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Risk Premiums and the Storage of Agricultural Commodities

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Abstract

The existence of a commodity market risk premium has attracted the interest of researchers for several decades. Most attempts to measure risk premiums have been focused on futures markets. However, if the risk premium is a payment made by hedgers (as suggested by Keynes) to reduce their risk profile, then the risk being reduced originates in the cash market. This suggests that the risk premium may also originate in the cash market. As such, the search for a risk premium should focus on the cash market, and, given Working's Supply of Storage Curve, should be measured as a function of stored inventory. This paper develops an expected utility based model that separates the risk premium from other storage incentives, and illustrates the role of the cash market risk premium on the storage decisions of two different market agents.

Risk Premiums and the Storage of Agricultural Commodities

Introduction

The search for a risk premium in agricultural commodity markets has attracted the interest of market researchers for decades. Keynes (1930) first introduced the concept to explain speculative behavior in commodity futures markets. Keynes assumed speculators were generally net long in futures, and hedgers net short. He argued the risk premium was manifested by a downward bias in futures prices (called normal backwardation), meaning that prices for deferred delivery would be expected to rise as contracts approached expiration, ceterus paribus. This rise in price represented the cost to hedgers of eliminating price risk over time, and the reward to futures speculators for accepting that risk. Hardy (1940) challenged Keynes' description of market dynamics arguing speculators receive no reward for accepting the risk passed on by hedgers. In short, Hardy viewed the futures market as purely a game of chance for speculators. More recent research has suggested that risk premiums may be more complicated than first envisioned by Keynes, but the general concept remains controversial (Dusak (1973) and Carter, Rausser, and Schmitz (1983)).

Parallel to searches for market risk premiums have been attempts to measure a convenience yield (Kaldor (1939), Working (1948, 1949), Brennan (1958), Telser (1958)). A convenience yield exists if the potential costs of not having access to inventory at a future time are greater than the expected decline in inventory value. In this instance, a risk-averse market agent would engage in storage even though the value of inventory is expected to deteriorate. The concept of convenience yield explains the holding of inventories in inverted markets – markets where prices for immediate delivery are higher than prices for deferred delivery.

Brennan combined the concepts of risk premium and convenience yield in describing Working's Supply of Storage Curve (Figure 1). He used supply of storage to delineate where, in the temporal price space, storage decisions are driven by risk premiums and where they aredriven by convenience yields. In Brennan's analysis, the incentive to hold additional inventory is dominated by a market risk premium when stocks are high. At very low stock levels, the motivation for holding inventory is dominated by the convenience yield. Consider a soybean processor. Even if the market is rewarding soybean storage, the processor's risk (or physical costs) increase significantly when a storage capacity constraint is reached. To store additional inventory, the processor would need to either invest in additional storage space, or resort to non-traditional storage strategies (for example, piling inventory on the ground). This increases his risk profile, and he would demand a risk premium to increase storage. At the other extreme, the processor may choose to store soybeans in an inverted market because the risk and associated costs of not having access to soybeans later could exceed the expected loss from storing beans. The cost of not having access to soybeans would be those costs associated with an idle plant. If the costs of shutting the plant down exceed the costs associated with deteriorating inventory value, then even a risk averse soybean processor would choose to hold inventory in an inverted market.

As an alternative to convenience yield, recent work has focused on *marginal transaction cost* to explain the holding of stocks (Chavas, Despins and Fortenbery (2000)). The convenience yield and the marginal transaction cost both describe the benefits of holding inventories in inverted markets. Although they attempt to explain a similar phenomenon, the transaction cost concept has some advantages. For one, unlike convenience yield, the marginal transaction cost is not necessarily related to production, thus it can be applied to a pure storage business. Second, the convenience yield is not directly observable, but the transaction cost can be specified and separated from the risk premium. Because of this it may be more manageable to identify and measure risk premiums and marginal transaction cost simultaneously, as opposed to trying to measure the convenience yield directly.

Interestingly, empirical investigations of convenience yield have focused on both futures and cash markets, while the search for a risk premium has been dominated by a focus on futures markets. But if there is a close relationship between the futures and cash markets (such a relationship has been documented in a large body of research – see Fortenbery and Zapata (1997)), then risky positions in cash markets should also be rewarded if a market risk premium exists. If, as argued by Keynes, hedgers pay a risk premium to futures speculators in order to reduce price risk, then the risk is one which originates in the cash market, implying the risk premium may also be present in the cash market. Further, if holders of inventory choose to forgo hedging, perhaps they are simply deciding to earn the risk premium directly in the cash market, rather than passing it to futures speculators in the form of a hedge (based on USDA (2003) data, it appears most on –farm storage is not hedged).

Objectives

To date the literature lacks a theoretical model that segregates storage incentives, and simultaneously measures their individual contributions to market agent behavior. The objective of this paper is to measure risk premiums in the cash market, and to simultaneously deal with identifying the interaction between risk premiums and marginal transaction cost. This is done for two different type cash market agents that hold inventory. Using an expected utility framework, estimates of the specific impacts of both risk premiums and marginal transaction cost on storage decisions are evaluated. The paper proceeds by defining the general storage problem, and introducing theoretical models of storage behavior. Next, empirical results associated with estimation of the theoretical models are presented. The implications of the research are then summarized in the conclusions section.

Defining the Problem

The analysis here assumes two types of major market participants that engage in storage: crop growers, referred to as *producers*, and professional storage firms (e.g. commercial elevators),[1] referred to as *commercials*. According to USDA's January 2003 Stocks Reports, 1,170 million bushels of soybeans were stored on-farm, and 944 million bushels were stored off-farm at the end of 2002. In addition, on and off-farm storage of corn totaled 4,800 and 2,838 million bushels, respectively, and 580 million on-farm and 1,171 million off-farm bushels of wheat were held in storage. This suggests that producers and commercials are both important in storing agricultural products. Thus, in discussing the effect of storage on commodity prices, both on farm and off farm storage must be considered.

Both producers and commercials are considered to be rational decision makers, and the purpose of their businesses is to maximize net income from sales (gross income is used synonymous with sales revenue). The costs incurred by producers include production costs (e.g., seed, fertilizer, irrigation, fuel, chemicals, and interest on operating costs), costs of storage, and costs spent to facilitate sales. Commercials do not face production costs, but other costs are similar to those borne by producers. It is assumed that both producers and commercials are long term market participants. Thus, their decisions regarding production and storage are based not only on current net income but also future income. That is, their decision making can be characterized as a multi-period optimization problem.

Optimal On-Farm Storage

The main business of agricultural producers is to grow crops. Their profits come from the difference between their sales price and production costs. Although some producers hedge in futures markets in order to reduce price risk, much of the literature on hedging (Helmuth (1977)), Berck (1981), Brorsen (1995)) indicates the percentage of primary producers who use futures to hedge is very low. Thus, gains from hedging are assumed and hedging is not considered in the model for producers.

