. These dates are therefore excluded from the empirical analysis.

Empirical Results

Figures 2 and 3 contain a graph for corn and soybeans, respectively, of the net expected returns to storage calculated using the traditional calculation method and the option calculation method. Both graphs reveal that the traditional method of calculation generates the same values as the difference in the premiums for the call and puts options.

R^2 rounds to 1.0 in all six cases. Thus, the traditional calculation of the net return to storage can be expressed as the difference between two options.

Summary and Conclusions

This article has shown conceptually that the traditional method used to calculate the net return to storage is equivalent to the calculation involving options with a strike price equal to nearby futures price plus the cost of storing from the delivery month of the nearby futures price to the delivery month of the more distance futures price. This conceptual derivation is confirmed by using data generated from the trading of corn and soybean options on the Chicago Mercantile Exchange.

Ever since Working published his seminal articles on the supply of storage (1948, 1949), debate has swirled around the apparently economically irrational empirical observation that stocks exceed zero even when price is expected to decline. Many explanations have been put forward, but none has been accepted.

The finding of this study that the net returns to storage can be expressed using options may provide a path for explaining why stocks are held when price is expected to decline. Specifically, does the current understanding of storage include all the possible options associated with storage? This proposed approach is related to but different than the approach proposed by Milonas and Thomadakis (1997a) as an explanation for why stocks are stored when price is expected to decline. Future research will explore whether options offer a potential explanation for storage when price is expected to decline.

Footnotes

1. Consistent with the supply of storage theory, Heaney (1998) found that only one cointegrating vector exists among a constant term, interest rate, three month futures price of lead at the London Metals Exchange (LME), cash LME price of lead, and stocks of lead held in LME-approved warehouses.
2. Heaney (2002) notes that the call option on holding stocks attains its highest value when the agent has perfect foresight to sell at the highest price that occurs over the storage period. He develops a formula to estimate this call value by drawing on Longstaff's (1995) model for estimating the value of marketability (liquidity) of securities. Heaney's derivation finds that the value of the call options is related to the difference between the variance of the cash market price and the variance of the price of the futures contract at the end of the storage period, as well as the time to futures contract maturity. In essence, the greater the variability of the cash market relative to the futures market, the greater is the value of the call option to sell stock before the end of the storage period.

$$\begin{aligned}
 3. \int_{P^*}^{\infty} (P - P^*) f(p) dP - \int_0^{P^*} (P^* - P) f(p) dP &= \int_{P^*}^{\infty} P f(p) dP - \int_{P^*}^{\infty} P^* f(p) dP - \int_0^{P^*} P^* f(p) dP + \int_0^{P^*} P f(p) dP \\
 &= \int_{P^*}^{\infty} P f(p) dP + \int_0^{P^*} P f(p) dP - \int_{P^*}^{\infty} P^* f(p) dP - \int_0^{P^*} P^* f(p) dP = \int_0^{\infty} P f(p) dP - \int_0^{\infty} P^* f(p) dP = \bar{P}_{t+1,t} - P^*
 \end{aligned}$$

