An Empirical Test of the Effect of Basis Risk on Cash Market Positions

JANET S. NETZ

INTRODUCTION

A large literature, theoretical and empirical, explores the effect of basis risk on the effectiveness of futures markets as a risk-management tool and on the hedge ratio. It is widely accepted and empirically shown that, in the face of basis risk, the hedge ratio should be less than one.[1] Because basis risk affects the hedging effectiveness of futures markets, work has also been done on empirically determining what variables affect the basis (the difference between the cash and futures prices) and basis risk (unexpected changes in the basis over time).[2]

[1]Estimates of the optimal hedge ratio in the face of basis risk range from a low of 0.3 to close to 1. See Peck (1975) for eggs; Ederington (1979) for wheat, corn, GNMAs, and T-bills; Figlewski (1984) for S&P 500 index futures; Castelino (1992) for wheat, corn, T-bills and Eurodollars; and Moser and Helms (1990) for British pounds, Canadian dollars, Deutsche marks, and Swiss francs.

[2]Vollink and Raikes (1977) analyze the live cattle basis, showing that basis risk exists because the basis does not move as expected at the delivery point and during the delivery period; Tilley and Campbell (1988) analyze determinants of the wheat basis; Martin, Groenewegen, and Pidgeon (1980) the determinants of the corn basis in Southwestern Ontario; and Ward and Dasse (1977) the determinants of the frozen concentrated orange juice basis, showing that basis risk exists in this market, especially during a freeze scare. Garcia, Leuthold, and Sarhan (1984) analyze the random component of the livestock basis, identifying variables that can indicate periods of high basis risk, and Figlewski analyzes factors influencing the S&P 500 index basis risk.

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■ *Janet S. Netz is an Assistant Professor in the Department of Economics, Purdue University.*

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Despite the abundance of work on the effect of basis risk on futures markets positions, economists have largely ignored the effect of basis risk on cash market positions. Paroush and Wolf (1989, 1992) and Anderson and Danthine (1981) have theoretically shown that basis risk affects the cash market position, but the theoretical results have not been empirically tested. Furthermore, models that include futures markets routinely ignore the presence of basis risk.[3] Although in many situations this simplification can be made without loss of generality, in some situations incorrect inferences are made. For example, the standard separation result in which the cash market position does not depend on risk variables does not obtain in the face of basis risk. The goal of this article is to empirically test the hypothesis that basis risk affects the cash market position and to estimate the magnitude of this effect. The results show that the presence of basis risk does indeed reduce the cash market position and, though the impact is not trivial, it is sufficiently small that ignoring basis risk will, in many situations, not substantively change results.

Intuitively, why should basis risk matter? To illustrate, consider a simple case of a storer who takes a long position in the cash market and a short position in the futures market in Period 1 and reverses the position in Period 2. The storer buys the cash good at c_1 and sells at c_2, and sells the futures contract at f_1 and buys at f_2. The profits are $(c_2 - c_1) + (f_1 - f_2)$; or, in terms of the basis, defined as $b_i \equiv c_i - f_i$, profits are given by $b_2 - b_1$. Thus, the change in the basis over the life of the hedge determines the agent's profits. The riskiness or variance of the storer's profits will be a function of the variance of the basis.[4] Because basis risk affects the risk of profits from the hedged position, it seems likely that it affects the cash position. In particular, basis risk should reduce the cash position of risk-averse agents.[5]

More precisely, *unexpected* changes in the basis affect the riskiness of the hedge. The basis is expected to change over the life of the hedge. In particular, for storable commodities, the basis will change by the reduction in the storage costs over the period. That is, the theory of storage [Working (1949)] suggests that the basis should be equal to no more than

[3]For example, Kawaii (1983), Sarris (1984), and Turnovsky (1983).

[4]This simple example assumes a complete hedge (a hedge ratio of 100%). A more realistic model is developed below. With a complete hedge, the agent only faces basis risk. For an agent to undertake such a hedge, basis risk must be less than price risk. So long as the futures contract is related to the physical commodity being hedged, basis risk should be less than price risk.

[5]The importance of the basis and basis risk arises because very few contracts (less than 3%) are offset through delivery. If delivery occurs, in the case of storage, profits are given by $f_1 - c_1$; the agent simply contracts today for delivery tomorrow. In this case the existence of a futures market allows the agent to completely shift risk.

the cost of storage between today and the expiration date of the contract. If the basis is higher than the costs of storage, an arbitrage opportunity exists. Thus, if the hedge is opened 2 months before the contract expiration date and closed 1 month before expiration, the basis should narrow by 1 month's storage cost. Because this change in basis can be anticipated, it should not be considered risk. The agent can take into account any predictable changes in the basis when selecting cash and futures positions.