In this economic framework, agricultural producers are assumed to only grow crops, and not invest in other markets. They also keep stocks for future sales. If y_t, x_t and q_t denote a producer's crop output, inventory level, and net sales at time t, then the relationship between two periods t and $t-1$ is characterized by:

$$(1 - \delta)\, x_{t-1} + y_t = x_t + q_t. \qquad (2.1)$$

In other words, the total amount of agricultural product available in the current period includes the amount to be sold immediately and the amount to be stored for a future sale. Since the stored product is subject to deterioration over time a depreciation rate of inventory δ is included in the equation. This rate could depend on the technology that producers possess, and is assumed to be constant over time.

When producers sell product, the net revenue they receive is not equal to the prevailing cash price. During the process of selling they incur inevitable expenses. These include gathering market information on who the buyers are, negotiating with buyers, and transporting products to buyers' places of business. All these expenses are called transaction cost, consistent with Chavas, Despins and Fortenbery (2000).

If an entity is a large business, it may have more power when negotiating with buyers. In addition, the information gathering will be more efficient and average information costs will be less. On the other hand, when sellers want to sell more, they have to put more effort into finding sufficient buyers, thus increasing transaction costs. As a result, not only available product but also the sales activity impacts the transaction cost. This means transaction cost is a function of inventory level (x_t) and sales (q_t) since available product is a function of x_t and q_t. As such, transaction cost is assumed to be a varying proportion of the current cash price and has the following specification:

$$s_t(q_t, x_t) = sp_t \frac{q_t}{(1-\delta)x_{t-1} + y_t} = sp_t \frac{q_t}{q_t + x_t} = p_t S(q_t, x_t)\,, \qquad (2.2)$$

where s is a constant and p_t is the cash price.

Following the sale of product profits are calculated by subtracting production costs and storage costs from revenue. The producers' current period profits (π_t) are then defined as:

$$\pi_t = [p_t - s(q_t, x_t)]\, q_t - c_1(y_t) - c_2(x_t), \qquad (2.3)$$

where $c_1(y_t)$ and $c_2(x_t)$ are the cost functions for production and storage respectively.

Producers maximize their utility of profits from production and storage. Their decision is represented by the following optimization problem:

$$J_t(x_{t-1}) = \max_{q,x} E_t \sum\nolimits_{\tau=t}^{\infty} \beta^{\tau-t} U(\pi_t) = \max_{q,x} \left\{ U(\pi_t) + \beta E_t J_{t+1}(x_t) \right\},$$

subject to equations (2.1), (2.2) and (2.3), where E_t is the expectation operator based on current available information, π_t is current profit, $U(\pi_t)$ is the producers' preference function that is assumed to be increasing and differentiable with respect to π_t, and β is the time discount factor ($0 < \beta < 1$). In solving this problem it is assumed current net sales are positive ($q_t \geq 0$); that is, producers always sell but do not buy stocks. This results in transaction cost s_t (equation 2.2) always being non-negative. Also assume that producers keep at least some inventory at all times (i.e., the amount of inventory level x_t is positive). Based on this, the profit function π_t, and thus the value function $J_t(x_{t-1})$, are continuous and differentiable within their domains.

The first-order necessary conditions with respect to q_t and x_t are:[2]

$$\frac{\partial U_t}{\partial \pi_t}\left(p_t - s_t - \frac{\partial s_t}{\partial q_t} q_t - \frac{\partial c_1}{\partial y_t}\right) = 0\;, \qquad (2.4)$$

$$\frac{\partial U_t}{\partial \pi_t}\left(-\frac{\partial s_t}{\partial x_t} q_t - \frac{\partial c_1}{\partial y_t} - \frac{\partial c_2}{\partial x_t}\right) + \beta E_t \frac{\partial J_{t+1}}{\partial x_t} = 0\,. \qquad (2.5)$$

Since $U(\pi_t)$ is an increasing function, i.e. $\partial U_t/\partial \pi_t > 0$, equation (2.4) can be rewritten as

$$\frac{\partial c_1}{\partial y_t} = p_t - s_t - \frac{\partial s_t}{\partial q_t} q_t \,. \tag{2.6}$$

Recall from (2.1) and (2.3),

$$y_t = x_t + q_t - (1-\delta)\, x_{t-1} \text{ and } \pi_t = [p_t - s(q_t, x_t)]\, q_t - c_1(y_t) - c_2(x_t).$$

Hence,

$$\frac{\partial \pi_t}{\partial x_{t-1}} = -\frac{\partial c_1}{\partial y_t}\frac{\partial y_t}{\partial x_{t-1}} = -\frac{\partial c_1}{\partial y_t}(-(1-\delta)) = (1-\delta)\frac{\partial c_1}{\partial y_t}\,.$$

Applying the Envelop Theorem to the optimization problem yields

$$\frac{\partial J_t}{\partial x_{t-1}} = \frac{\partial U_t}{\partial x_{t-1}} = \frac{\partial U}{\partial \pi_t}\frac{\partial \pi_t}{\partial x_{t-1}} = \frac{\partial U}{\partial \pi_t}[(1-\delta)\frac{\partial c_1}{\partial y_t}]$$

or $$\frac{\partial J_{t+1}}{\partial x_t} = (1-\delta)\frac{\partial U}{\partial \pi_{t+1}}\frac{\partial c_1}{\partial y_{t+1}}\,. \tag{2.7}$$

Substituting equations (2.6) and (2.7) into equation (2.5) yields:

$$\beta E_t U'_{t+1}(\pi)(p_{t+1} - s_{t+1} - \frac{\partial s_{t+1}}{\partial q_{t+1}} q_{t+1})(1-\delta) = U'_t(\pi)(p_t - s_t - \frac{\partial s_t}{\partial q_t} q_t + \frac{\partial s_t}{\partial x_t} q_t + \frac{\partial c_2}{\partial x_t})\,. \tag{2.8}$$

From equation (2.2), we have

$$\frac{\partial s_t}{\partial q_t} = s p_t \frac{x_t}{(q_t + x_t)^2} \tag{2.9}$$

and $$\frac{\partial s_t}{\partial x_t} = -s p_t \frac{q_t}{(q_t + x_t)^2}\,. \tag{2.10}$$

By substituting equations (2.2), (2.9) and (2.10) into equation (2.8), the first-order condition becomes:

$$E_t\left[\beta(1-\delta)[p_{t+1} - s p_{t+1} q_{t+1}\frac{q_{t+1} + 2x_{t+1}}{(q_{t+1} + x_{t+1})^2}]\frac{\partial U_{t+1}}{\partial \pi_{t+1}} - (p_t - \frac{2 s p_t q_t}{q_t + x_t} + \frac{\partial c_2}{\partial x_t})\frac{\partial U_t}{\partial \pi_t}\right] = 0\,.$$

(2.11)