4. Soybean also is the only major U.S. crop that never had an annual acreage control program.

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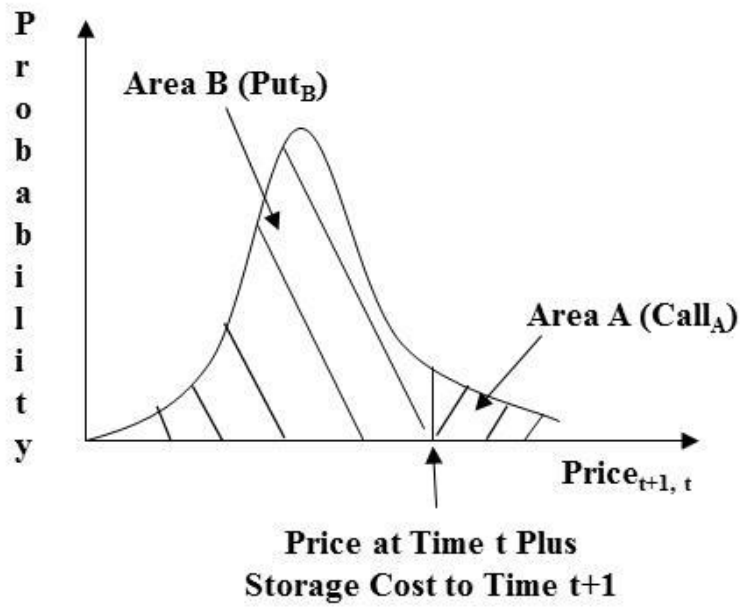
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