A standard portfolio model of storage and hedging illustrates that an increase in basis risk reduces the cash market position. In contrast to initial portfolio approaches to hedging [Stein (1961)], both the cash and futures positions are endogenous.[6] Under a portfolio approach, an agent faces both basis risk (from hedged inventories) and price risk (from unhedged inventories). Other theoretical articles are discussed to show that the result is fairly general and is not dependent on the functional form used or on other assumptions. The result is that, given the return to storage, as either basis risk or price risk increases, the agent will reduce the level of inventories.

The article develops an empirical test of the hypothesis that basis risk affects the level of storage, and discusses the empirical method. The test is applied to the storage of corn.[7] This application is chosen because detailed data on corn are available from the U.S.D.A. Data are used to estimate storage at the nine major corn markets in the United States using weekly data from 1984 to 1989. It is the variation in basis risk across time and location that allows the impact of basis risk to be empirically isolated. Basis risk differs across markets because of different types and qualities of corn grown locally compared to the type and quality of corn specified in the contract (No. 2 yellow at par). Basis risk varies over time because of the arrival of new information between the time the hedge is placed and the time the hedge is lifted. For example, announcements of crop expectations or changes in the weather affect the future basis, and so long as the information in the announcements is unexpected, basis risk will arise. Basis risk varies across time and location because random shocks in each period may affect the local market (impacting the cash price) and the national market (impacting the futures price) differently.

[6]Obviously, if the cash position is exogenous, basis risk would not affect it.

[7]The working paper version of this manuscript also includes data on the storage of soybeans. That application is flawed because it only considers soybean contracts. A soybean storer can also use soybean oil and meal contracts to hedge. Basis risk arising from the soybean contract could lead to a re-allocation to meal and oil contracts rather than affecting the cash position. A more sophisticated empirical test that included data on the relationship between the cash price and the three futures prices would be required. See Anderson and Danthine for a model of hedging with multiple contracts.

The data are described and the results, which demonstrate that basis risk has a significant negative impact on the level of storage, are presented. On average, a one-standard-deviation increase in basis risk reduces the level of stocks by 4% of a standard deviation or 3.5% of the mean. To contrast, a one-standard-deviation increase in the return to storage increases the level of stocks by 18% of a standard deviation or 16% of the mean. Thus, basis risk has almost a little less than half the effect of the return to storage. The implications and the need for further research are discussed. In general, both commodity exchanges and policy makers have an incentive to structure contracts in such a way so as to minimize basis risk.

THE MODEL

The impact of basis risk on the cash and futures positions can be illustrated with the use of a standard mean-variance model of storage (*e.g.*, Turnovsky). After the effect of basis risk on the level of inventories is illustrated, other models that incorporate basis risk are presented to show that basis risk negatively affects the cash position under other assumptions and approaches.

Assume a perfectly competitive, risk-averse agent faces uncertainty and uses futures contracts to manage risk. Risk arises in this application because the output price is unknown. The storer is motivated by intertemporal arbitrage.[8] Storage costs are assumed to be linear, and the production function is one to one, so that one unit of input (grain today) gives one unit of output (grain tomorrow).[9] The futures market is assumed to be perfectly competitive and populated by a large number of risk-neutral speculators. Thus, hedgers take the futures price as given. For simplicity, a mean-variance approach is taken, which assumes that utility as a function of profits is exponential. Maximizing utility is then equivalent to maximizing expected profits less one-half the variance of profits multiplied by the coefficient of absolute risk aversion.

Variables are defined as follows: p_t is the real spot price in period t; a tilde over any variable indicates that it is a random variable; s_t denotes storage from period t to period $t + 1$; e and F are positive constants, where e is the per unit cost of storage and F is the fixed cost of storage; z_t is the number of contracts sold (purchased if $z_t < 0$); $f_{i,j}$ is the real price in period i of a futures contract that expires in j; A is the coefficient

[8]This assumption is relaxed later.
[9]Spoilage is ignored in the model.

of absolute risk aversion; ${}_tx_{t+1}$ is the time t expectation of variable x in the following period; σ_i^2 (σ_i) is the variance (standard deviation) of variable i; and σ_{ij} is the covariance of variables i and j.