Equation 2.11 is the conceptual model used to derive the empirical results below. It states that at optimal inventory levels, the discounted expected marginal value of storage equals the current marginal value of storage. Re-arranging equation (2.8) results in the following arbitrage pricing equation relating the cash prices in two periods:

$$\frac{Ep_{t+1}}{U_t^{'}/\beta(1-\delta)EU_{t+1}^{'}} - p_t$$

$$= \frac{E(s_{t+1} + q_{t+1}\frac{\partial s_{t+1}}{\partial q_{t+1}})}{U_t^{'}/\beta(1-\delta)EU_{t+1}^{'}} - s_t - \frac{\partial s_t}{\partial q_t}q_t + \frac{\partial s_t}{\partial x_t}q_t - \frac{\text{cov}(p_{t+1} - s_{t+1} - q_{t+1}\frac{\partial s_{t+1}}{\partial q_{t+1}}, U_{t+1}^{'})}{U_t^{'}/\beta(1-\delta)} + \frac{\partial c_2}{\partial x_t}.$$

(2.12)

Equation (2.12) can be viewed as the optimal decision rule of producers. It states that the marginal benefit of storing (the left hand side of the equation) must equal the marginal cost (the right hand side of the equation) at the optimal storage level. The right hand side of equation (2.12) consists of three parts: MTC_t, MRP_t, and $\partial c_2/\partial x_t$,

where $$MTC_t = \frac{E(s_{t+1} + q_{t+1}\frac{\partial s_{t+1}}{\partial q_{t+1}})}{U_t^{'}/\beta(1-\delta)EU_{t+1}^{'}} - s_t - \frac{\partial s_t}{\partial q_t}q_t + \frac{\partial s_t}{\partial x_t}q_t, \quad (2.13)$$

$$MRP_t = -\frac{\text{cov}(p_{t+1} - s_{t+1} - q_{t+1}\frac{\partial s_{t+1}}{\partial q_{t+1}}, U_{t+1}^{'})}{U_t^{'}/\beta(1-\delta)}, \quad (2.14)$$

and $\partial c_2/\partial x_t$ is the marginal cost of storing.

When there are no transaction costs during a sale, i.e. $s_t = 0$, MTC_t will be zero. Thus, it is reasonable to think of MTC_t as the *marginal transaction cost* because it reflects how changes in stocks will affect transaction cost at the optimal storage level. It should also be noted that when producers are risk neutral, i.e. $\partial U_t/\partial \pi_t$ is constant during all periods, the covariance in equation (2.14) is zero, thus MRP_t becomes zero. Even though MRP_t is irrelevant to the optimal decision rule in this case, the marginal transaction cost is still valid with a new form:

$$MTC_t = \beta(1-\delta)E(s_{t+1} + q_{t+1}\frac{\partial s_{t+1}}{\partial q_{t+1}}) - s_t - \frac{\partial s_t}{\partial q_t}q_t + \frac{\partial s_t}{\partial x_t}q_t .$$

Otherwise, marginal risk preference $\partial U_t/\partial \pi_t$ will differ over time and cause the covariance and MRP_t to vary. Thus, MRP_t measures how producers' risk preferences affect storage behavior. It is referred to as the *marginal risk premium*, but here it is measured in the cash market, not the futures market.

From examination of equations (2.13) and (2.14), it is not clear whether the marginal transaction cost and marginal risk premium for each period are positive or negative. For MTC_t, the first term in (2.13) is positive but the last three terms are all negative.[3] In the case of MRP_t, the covariance in (2.14) could be either positive or negative depending on how changes in price and transaction cost change marginal utility at a specific time.

Description of Data

Because there has typically been less U.S. government influence in soybean pricing relative to other storable commodities, soybeans are chosen as the commodity of interest. Empirical tests of the conceptual model above are based on quarterly data for the period 1986 through 2002, 68 observations in total. Quarterly data are used to coincide with the frequency of USDA Stocks Reports.

The quarterly data for soybean cash prices, p_t, were taken from Commodity Research Bureau (CRB) InfoTech Data. They represent cash prices in central Illinois. The data for production output y_t and inventory levels x_t are from the USDA Crop Production and Grain Stocks reports. Crop Production reports the annual output for many agricultural products including soybeans. Because soybeans are usually harvested in the fourth calendar quarter, the annual production estimate was treated as the output level in the fourth quarter each year, with the output in other quarters set to zero. The USDA's Grain Stocks Report estimates on farm and off farm stocks for soybeans each quarter. The on farm stocks data were used as producers' quarterly inventory levels, and off farm stocks data represents commercials' inventory.

Soybean production cost data were taken from USDA-ERS. ERS gives annual average production cost per planted acre including operation costs and allocated overhead. Using USDA data, the average cost per bushel was calculated and then multiplied by production output to get the total production costs for each year. Because soybeans are planted and harvested during the last three quarters, the total production costs were divided equally into the last three quarters of each year, and represented by $c_1(y_t)$. The first quarter's production cost was set to zero. Storage costs were assumed to be 3 cents/bushel/month (or 9 cents/bushel/quarter). This is consistent with recommendations from the Professional Education for Farmers of Iowa Farm Bureau Federation (2002). The depreciation rate δ in equation (2.1) was assumed to be 0.03 (this is consistent with Chavas, Despins and Fortenbery (2000)). The data are summarized in Table 1.

Estimation and Empirical Results for Producers

In order to estimate the conceptual model, one needs to specify a utility function. The producers' utility function is assumed to be an increasing function, implying the marginal utility function is positive, i.e., $U'(\pi_t) > 0$. It is also assumed that producers can be risk neutral, risk averse, or even risk seeking. Each of these could be true under some circumstances. Research by Pennings and Smidts (2003) found that utility functions can be S-shaped, or fully concave or convex among decision makers. Also, since producers are doing business in risky markets, it is possible that profits can negative. Therefore, the utility function should be able to accept non-positive values as its arguments. For the reasons above a quadratic marginal utility function with the following specification was adopted:

$$U'(\pi_t) = EXP(a\pi_t + b\pi_t^2).$$

This specification is similar to the utility function proposed by Chavas and Holt (1996). With this specification, it is guaranteed that marginal utility is always non-negative regardless of whether π_t is positive or negative. Thus, the assumption of non-decreasing utility is not violated. Also, this utility specification has the advantage of accommodating many possibilities of risk preference: (1) risk neutral: $a = 0$ and $b = 0$; (2) risk averse: $a < 0$ and $b = 0$; (3) risk seeking: $a > 0$ and $b = 0$; (4) S-shaped (risk seeking for small profits and risk averse for large profits): $b < 0$; and (5) reversed S-shaped: $b > 0$.

Note that equation (2.11) is a nonlinear specification and the probability distribution of its error term is unknown. The Hansen's generalized method of moments (GMM) does not require full knowledge of the model's probability distribution, and only demands the specification of a set of moment conditions that the model should satisfy (Hansen (1982), Hansen and Singleton (1982), and Harris and Mátyás (1999)). Therefore, equation (2.11) was estimated with iterative non-linear GMM.