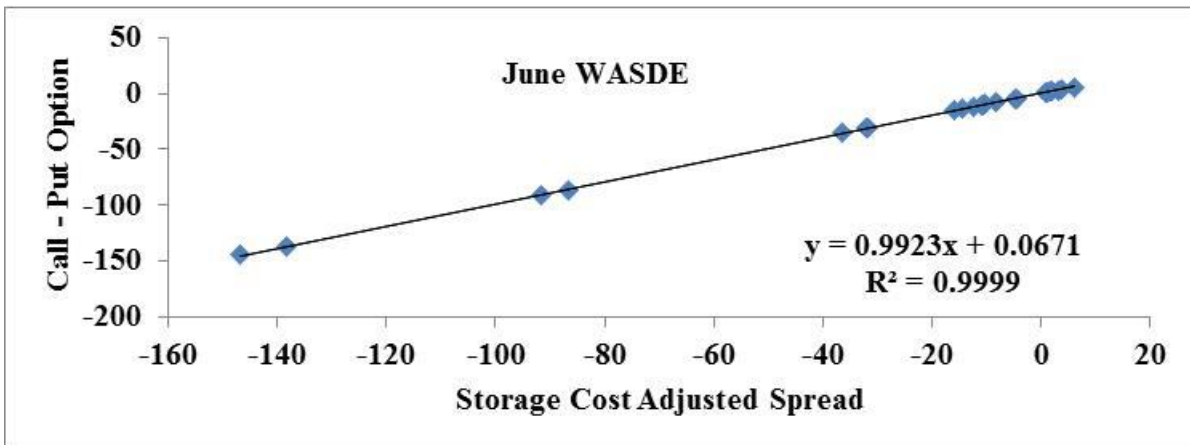
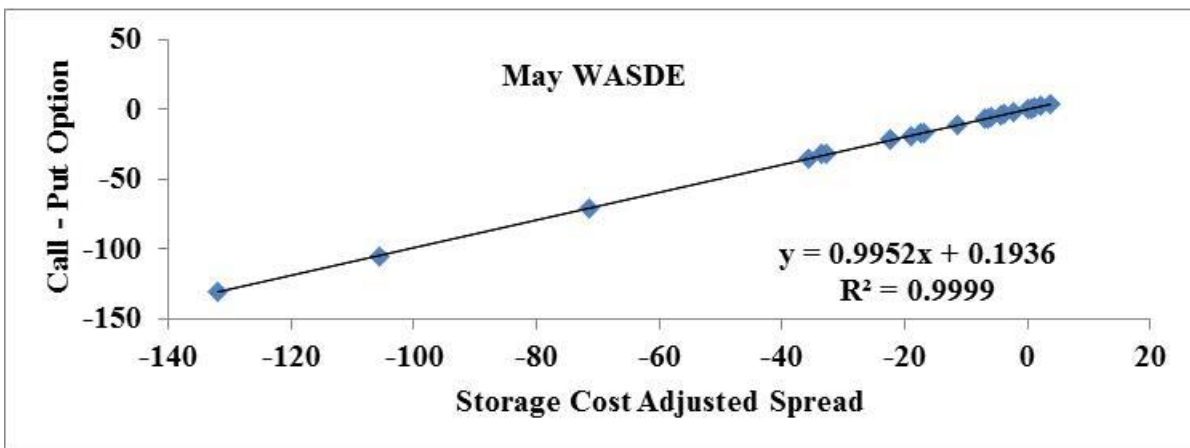
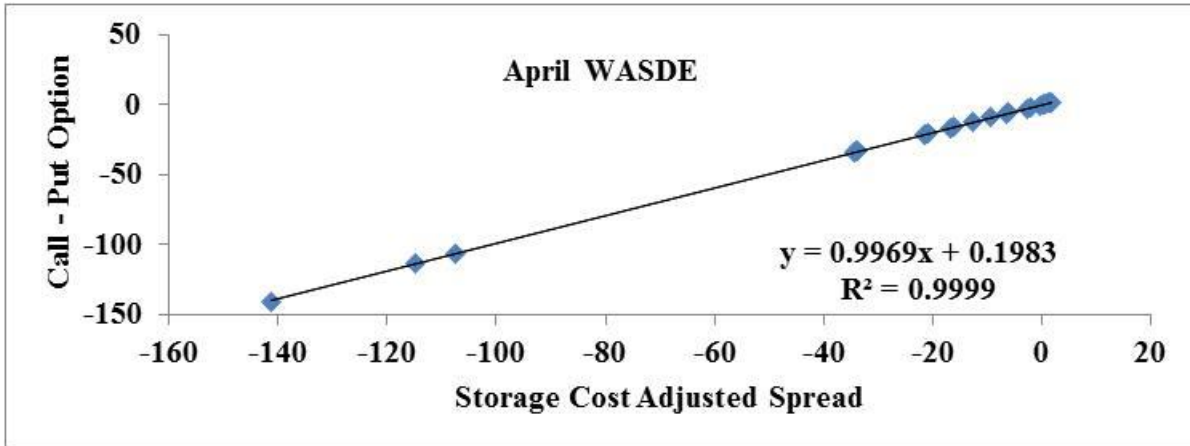
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FIGURE 1: Options associated with the return to storage calculation.