The storer solves the following maximization problem:

$$\begin{aligned}\max_{s_t, z_t} \; & ({}_tp_{t+1} - p_t)\, s_t - (es_t + F) \\ & + (f_{t,t+1} - {}_tf_{t+1,t+1})\, z_t \\ & - \frac{1}{2} As_t^2\sigma_p^2 - \frac{1}{2} Az_t^2\sigma_f^2 + As_t z_t \sigma_{pf} \\ & s.t.\; s_t \geq 0\end{aligned}$$

The first two terms represent the expected profits from storage; the third term represents the expected profits from selling futures;[10] and the last three terms represent the effect on utility arising from uncertainty. An increase in the variance of either the spot or futures price reduces utility because the increased variance indicates that operations in the spot or futures market, respectively, are riskier. The covariance term raises utility.[11] This term increases utility because it represents hedging; losses in one market are offset, to some extent, by gains in the other market.

This model yields the standard implications of basis risk on the futures position. Optimization yields the standard hedging position

$$z_t = \frac{(f_{t,t+1} - {}_tf_{t+1,t+1})}{A\sigma_f^2} + \frac{\sigma_{pf}}{\sigma_f^2} s_t \tag{1}$$

The two terms are the speculative and hedging components, respectively. Assuming that a large number of risk-neutral speculators operate in the futures market, equilibrium in the futures market requires that speculative profits be zero, in which case $f_{t,t+1} = {}_tf_{t+1,t+1}$.[12] In this case, the speculative (first) term disappears, and the optimal futures position is some fraction of the inventory level for an interior solution and zero for a corner solution.

The hedge ratio is given by σ_{pf}/σ_f^2, or, alternatively, as $(\sigma_p/\sigma_f)\rho$, where

[10] Transaction costs in the futures market are ignored.

[11] As shown below, the position in the futures market (short or long) depends on the sign of the covariance between the spot and futures prices (positive or negative); thus, the final term is always positive.

[12] Risk-averse speculators must receive a risk premium to operate in the futures market to offset the acceptance of risk, in which case the futures price must be less than the expected future spot price. Empirical tests for the existence of a risk premium in commodities markets extend back at least to Telser (1958) for a variety of commodities. More recently, see Kolb (1992). Results show no risk premium or are inconclusive.

ρ is the correlation coefficient between the spot and futures price over the life of the hedge. So long as the futures and cash prices are positively correlated, as they are when the stocks and the futures contract are based on the same fundamental commodity (*e.g.*, corn futures and corn inventories), then the agent will take opposite positions in the two markets. That is, a storer will offset inventories of corn by selling corn futures. As price risk rises (as measured by the standard deviation of the spot price), the hedge ratio increases; that is, the agent hedges more of the inventory using futures markets. As basis risk rises (ρ or σ_{pf} falls), the agent reduces the futures position for a given level of inventories. Intuitively, the futures market is not as good an instrument for managing price risk when basis risk is present; therefore, the agent relies on futures less, insuring a fraction of stocks with futures and self-insuring the remainder.

The first-order conditions can be solved for the level of inventories, which for the interior solution is given by

$$s_t = \frac{({}_tp_{t+1} - p_t - e)}{A\sigma_p^2(1 - \rho^2)} \tag{2}$$

As the expected return rises, agents carry a larger inventory. As risk aversion increases (A rises), the level of storage falls. The variance of the spot price and $(1 - \rho^2)$ can be interpreted as direct measures of price risk and basis risk, respectively. The more variable the spot price, the more price risk the agent faces. Basis risk is higher the more independently the spot and futures prices move over the life of the hedge [$(1 - \rho^2)$ is high]. For each of these measures of risk, as risk increases, storage decreases. Thus, in a very simple model, it is easy to show that the cash market position depends on basis risk. The rest of this section explores the robustness of this result.

The corner solution states that storage is zero when the return to storage is nonpositive. However, storage is often observed to be positive even when the return is negative. To explain this observed paradox, Kaldor (1939) introduced the concept of convenience yield. The intuitively appealing idea is that agents find it convenient to hold inventory. This convenience may arise, for example, because it allows agents to meet unexpected demand. Convenience yield is assumed to be a nonlinear function of storage, with a negative first and positive second derivative. With convenience yield, positive storage may occur with a negative return because of the convenience it gives the agent. Does the existence of an additional motive for inventories eliminate the impact of basis risk? No. Taking the maximization problem for a risk-averse storer and adding convenience yield leads to the following implicit interior solution for the level of storage:

$$(A\sigma_p^2(1 - \rho^2))s_t - c'(s_t) = {}_tp_{t+1} - p_t - e,$$

where $c(s_t)$ is convenience yield as a function of the level of inventories. Total differentiation shows that, again, storage decreases as price risk or basis risk rises (and increases as the return to storage rises).