The instruments selected for GMM estimation are required to be uncorrelated with the error term. Instruments for GMM estimation are selected based on the criteria that estimated parameters be significant and the *J*-statistic of the model be small. Several instruments were tested. The final instruments chosen were the producer price index (PPI), a time variable that has the value of 1 through 68, and lagged one through four periods' value of the cash prices, i.e. p_{t-1}, p_{t-2}, p_{t-3} and p_{t-4}, for a total of 7 instruments including a constant.[4]

The empirical results of equation (2.11) are presented in Table 2. The low *J*-statistic indicates that the model is specified correctly. The estimated parameter s is significantly different from zero at the one percent level, providing evidence that the transaction cost is indeed a very important element influencing producers' storage decisions. The significance of b indicates that producers are not risk neutral, and that marginal risk premiums may exist in the cash market for producers. Although the parameter a is not significantly different from zero, this parameter is still kept in the model to maintain the original specification for the marginal utility function.[5]

The estimates of parameters a and b were both positive. The Arrow-Pratt coefficient of absolute risk aversion (ar) is measured as

$$ar = - U''/U' = - (a+2b\pi_t)\, EXP(a\pi_t+b\pi_t^2) / EXP(a\pi_t+b\pi_t^2) = - (a+2b\pi_t).$$

Risk averse behavior corresponds to $ar > 0$ and risk seeking behavior to $ar < 0$. Hence, the empirical results indicate that producers exhibit risk seeking behavior (i.e. $ar < 0$) when they have profits and risk averse behavior (i.e. $ar > 0$) when they incur a large loss (when $\pi_t < -11.94$). According to ERS's soybean production costs and returns report, during the period 1986-2002 the economic returns from soybean production were positive in six years and negative in the other eleven years. Therefore, even if returns to storage are included, we should expect to see risk averse behavior in some years and risk seeking in others. Following Pratt (1964), producers' risk preferences exhibit decreasing absolute risk aversion (DARA) because $\partial ar/\partial \pi_t = - 2b < 0$.

After estimating the model, the marginal risk premium MRP_t and marginal transaction cost MTC_t were calculated for each period by applying equations (2.13) and (2.14), and then the average of each were calculated. The expectation and covariance terms in these two equations were simulated using bootstrap techniques. The random variable p_t in equation (2.3) was fitted by an autoregressive time-series model. Results indicated that an AR(2) was the most appropriate model for p_t:

$$\underset{}{p_t =} \underset{(19.77)}{586.5673} - \underset{(14.99)}{0.9894\, p_{t-1}} + \underset{(2.57)}{0.1741\, p_{t-4}}. \qquad (2.15)$$

Asymptotic t values are presented in parentheses below the corresponding parameters. The residuals ε_t can be calculated from the above empirical model. For each time t, 1000 values of p_t were simulated and substituted into equation (2.3) to calculate the profits π_t. This involved two steps. First, for each period $t = i$, ε_i^* was drawn randomly from the empirical distribution of the residuals $\{\varepsilon_1, \ldots, \varepsilon_T\}$. Second, the selected residuals were added to the estimated p_i to produce the simulated future price p_i^*. This procedure was then repeated 1000 times. The resulting values of π_t were used to generate the marginal utilities U'_t. The values of $(s_t + q_t\, \partial s_t/\partial q_t)$ and $(p_t - s_t - q_t\, \partial s_t/\partial q_t)$ were also calculated by using the simulated values of p_t. Finally, the average of U'_t and $(s_t + q_t\, \partial s_t/\partial q_t)$, and the sample covariance between U'_t and $(p_t - s_t - q_t\, \partial s_t/\partial q_t)$ were obtained and used in equations (2.13) and (2.14) to get the values of the marginal risk premium and marginal transaction cost for each period.

The estimated marginal risk premium and marginal transaction cost (in cents per bushel) are reported in Table 3. The marginal risk premium is found to be significantly non-zero. This indicates producers earn marginal risk premiums in the cash market by holding stocks, although the marginal risk premium is not large compared to the average cash price of 595 cents per bushel. The average marginal risk premium is only 0.28% of the average cash price. The marginal transaction cost is negative and also statistically significant. Its average is 14.52% of the average cash price. This suggests producers reduce their transaction cost by keeping stocks.

The marginal risk premium measures how much the risk premium itself will increase by holding more inventory, while the risk premium measures the producers' willingness to pay in order to eliminate future profit risk. Denote the Arrow-Pratt risk premium as *RP*. Following Arrow (1971) and Pratt (1964), the risk premium at each time *t* can be measured based on the following equation:

$$EU(\pi_t) = U(E(\pi_t) - RP_t),$$

where *E* is the expectation operator. The above equation can also be written in the following way by substituting in the utility function:

$$E\left[\int_0^{\pi_t} EXP(a\pi + b\pi^2)d\pi\right] = \int_0^{E(\pi_t)-RP_t} EXP(a\pi + b\pi^2)d\pi\,. \qquad (2.16)$$

Note that we have already simulated 1000 values of profit π_t in each period t. The expected profit $E(\pi_t)$ in the right hand side of equation (2.16) can be approximated as the average of those 1000 values. The value of $U(\pi_t)$, or the integral of the marginal utility, was calculated for each of the 1000 values of π_t, and the average used as the approximation of the expectation of utility – the left hand side of equation (2.16). The simulated values of the estimated parameters *a* and *b* were substituted into (2.16) to solve for the risk premium RP_t in each time period.

The transaction cost also affects producers' profits. In order to compare the effects of risk premiums and transaction cost on profits, the total transaction cost, TC_t, in each period was calculated as the unit transaction cost times sales. Based on equation (2.2), this is written as:

$$TC_t = s_t(q_t, x_t)q_t = sp_t \frac{q_t}{q_t + x_t},$$

where $s_t(.)$ is the unit transaction cost. The results for RP_t and TC_t (in billion cents) are reported in Table 4.

The risk premiums are not always positive, indicating that producers are not always risk averse. This result is consistent with the fact that the estimated parameters *a* and *b* are positive, and thus producers are risk averse only when they incur a loss. When producers can obtain profits from soybean production and storage, they are risk seeking and willing to pay to bear risk. It can be seen from the estimation results that the risk premium and the transaction cost have similar effects on producers' final profits. On average, they are between 15% and 20% of the expected profits.

Optimal Commercial Storage

In addition to agricultural producers, merchandisers maintain agricultural stocks for future trade. Commercials purchase commodities from producers, but usually do not consume the commodities themselves. Their main business is to store commodities and sell them to processors and wholesalers.[6] Some of the commodities are sold immediately and some are stored for extended times. Commercials' profits come from the price difference between the time of purchase and sale. In order to avoid risk, they may hedge some of their inventory in the futures market.

Commercials maximize their utility of profits, and their decision is represented by the following optimization problem:

$$J_t(x_{t-1}, \xi_{t-1}) = \max_{x,\xi} E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} U(\pi_t) = \max_{x,\xi} \{U(\pi_t) + \beta E_t J_{t+1}(x_t, \xi_t)\},$$

subject to (1) $\pi_t = [p_t - s_t]\, q_t - c(x_t) + (p_t - f_{t-1})\, \xi_{t-1}$, (3.1)

(2) $(1 - \delta)\, x_{t-1} - q_t = x_t$, (3.2)

where f_t is the price of a futures contract and ξ_t is the amount of the inventory to be hedged in the futures market. For commercials, the net sales, q_t, can be positive or negative depending on whether they are increasing or decreasing inventories in a given period.