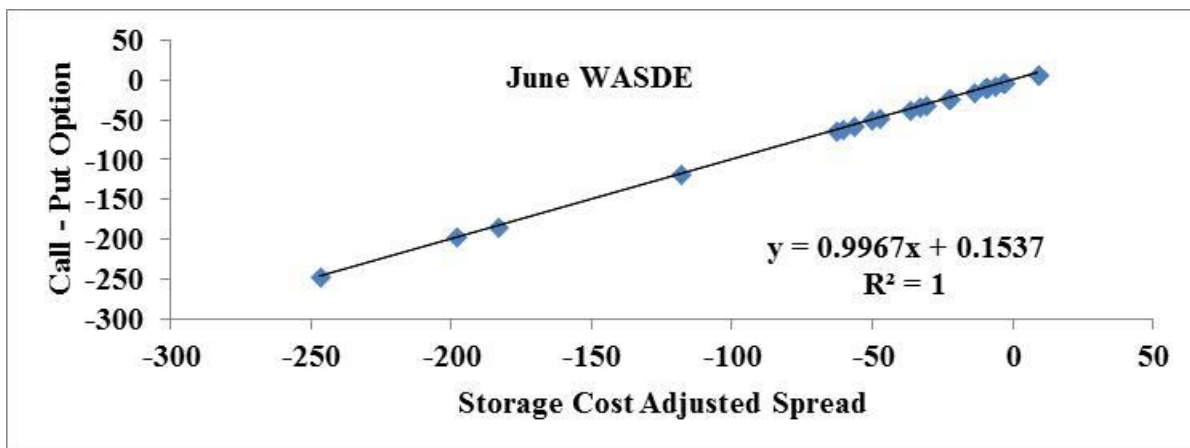
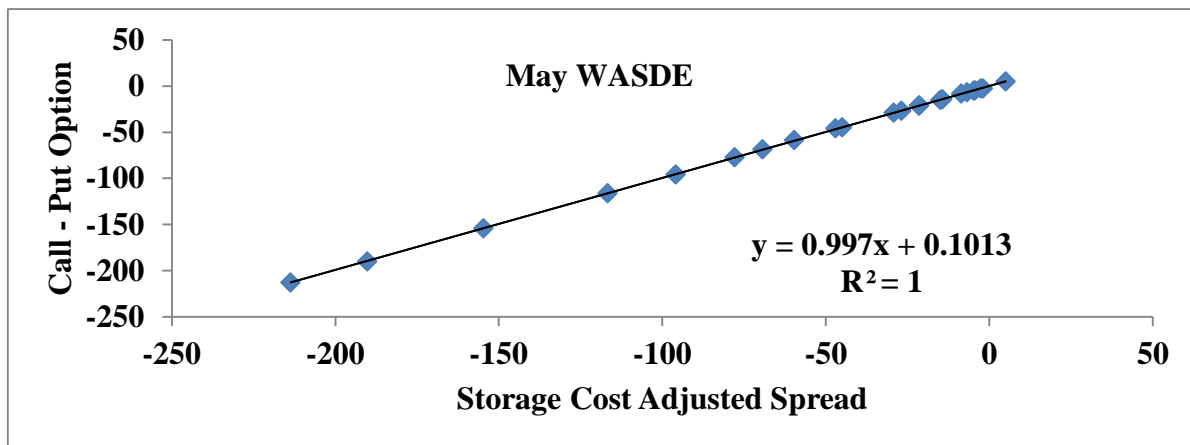
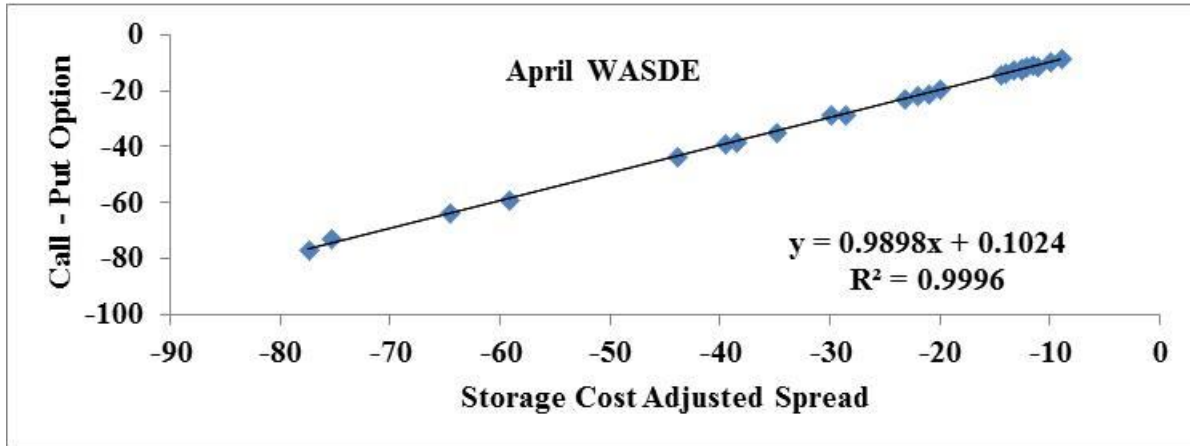
Notes: (A) Area A is the value of a European call with a strike price equal to the cash price at time t plus storage cost from time t to time t+1. (B) Area B is the value of a European put with a strike price equal to the cash price at time t plus storage cost from time t to time t+1.

FIGURE 2: Relationship between the storage cost adjusted price spread and the November call option minus November put option, with both options having a strike price equal to the July futures price plus storage costs to November, U.S. Corn, April, May, and June *World Agricultural Supply and Demand Estimates* release dates, 1990-2013.



SOURCE: original calculations.

FIGURE 3: Relationship between the storage cost adjusted price spread and the November call option minus November put option, with both options having a strike price equal to the July futures price plus storage costs to November, U.S. Soybeans, April, May, and June World Agricultural Supply and Demand Estimates release dates, 1990-2013.



SOURCE: original calculations.