Thus, risk-averse agents who store to make profits from intertemporal arbitrage will hold less inventory in the face of increased basis or price risk, regardless of whether they also hold inventories for convenience yield purposes. Anderson and Danthine and Paroush and Wolf (1989) utilize similar models to examine the impact of basis risk on the cash market position, but they relax two assumptions that are made in the simple example above. Anderson and Danthine relax the assumption that all speculative profits in the futures market have been arbitraged away, and Paroush and Wolf maximize expected utility rather than using a mean-variance approach.

Anderson and Danthine present a model of hedging with multiple contracts (of which this model is a special case with one futures contract), also using a mean-variance framework. They allow the cash market participant the opportunity to make speculative profits in the futures market. That is, they do not make the assumption that $f_{t,t+1} = {}_tf_{t+1,t+1}$. In the case where the storer does have the opportunity to make speculative profits, it is possible for basis risk to increase the cash market position. However, this occurs only when speculative profits from *buying* futures ($f_{t,t+1} < {}_tf_{t+1,t+1}$) when the hedge is opened are so large that speculative buying offsets hedge selling, so that the agent is long both cash and futures. As pointed out by Peck (1975), this seems unlikely to occur. In any event, their model shows that the cash position will not be independent of basis risk. The empirical test below does not constrain basis risk to negatively impact on the cash market position. A positive coefficient will arise in situations where storers are long cash and futures.

Anderson and Danthine and the model above use a mean-variance approach, which assumes that profits are distributed normally and that the storer's utility function of wealth is exponential so as to maintain a constant absolute risk aversion. In contrast, Paroush and Wolf (1989) maximize the expected utility as a function of profits. Although this puts no restrictions on the shape of the utility function, the Taylor-series expansion implies that the implications hold only for small changes in risk. Paroush and Wolf also make no distributional assumptions in the theoretical analysis. The firm operates in a cash market and has access to a futures market in a two-period model. In the first period the firm commits to its position in the cash and futures markets; in the second the firm sells the product in the cash market and closes its futures position. Paroush and Wolf assume that the futures price is a linear function of the spot price (which is random) plus another, independent, homoskedastic random error. The random errors can be interpreted as price risk and basis risk, respectively. Paroush and Wolf show that production (or storage) in the presence of basis risk is less than in the absence of basis risk, and that production (or storage) declines as basis risk rises.[13]

To this point, it is shown that, under a variety of assumptions and approaches, basis risk reduces the cash market position and the hedge ratio. The following section empirically tests that result.

EMPIRICAL METHOD

The model indicates that storage, from the point of view of an individual risk-averse agent, is a function of the return to storage, basis risk, and price risk.[14] At the market level, storage will also depend on the amount available to be stored. To capture these effects, the following equation is estimated[15]

$$\begin{aligned} s_{it} = a + \beta_1\, ret_{it} + \gamma_1\, brsk_{it} + \gamma_2\, prsk_{it} \\ + \beta_2\, prodn_t + \beta_3\, harvest_t + \varepsilon_{it} \end{aligned} \tag{1e}$$

where

s = the level of corn storage, in thousand bushels, at each of nine Midwest cities by elevators
ret = the present value of the expected return to storage, in 1988 cents
$brsk$ = basis risk, in 1988 cents
$prsk$ = price risk, in 1988 cents
$prodn$ = the level of U.S. production, in billion bushels

[13]In a separate article Paroush and Wolf (1992) theoretically examine the impact of basis risk on the demand for inputs (for example, flour millers). They find that as basis risk increases, demand for the risky input declines, another example where basis risk affects a cash market position.

[14]The role of convenience yield is discussed later.

[15]The illustrative model presented above suggests a log-linear functional form. Estimation of a log-linear form, however, gives poor results. This is a reflection on the assumption of exponential utility necessary to use a mean-variance framework. The expected utility approach of Paroush and Wolf (1989) does not suggest any particular functional form, while implying the same impact of basis risk on storage. Thus a linear functional form is used.

harvest = a dummy variable equal to 1 for observations in October, November, and December.

The error term, ε, captures exogenous supply shifts and forecast errors and is assumed to be distributed normally.[16] β_1 is expected to be positive; as the return to storage rises, storage levels will rise. γ_1 and γ_2 are expected to be negative; as either basis or price risk increases, storage decreases. β_2 is expected to be positive; the larger the crop, the more that will be stored. β_3 is also expected to be positive; during and shortly after harvest, stocks are expected to build up independently of the return to storage and risk.