Like producers, commercials incur transaction costs when they buy commodities from growers. Some of the transportation and information costs are passed to sellers (i.e., producers), but the rest is incurred by commercials. When commercials sell inventory, the cost of trading is shared between the commercials and the buyers. Thus, transaction costs are incurred by commercials whether they buy or sell stocks. Like producers, it is assumed that the transaction cost for commercials is a function of inventory level (x_t) and net sales (q_t). But according to equation (3.2), q_t is a function of x_{t-1} and x_t. Therefore, transaction cost s_t is actually a function of inventory levels x_{t-1} and x_t:

$$s_t(q_t, x_t) = sp_t \frac{q_t}{q_t + x_t} = sp_t \frac{(1-\delta)x_{t-1} - x_t}{(1-\delta)x_{t-1}} \equiv s_t(x_{t-1}, x_t), \quad (3.3)$$

where s is a constant. Since net sales q_t can be negative, the transaction cost can also be negative. Because the inventory of last period, x_{t-1}, is positive (assuming commercials don't deplete their inventory), the sign of s_t depends on q_t. There will be no transaction cost if there are no sales.

When commercials sell stocks ($q_t > 0$), the transaction cost s_t is positive, i.e., the real revenue received by commercials per unit of sale is the cash price less transaction cost. When commercials buy stocks ($q_t < 0$), the real expense paid by commercials is the cash price plus transaction costs.

Solving the commercials' optimization problem yields the following first order conditions with respect to x_t and ξ_t:

$$\begin{cases} \frac{\partial U}{\partial \pi_t}((p_t - s_t)\frac{\partial q_t}{\partial x_t} - \frac{\partial s_t}{\partial x_t} q_t - \frac{\partial c}{\partial x_t}) + \beta E_t \frac{\partial J_{t+1}}{\partial x_t} = 0 \\ \beta E_t \frac{\partial J_{t+1}}{\partial \xi_t} = 0 \end{cases}. \tag{3.4}$$

The transaction cost function (3.3) can be discontinuous or non-differentiable only at the point that $q_t + x_t = 0$. But it is already assumed that the inventory level x_{t-1} is never non-positive. As a result, the transaction cost function $s_t(x_{t-1},x_t)$ is by assumption continuous and differentiable everywhere regardless of inventory or net sales, as is the value function $J_t(x_{t-1},\xi_{t-1})$. Applying the Envelop Theorem to the commercials' optimization problem yields

$$\frac{\partial J_{t+1}}{\partial x_t} = \frac{\partial U_{t+1}}{\partial \pi_{t+1}}\frac{\partial \pi_{t+1}}{\partial x_t} = U'_{t+1}(\pi)((p_{t+1} - s_{t+1})\frac{\partial q_{t+1}}{\partial x_t} - \frac{\partial s_{t+1}}{\partial x_t} q_{t+1}),$$

and $$\frac{\partial J_{t+1}}{\partial \xi_t} = E_t \frac{\partial U}{\partial \pi_{t+1}}(p_{t+1} - f_t).$$

Substituting the above two equations into (3.4) yields

$$\begin{cases} U'_t(\pi)((p_t - s_t)\frac{\partial q_t}{\partial x_t} - \frac{\partial s_t}{\partial x_t} q_t - \frac{\partial c}{\partial x_t}) + \beta E_t U'_{t+1}(\pi)((p_{t+1} - s_{t+1})\frac{\partial q_{t+1}}{\partial x_t} - \frac{\partial s_{t+1}}{\partial x_t} q_{t+1}) = 0 \\ E_t U'_{t+1}(\pi)(p_{t+1} - f_t) = 0 \end{cases}.$$

Calculating the derivatives of s_t with respect to x_{t-1} and x_t based on equation (3.3) and plugging them into the above equations, the first order conditions become:

$$\begin{cases} U_t^{'}(\pi)((p_t - s_t)(-1) - \frac{-sp_t q_t}{(1-\delta)x_{t-1}} - \frac{\partial c}{\partial x_t}) + \beta E_t U_{t+1}^{'}(\pi)((p_{t+1} - s_{t+1})(1-\delta) - \frac{sp_{t+1}x_{t+1}q_{t+1}}{(1-\delta)x_t^2}) = 0 \\ E_t U_{t+1}^{'}(\pi)(p_{t+1} - f_t) = 0 \end{cases}$$

The above two-equation system is re-arranged to get the following econometric model which can be estimated with non-linear GMM:

$$\begin{cases} E\left[\beta U_{t+1}^{'}(\pi)((p_{t+1} - s_{t+1})(1-\delta) - \frac{sp_{t+1}x_{t+1}q_{t+1}}{(1-\delta)x_t^2}) - U_t^{'}(\pi)(p_t - s_t - \frac{sp_t q_t}{(1-\delta)x_{t-1}} + \frac{\partial c}{\partial x_t})\right] = 0 \\ E_t U_{t+1}^{'}(\pi)(p_{t+1} - f_t) = 0 \end{cases}.$$

(3.5)

From the first equation in (3.5) we can obtain the following arbitrage pricing equation reflecting the relationship between the prices in two periods:

$$\begin{aligned} &\frac{Ep_{t+1}}{U_t^{'}/\beta(1-\delta)EU_{t+1}^{'}} - p_t \\ &= \frac{E(s_{t+1} + q_{t+1}\frac{\partial s_{t+1}}{(1-\delta)\partial x_t})}{U_t^{'}/\beta(1-\delta)EU_{t+1}^{'}} - s_t + \frac{\partial s_t}{\partial x_t}q_t - \frac{\operatorname{cov}(p_{t+1} - s_{t+1} - q_{t+1}\frac{\partial s_{t+1}}{(1-\delta)\partial x_t}, U_{t+1}^{'})}{U_t^{'}/\beta(1-\delta)} + \frac{\partial c_t}{\partial x_t} \\ &= \frac{E(s_{t+1} + q_{t+1}\frac{sp_{t+1}x_{t+1}}{(1-\delta)^2 x_t^2})}{U_t^{'}/\beta(1-\delta)EU_{t+1}^{'}} - s_t - \frac{sp_t q_t}{(1-\delta)x_{t-1}} - \frac{\operatorname{cov}(p_{t+1} - s_{t+1} - q_{t+1}\frac{sp_{t+1}x_{t+1}}{(1-\delta)^2 x_t^2}, U_{t+1}^{'})}{U_t^{'}/\beta(1-\delta)} + \frac{\partial c_t}{\partial x_t} \end{aligned}$$