Econometric Structure

The equation is estimated using weekly data on storage of corn at nine major corn markets in the U.S. from 1984 to 1989. Although storage fluctuates in both directions throughout the year, there is a clear seasonal pattern, with stocks building up after harvest and being depleted over the course of the year. The level of storage clearly exhibits a high degree of serial correlation. Initial estimates of eq. (1*e*), with the use of the Cochrane–Orcutt procedure, provide estimates of the degree of serial correlation at about 0.97 or higher at each location, which suggests the presence of a unit root. Univariate tests for nonstationarity of the level of stocks, involving regressing the variable on its lag, its lag and a constant, or its lag, a constant, and a time trend, and a multivariate test for nonstationarity give similar results.[17] Storage is nonstationary, except for Peoria; however, even the result at Peoria is borderline. To eliminate nonstationarity, eq. (1*e*) is estimated in differences.[18] Additional serial correlation is controlled for by using the Cochrane–Orcutt technique on the differenced data.

As well as controlling for an econometric difficulty, estimating the equation in differences eases interpretation and measurement concerns. For example, the model as devised thus far has treated building-up and

[16]Its variance structure is discussed in the next section.

[17]The multivariate test is derived by quasidifferencing eq. (1*e*), adding $(s_t - s_{t-1})$ to both sides, and adding and subtracting the one-period lag of each independent variable to the RHS. To test for stationarity, the transformed equation is estimated with the use of OLS. Under the null hypothesis of a unit root, the coefficients on the lagged dependent variable and the lagged independent variables should all be zero. The test statistic on the lagged dependent variable will be distributed as $\hat{\tau}_u$ in Fuller (1976), and the test statistic on the other coefficients will follow the standard t distribution.

[18]The independent variables are all stationary, so that a co-integration technique is not appropriate.

drawing-down storage levels symmetrically. This might seem ill-advised, given that stocks clearly trend downwards over three-quarters of the year and upwards over the other quarter. Analysis of changes in the level of storage, however, reveals that stocks rise relative to the previous week for 49% of the observations. The average level of change from one week to another is virtually identical whether the change is positive or negative (211,000 bushels when stocks rise relative to the previous week, 218,000 bushels when stocks fall); the standard deviation is quite similar (430,000 bushels for increases in stocks, 442,000 bushels for decreases); and the maximum observed change is about the same (4,609,000 bushels for increases, 4,681,000 bushels for decreases).[19] Thus, increases and decreases in stocks can be treated largely symmetrically, though that would be inappropriate for levels of stocks.[20] One variable is added to the estimation equation to help control for seasonal patterns. That variable is *harvest,* which is a dummy variable equal to one during the months of October, November, and December, the months during and after harvest when stocks build up. The coefficient on this variable is expected to be positive. During and shortly after harvest, *on average,* it is expected that the change in stocks will be positive, whereas during the rest of the year the change in stocks is expected to be, *on average,* negative. Without the *harvest* dummy, the constant would pick up both effects.

Another structural issue is the assumed form of the variance of the error term, which is time and location specific. Correlation of the error term over time is discussed above. It seems logical to hypothesize that the error term is contemporaneously correlated across locations. However, a likelihood-ratio test rejects this hypothesis. Thus, the error term is assumed to be distributed normally, with a mean of zero, $E(\varepsilon_{it}\varepsilon_{it}) = \sigma^2$, $E(\varepsilon_{it}\varepsilon_{it-1}) \neq 0$, and $E(\varepsilon_{it}\varepsilon_{jt}) = 0$.

Finally, the data are pooled over the nine locations and the 6 years. Chow tests for structural change do not reject the hypothesis that coefficients are equal across locations and years. Time-fixed effects and location-fixed effects are jointly insignificant, so they are not included.[21]

[19]Observations where stocks go up relative to the previous week are of course concentrated during the period shortly after harvest (October, November, and December). During this period, 63% of observations have stocks rising; during the rest of the year, 45% of observations have stocks rising.

[20]Stocks can rise even well after the harvest because the sites studied are located along the distribution pipeline. Grain is flowing from production areas and other storage locations further up the distribution pipeline.

[21]The insignificance of time and location effects is not surprising, because the data are differenced before estimation to deal with nonstationarity of the error term. Thus, any fixed effects will be differenced out.