As a result the marginal risk premium and marginal transaction cost in each time period can be estimated as

$$MRP_t = -\frac{\operatorname{cov}(p_{t+1} - s_{t+1} - q_{t+1}\frac{sp_{t+1}x_{t+1}}{(1-\delta)^2 x_t^2}, U_{t+1}^{'})}{U_t^{'}/\beta(1-\delta)}, \qquad (3.6)$$

and $$MTC_t = \frac{E(s_{t+1} + q_{t+1}\frac{sp_{t+1}x_{t+1}}{(1-\delta)^2 x_t^2})}{U_t^{'}/\beta(1-\delta)EU_{t+1}^{'}} - s_t - \frac{sp_t q_t}{(1-\delta)x_{t-1}}. \qquad (3.7)$$

Description of Data

As in the case of producers, quarterly soybean data from 1986 through 2002 are used to test the commercials' storage model. The quarterly data for the soybean cash and futures prices, p_t and f_t, are taken from CRB InfoTech Data. The data for inventory level x_t are taken from USDA's quarterly Grain Stocks Report. Assuming commercials use the same technology as producers to store products, the storage cost is also 3 cents/bushel/month. The commercials' positions in the futures market, ξ_t, were simulated from the Commitments of Traders Report (COT), released by the Commodity Futures Trading Commission. In this report, long and short positions for commercial traders are reported. It was assumed that among commercial traders, holders of inventory only take short positions when they hedge in the futures market,[7] and their customers only take long positions. Therefore, ξ_t was approximated by the short-side commercial positions reported in the COT, and is always negative.

Since commercials use futures markets mostly for the purpose of protecting storage against adverse price changes, they seldom deliver the commodities to the buyers of futures contracts. As such, it was assumed that commercials are short-term hedgers and that they are continuously active in the futures market. The following simple hedging strategy was constructed for commercials: in the first quarter of each year, they short the July contract and offset hedges that were placed in the earlier March contract. In the second quarter, they short the September contract and offset positions placed in the July contract. In the third quarter, they short the January contract and offset positions in the September contract. Finally, in the fourth quarter they short the March contract and offset the September contract hedges. A summary of the commercials' data is presented Table 5.

Empirical Results for Commercials

The commercials' marginal utility function was assumed to have the following specification: $U'(\pi_t) = Exp(a\pi_t+b\pi_t^2)$. The constant depreciation rate δ was also chosen to be 0.03 in each quarter.

The two-equation system (3.5) was estimated with iterative non-linear GMM. Similar to the instruments chosen for the producers' model, seven instruments were chosen for the commercials' model; namely a constant, the producer price index (PPI), a time trend variable, and lagged one through four periods' value of the cash prices.[8]

The results from equation (3.5) are reported in Table 6. The *p*-value of the *J*-statistic indicates the model is correctly specified. The estimated parameter *s* is significantly different from zero at the one percent level, implying that the transaction cost impacts on the commercials' storage decision. The possibility of marginal risk premiums is indicated by the significance of parameters *a* and *b*. Note that the estimates of parameters *a* and *b* are both negative. The Arrow-Pratt coefficient of absolute risk aversion *ar* is measured as

$$ar = - U''/U' = - (a+2b\pi_t) > 0,$$

indicating commercials are risk averse. Commercials' risk preference exhibits increasing absolute risk aversion (IARA) because $\partial ar/\partial \pi_t = - 2b > 0$.

Next, the estimated parameters were plugged in equations (3.6) and (3.7) to calculate the marginal risk premium and the marginal transaction cost. As in the case of producers, the expectation and covariance terms in (3.6) and (3.7) were simulated using bootstrap techniques. Since the random variable here is also the cash price p_t, the same AR(2) model from equation (2.15) was used in the simulation process.

The statistics of MRP_t and MTC_t (in cents per bushel) for commercials are reported in Table 7. The average marginal risk premium and the average marginal transaction cost are 0.951% and 3.355% of average cash price, respectively. The marginal risk premium is found to be significant and positive, which implies commercials earn a marginal risk premium from holding stocks. However, notice that the marginal risk premium of commercials is larger than that of producers. This means producers require less risk premium compensation for bearing the risk of storage.

The marginal transaction cost for commercials is also significant. As in the case of producers, commercials benefit from storage by reducing their transaction cost associated with selling inventory. However, the marginal transaction cost for commercials is smaller than that of producers. This may be because individual commercials generally hold larger inventories than producers. If there are economies of scale in storage the average transaction cost of commercials is lower than that of producers. This, in turn, would result in a smaller transaction cost savings per unit as a result of maintaining inventory.

Table 8 presents the calculated risk premium and transaction cost values for commercials. These were calculated in the same manner as the producers' values. The risk premium is positive, indicating that commercials are risk averse. Commercials are willing to pay 8.98% of expected profits to avoid the price risk associated with storage. Unlike producers, the risk premium for commercials is large (about 17% of expected profits), and the transaction cost is small. This suggests that the transaction cost is not as important a component of commercials' final profits as it is for producers.

Marginal Risk Premium, Marginal Transaction Cost and Inventory

The storage behavior of producers and commercials has been discussed above. In both cases, average marginal risk premiums are positive and significant, and average marginal transaction costs are negative and significant. Thus, both producers and commercials earn marginal risk premiums and reduce marginal transaction costs by engaging in storage. The next step is to examine how inventory levels and marginal risk premiums relate to each other.

The marginal risk premiums measure how much the cash market would pay a firm to engage in storage. Figures 2 and 3 provide plots of the calculated MRP_t against inventory levels for producers and commercials, respectively. Note that MRP_t increases at an increasing rate as x_t increases. For both producers and commercials, the marginal risk premiums in most periods are positive, and when there are large inventories, the marginal risk premiums are all positive. This finding is consistent with the Supply of Storage Curve (Figure 1).

The results are intuitively appealing. By storing inventories for future sale, a storage firm bears price risk. The positive marginal risk premiums represent compensation to the firm for absorbing the risk of storage. The larger the inventory held in storage, the greater the price risk faced by a firm. Even small unexpected price reductions could lead to huge losses and threaten a firm's existence. Although a firm may be able to obtain financial help from banks or other sources to facilitate cash flow when it encounters large losses, the average cost of financing could still be much larger than in normal times. Therefore, as a firm's inventory increases, the marginal risk premium should also increase commensurate with the increased risk. That is, $\partial MRP_t/\partial x_t > 0$ and $\partial^2 MRP_t/\partial x_t^2 \geq 0$. This is consistent with the mapping in Figures 2 and 3.

On the other hand, when inventories are low, marginal risk premiums can be negative and marginal transaction cost tends to be negative and large. Thus, firms can benefit from storage even though the inventory will lose value over the storage period. However, while marginal risk premiums can be negative, and marginal transaction costs are negative at low inventory levels, they are not measuring the same thing. Marginal transaction cost measures the reduction of a firm's costs of trading inventory, while marginal risk premiums reflect risk preferences. The finding of negative marginal risk premiums is consistent with Chavas (1988), who also found that marginal risk premiums can be negative. The results here, as well as Chavaz (1988), suggest Brennan's assumption of non-negative marginal risk premiums was overly restrictive.

The effects of the marginal risk premium and marginal transaction cost combined determine the overall net costs (or benefits) of storage. At low inventory levels, the marginal transaction cost dominates (and the marginal risk premium may be negative), leading to a negative cost of storage; that is, storage provides benefits but the market exhibits inverse carrying charges. At high levels of inventory, the marginal risk premium dominates, and we have a positive net cost of storage.

Conclusions

The marginal risk premiums for holders of inventory in commodity markets were found to be significant, and the average of marginal risk premiums positive. This suggests that marginal risk premiums do provide incentives for firms to hold inventories. The marginal transaction costs were also significant but the average was negative, implying that stockholding can provide benefits to firms by reducing transaction costs. The marginal risk premium and marginal transaction cost, together with the storage cost, determine how much the future cash price of commodities will differ from the current price.

A risk premium, calculated from the marginal risk premiums, was found to exist in the soybean market. The existence of a risk premium is due to the price uncertainty in the market, and gives storage businesses the incentive to store commodities. Without this compensation, fewer inventories would generally be held. It was also found that the risk premium is an important factor determining the final profits of both producers and commercials. In contrast, the transaction cost was found to affect producers' expected profits significantly, but the impact on commercials was substantially less. This may be due to the relative size of commercials, and associated with economies of scale in market transaction costs.

Previous studies (e.g. Dusak (1973), Deaves and Krinsky (1995), Telser (1958)) have claimed there is no risk premium in commodity markets. However, they were actually measuring the marginal risk premium, not the risk premium itself. The risk premium measures willingness to pay in order to eliminate risk, while the marginal risk premium measures changes in the risk premium. Although the risk premium is positive for risk-averse agents, the marginal risk premium may not always be positive. The marginal risk premium is a component in temporal price differences, but the risk premium is not. If we only look at average of marginal risk premiums, we may conclude they do not exist as a result of averaging negative and positive numbers. Also, if we assume, as Brennan did, that marginal risk premiums can only be positive we would not be able to accurately measure the risk premium itself.

This paper has identified and measured a market risk premium in the cash market for soybeans, and separated that from transaction cost storage incentives. Further research is needed on how or if the cash market risk premium is transferred by hedgers to the futures market, and whether futures market speculators with relatively short investment horizons do in fact earn a risk premium. This is the focus of current work.

Table 1: Summary of the data for the producer's model

Variable	Mean	Std. Dev.	Minimum	Maximum
Soybean cash prices (cents/bushel):				
p_t	585.13	104.75	421.35	839.52
Soybean production output (1,000 bushels):				
y_t	571,418.60	1,016,938.50	1,548,841*	2,890,682
Producers' inventory levels (1,000 bushels):				
x_t	488,998.51	345,155.84	43,600	1,240,000
Production costs (1,000 cents):				
$c_1(y_t)$	338,953,625	211,418,831	316,879,528*	591,872,742

Note: Data period is 1986-2002, quarterly, 68 observations.
* Minimum of non-zero values

Table 2: Parameter estimate for equation (2.11)

Parameter	Estimate	Approx. Std. Error	t Value
β	0.8707	0.0668	13.03*
s	0.3898	0.0972	4.01*
a	8.55E-5	2.8E-4	0.31
b	3.58E-6	2.2E-6	1.65**

Summary of fit:

standard deviation of the error term = 96.25
J-statistic = 0.8915, p-value = 0.8275
ITGMM iteration = 4

* Statistically significant at the 0.01 level
** Statistically significant at the 0.10 level.
Study Period: 1986-2002.

Table 3: Estimate of marginal risk premium and marginal transaction cost

Variable	Mean	Standard Error
MRP_t	1.65	0.14
MTC_t	-86.41	11.96

Number of observations = 66; Data Period: 1986-2002, quarterly.

Table 4: Estimate of risk premium and transaction cost for producers

Variable	Mean	Std. Error	Minimum	Maximum
RP_t	12.97	4.94	-49.457	96.417
$RP_t/E(\pi_t)$	15.31%	1.45%	1.28%	94.68%
TC_t	31.04	1.19	9.363	55.613
$TC_t/E(\pi_t)$	18.56%	3.29%	2.86%	218.38%

Number of observations = 67; data period: 1986-2002, quarterly.

Table 5: Summary of the data for the storer's model

Variable	Mean	Std. Dev.	Minimum	Maximum
Soybean cash prices (cents/bushel):				
p_t	585.13	104.75	421.35	839.52
Soybean futures prices (cents/bushel):				
f_t	599.29	98.83	434.27	867.34
Commercials' inventory levels (1,000 bushels):				
x_t	529,776.72	296,554.41	88,233	1,116,156
Commercials' positions in futures market (1,000 bushels):				
ξ_t	-288,039.62	160,356.65	-612,558.28	-75,428.01

Note: Data period is 1986-2002, quarterly, 68 observations.

Table 6: Parameter estimate for equation (3.5)

Parameter	Estimate	Approx. Std. Error	t Value
β	0.9922	0.0097	102.15*
s	4.84E-3	0.0014	3.39*
a	-5.16E-4	0.0002	-2.18**
b	-1.70E-6	6.5E-7	-2.63**

Summary of overall fit:

std. dev. of the error term for first equation = 53.12
std. dev. of the error term for second equation = 42.64
J-statistic = 9.7067, p-value = 0.4666
ITGMM iteration = 19

* Statistically significant at the 0.01 level
** Statistically significant at the 0.05 level.
Study Period: 1986-2002.

Table 7: Estimate of marginal risk premium and marginal transaction cost

Parameter	Mean	Standard Error
MRP_t	5.66	1.66
MTC_t	-19.96	7.86

Number of observations = 66; Data Period: 1986-2002, quarterly.

Table 8: Estimate of risk premium and transaction cost for commercials

Variable	Mean	Std. Error	Minimum	Maximum
RP_t	17.08	1.28	10.1347	45.1593
$RP_t/E(\pi_t)$	8.98%	0.62%	5.03%	44.21%
TC_t	0.83	0.14	0.017	5.835
$TC_t/E(\pi_t)$	0.83%	0.26%	0.01%	13.54%

Number of observations = 67; data period: 1986-2002, quarterly.