Measurement Concerns

The agent chooses positions in the cash and futures markets at time t based on the expected return to storage between t and $t + 1$.[22] If the position were held to maturity in period T, the return to storage would be given by $\tilde{p}_T - p_t$, where p_i continues to denote the cash price in period i and the tilde denotes a random variable. Assuming that the futures market is efficient and unbiased, the futures price $f_{t,T}$ at time t for a contract maturing at time T is the best estimate of the spot price in period T less the delivery-period basis. Momentarily ignoring the delivery-period basis, the return to storage could be estimated as $f_{t,T} - p_t$. However, this is the return to storage over the period $T - t$. To approximate the return to storage over a week, $f_{t,T} - p_t$ is divided by the number of weeks to maturity (*i.e.*, $T - t$).

The storage equation is estimated for nine different cities with the use of data from all five corn contracts for 6 years. Even at the delivery point the delivery period basis will not be zero because of delivery costs. At nondelivery points the basis will not be zero because of the transportation cost between the location and the delivery point and possibly due to differences between the grade and quality of corn at that location relative to the grade and quality specified for delivery at par. The delivery-period basis will vary across each location, across each contract, and across years, because transportation costs, grade, and quality will vary across location, contract, and years. Thus, the futures price will overstate the expected spot price in the delivery period. Differencing the data eliminates the delivery-period basis bias. Each successive estimate of the return to storage will overstate the return by the delivery-period basis for that contract; subtracting the previous return from the current return will eliminate the delivery-period basis bias.[23]

To calculate measures of the basis risk and price risk expected to prevail over the week in which the agent holds inventory, assume that the agent uses historical data over the previous 8 weeks as the foundation for the expected basis risk and price risk.[24] Basis risk and price risk are measured as the standard deviations of the change in the basis and the spot

[22]The data are weekly.

[23]This assumes that the expected delivery period basis is constant over the life of the contract. Although it is probably not precisely constant, in most circumstances it should not be a bad approximation.

[24]An 8-week lag is chosen mostly arbitrarily. A longer lag period both reduces the amount of data available and may inappropriately bias the estimate of the risk variables in the direction of old, outdated information. A shorter lag period may not incorporate useful information. Use of 6- and 10-week lags does not substantially alter the results.

price, respectively, over the previous 8 weeks.[25] The basis is measured as the cash price less the futures price of the nearby contract.[26] Only unexplained changes in the basis can be classified as risk. Each week as maturity approaches, the basis should predictably narrow by storage charges for one week. To adjust for the change in the cost of storage, the weekly storage cost could be subtracted from the weekly change in the basis, requiring data on storage costs. However, although this adjustment affects the mean of basis changes, it does not affect the standard deviation of basis changes.[27] Thus, basis risk can be calculated as the standard deviation of observed changes in the basis without capturing expected changes in the basis due to expected changes in the storage costs.

As explained above, convenience yield is important in explaining storage when the return to storage is negative. However, there is no obvious way to measure convenience yield.[28] Convenience yield will have the largest influence when stocks are at their lowest, because at these times the probability of not having supplies to satisfy demand is highest. To remove observations with high noise from convenience yield, the equation is reestimated for a sample that omits observations with low storage. Low storage levels are defined as observations in the lowest decile at that location.

Econometric Concerns

The return to storage (*ret*) is clearly correlated with the error term, because the return to storage and the level of storage are determined simultaneously. A high return to storage leads to higher levels of storage, but higher levels of storage lead to a lower return to storage. Thus, standard estimation will result in a coefficient estimate that is biased downward. To the extent that the return to storage is correlated with basis risk and price risk, the coefficients on these variables will also be biased. Instrumental variables in a two-stage least-squares framework is used to control for simultaneity. The identifying instruments used are the yield of the surrounding farm area, the amount of corn inspected for export,

[25]This measure of volatility is common to the literature on the effect of exchange-rate risk on trade volumes, for example, Kenen and Rodrik (1986).

[26]Ederington shows that a nearby contract provides a more effective hedge than farther contracts for corn (as well as other commodities).

[27]Tilley and Campbell show that the particular futures contract used affects the level of the Gulf–Kansas City hard-red winter wheat basis. If there is a similar effect for the corn basis, use of the standard deviation of changes in the basis as the measure of risk removes this effect, because to compute basis risk the basis is calculated with the use of the same contract.

[28]Ward and Dasse devise a measure that is a function of the level of inventories, but is inappropriate here because the level of inventories is the dependent variable.

the amount of grain shipped by waterways, state rainfall and temperature, and monthly dummies. All instruments influence both supply and demand, current and future, for corn, all of which will influence the return to storage.

It is also possible that price risk and basis risk are correlated with the error term. Suppose that, *ceteris paribus,* storage does decline in the face of high basis risk and high price risk. Then, the chance of a stock out at a location that faces high basis risk or high price risk increases, which should lead to a more variable local cash price. A more variable local cash price leads to higher price risk and higher basis risk. Thus, it is possible that price risk and basis risk are correlated with the error term. The estimated coefficient on risk would pick up the effect of risk on stocks (expected to be negative) and stocks on risk (also expected to be negative), so the coefficient would be biased downward. Because price and basis risks involve unexpected changes in these variables, if measured correctly there are no instruments available to control for simultaneity. To give some idea of the possible existence of this effect, a Granger-causality test is run at each location between stocks and basis risk and between stocks and price risk. At every location the hypothesis stocks Granger-cause price risk is rejected at least at the 50% level. The hypothesis that stocks Granger-cause basis risk is not rejected only at Minneapolis. The equation is re-estimated across all nine locations and across a sample omitting observations at Minneapolis.[29]

A priori, it seems unlikely that basis risk and price risk are endogenous. Suppose that stocks decline as risk rises. Then, in a period subject to high risk, demand for the commodity today will be reduced because storers want to reduce inventories, which causes the cash price today to fall. The expected future cash price will rise because fewer inventories are carried into the future so there is a lower expected future supply. Thus, the expected return to storage rises, encouraging more storage despite the increase in risk. Thus, it does not seem likely that stocks will cause basis or price risk to change.

DATA

Given the concerns discussed above, the results presented in the next section are based on the use of differenced data (to control for a nonstationary error); are controlled for additional serial correlation using the

[29]A Granger-causality test is also run across the pooled sample, with and without Minneapolis. The null hypothesis that stocks Granger-cause basis risk is rejected when Minneapolis is excluded but is not rejected when Minneapolis is included. A VAR among stocks, basis risk, and price risk is also run. Again, there is no evidence that stocks cause basis risk except at Minneapolis.

Cochrane–Orcutt technique, allowing for different degrees of serial correlation at each location; and are controlled for simultaneity of the return to storage with instrumental variables. The data are pooled across time and location under the not rejected hypotheses that (a) there are not time and location effects, (b) the error terms are not contemporaneously correlated across locations, and (c) the coefficients are equal across time and location.

The model is tested by analyzing the primary corn markets in the United States using weekly data from 1984 to 1989. Weekly data on stocks and inspection of corn for export are from the Livestock and Grain Market News Branch publication *Stocks of Grain at Selected Terminal and Elevator Sites* for Chicago, Toledo, the Gulf (the sum of stocks at New Orleans, Baton Rouge, Ama and Belle Chasse, Mobile, and Pascagoula), Sioux City, Omaha–Council Bluffs, Peoria, Kansas City, Minneapolis, and St. Louis.[30] These are stocks held in country and terminal elevators.[31] Corn belt states include Minnesota, Iowa, Missouri, Illinois, Indiana, and Ohio.

Daily futures prices for corn on the Chicago Board of Trade are from the Center for the Study of Futures Markets at Columbia University. The average of the daily settlement prices for the nearby contract is used as the weekly futures price.[32]

The daily cash prices are from the United States Department of Agriculture. They are the bid prices for grain to arrive in 15 days at the major elevators in the area. The high and low bids are averaged over 6–30 elevators, depending on the area. The data are collected by calling the elevator shortly after the futures market closes. The daily cash price for each location is averaged to obtain a weekly cash price.

The price index used to transform nominal to real prices is the Census Bureau's monthly implicit consumer price deflator, from Citibase data tapes. Because the rest of the data are weekly, the monthly values of the interest rate and deflator are interpolated to estimate weekly data.[33]

U.S. production and yields are obtained from the Crop Reporting Board's (January, 1981–December, 1989) *Crop Production* publication.

[30]The availability of cash-price data in machine-readable form determined the choice of locations.

[31]Country and terminal denote the location of the elevator. Country elevators are near the production sites, and terminal elevators are located at the end of the domestic distribution path.

[32]The analysis using an average of Tuesday, Wednesday, and Thursday settlement prices, and using the settlement price for the nearest contract for each weekday to avoid possible day of the week effects, gives qualitatively similar results. For brevity, only results using the weekly average are presented.

[33]The results are substantially the same when it is assumed that each monthly value holds for each week of that month.