Figure 1: Brennan's supply of storage curve

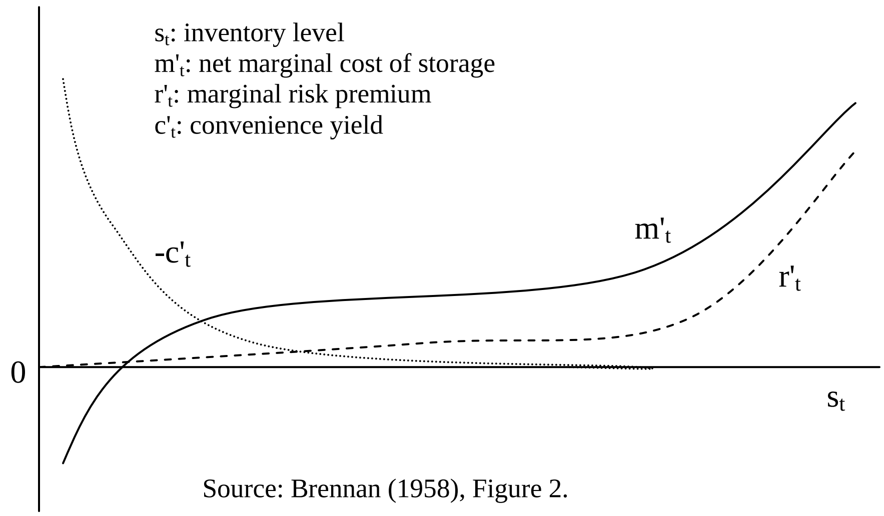


Figure 2: producers' inventory level and marginal risk premium

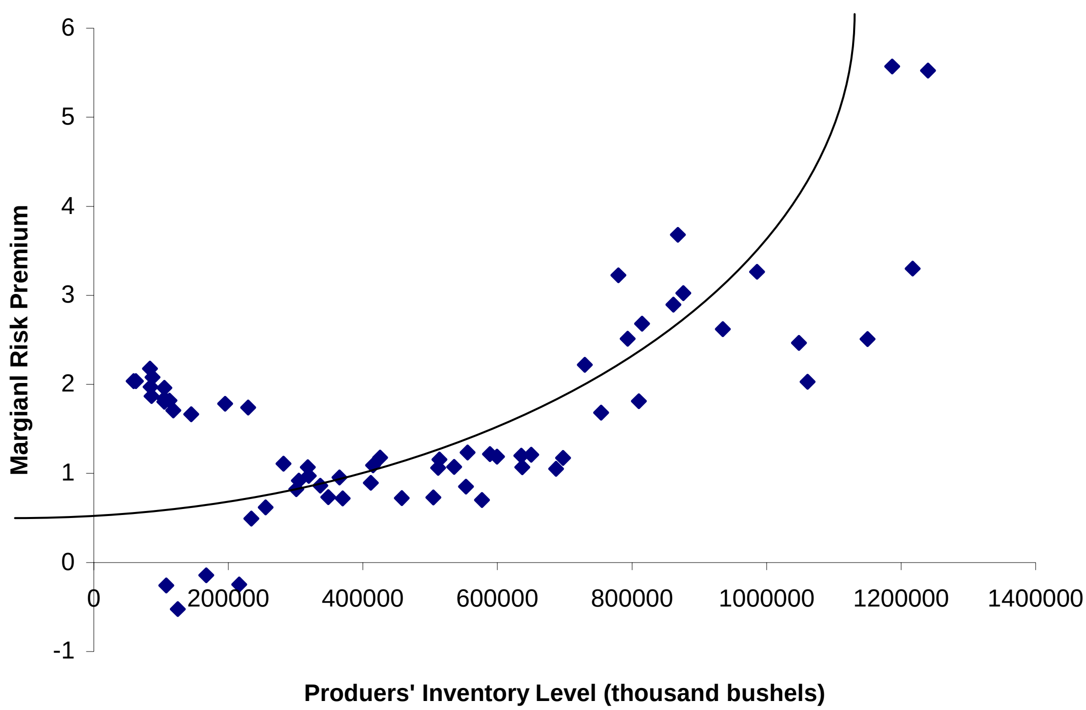
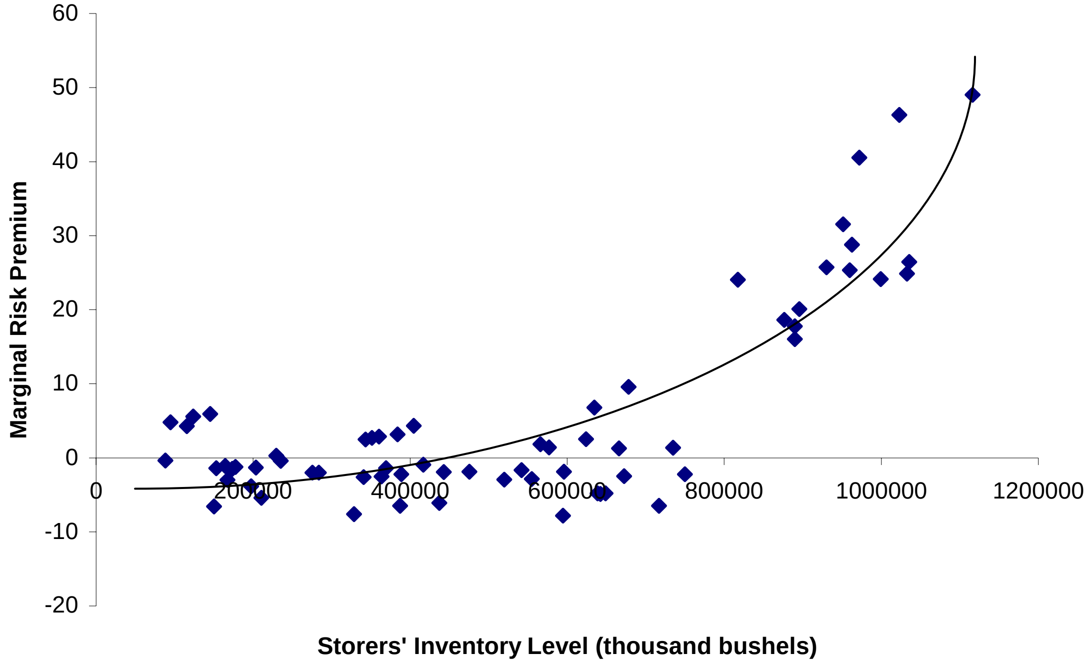


Figure 3: commercials' inventory level and marginal risk premium



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End Notes

[1] Food processors may also store agricultural commodities. To simplify the analysis, they are not separated from storage firms.

[2] Assume the second-order conditions hold for this optimization problem.

[3] Based on (2.9) and (2.10), $\partial s/\partial q$ is positive and $\partial s/\partial x$ negative. We also know the transaction cost s_t and sale q_t are both positive.

[4] There are seven instruments and one target equation; hence, seven moment conditions are present.

[5] Even if parameter a is removed from the marginal utility function, i.e. $U'(\pi_t) = EXP(b\pi_t^2)$, the estimates for other parameters are not changed qualitatively. These results are available from the authors.

[6] Much of the off-farm storage could be held by processors. But the main business of processors is not storing commodities and processors' overall operation costs are unknown. Also, the data for processors' inventory are not available. Hence, it is assumed that all the off-farm storage is held by commercials. As a result, the benefits of storage to the processing business are not discussed.

[7] Commercials may also hedge their future purchases, i.e., take long positions in future markets. It would be desirable to separate commercials' long position from other traders'. Unfortunately, such data are unavailable.

[8] There are two target equations and seven instruments; hence, fourteen moment conditions are present.