TABLE I
Descriptive Statistics
(Standard Deviations in Parentheses)

Location	*Cash Price*[1]	*Stocks*[2]	*Basis Risk*[3]	*Price Risk*[3]
St. Louis	2.41 (0.37)	1,777 (1,973)	5.41 (3.66)	7.39 (5.61)
Chicago	2.32 (0.37)	12,414 (9,436)	5.30 (3.64)	7.48 (5.20)
Toledo	2.33 (0.39)	18,372 (9,701)	4.91 (3.21)	6.98 (5.03)
Gulf	2.59 (0.37)	6,292 (2,684)	5.19 (3.26)	7.48 (5.36)
Peoria	2.26 (0.38)	2,020 (794)	5.07 (3.39)	6.96 (5.27)
Sioux City	2.14 (0.40)	4,765 (2,171)	5.01 (2.81)	6.40 (4.75)
Kansas City	2.33 (0.38)	5,805 (1,964)	5.04 (2.41)	6.95 (4.58)
Minneapolis	2.27 (0.38)	12,040 (5,288)	7.20 (8.28)	8.65 (8.69)
Omaha-Council Bluffs	2.14 (0.40)	13,684 (4,269)	5.01 (2.81)	6.40 (4.75)
Unweighted average	2.31 (0.40)	8,572 (7,560)	5.35 (4.12)	7.19 (5.62)
Without Minneapolis	2.32 (0.38)	8,139 (7,844)	5.12 (3.60)	7.01 (5.24)

[1]1988 real dollars.
[2]Thousand bushels.
[3]1988 real pennies.

For yields, the following states are matched with each location: Missouri and Illinois to St. Louis; Illinois and Indiana to Chicago; Michigan and Ohio to Toledo; Louisiana, Missouri, Arkansas, and Tennessee to the Gulf; Illinois to Peoria; Iowa, Nebraska, and South Dakota to Sioux City; Missouri and Kansas to Kansas City; Minnesota and Wisconsin to Minneapolis; and Iowa and Nebraska to Omaha–Council Bluffs.[34] Because distribution will be affected by production (harvest) at each location, national production is used.[35] Monthly data on temperature and precipitation by state is from *Weather in U.S. Agriculture: Monthly Temperature and Precipitation by State and Farm Production Region, 1950–1990,* and data on grain shipments on the Illinois Waterway and the Mississippi River (locks 11–22) are from *Feed Situation and Outlook Yearbook,* both from the Department of Agriculture's Economic Research Service (March, 1993).

RESULTS

Descriptive statistics are presented in Table I. Of interest is the fact that the mean level of basis risk is smaller than the mean level of price risk at

[34]Because only statewide data are available, some states have been matched with more than one location. For example, Illinois grain is available for storage in Peoria, Chicago, or St. Louis, each of which is either in or on the border of Illinois.
[35]Using local harvests, as defined above for the yield, leads to similar results.

TABLE II
Storage
(Standard Errors in Parentheses)

Independent Variable	*All Cities,*[1] *All Stocks*	*No Minneapolis, All Stocks*	*All Cities, No Low Stocks*	*No Minneapolis, No Low Stocks*
Constant	−407.96***	−409.67***	−425.36***	−427.99***
	(101.20)	(101.28)	(111.54)	(112.02)
Return	79.42***	65.22***	87.89***	74.93***
	(22.78)	(21.88)	(26.68)	(26.52)
Basis Risk	−28.70*	−31.71*	−29.17*	−36.40*
	(15.09)	(16.99)	(16.54)	(19.31)
Price Risk	−27.37**	−22.93	−34.89**	−30.65*
	(13.79)	(14.39)	(16.22)	(17.44)
U.S. Production	42.99***	44.17***	46.90***	48.17***
	(13.23)	(13.28)	(14.69)	(14.78)
Harvest	259.53***	250.45***	258.88***	249.87***
	(34.29)	(34.66)	(38.06)	(38.33)
F	14.38***	13.21***	11.89***	11.02***
$D\text{-}W$	2.06	2.07	2.07	2.08
n	2691	2393	2412	2145
ρ range	−0.36 to 0.45	−0.36 to 0.47	−0.37 to 0.46	−0.37 to 0.48

***Significant at the 1% level.
**Significant at the 5% level.
*Significant at the 10% level.
[1]St. Louis, Chicago, Toledo, Gulf, Peoria, Sioux City, Kansas City, Minneapolis, and Omaha–Council Bluffs.

all locations.[36] The mean cash price (and, to a lesser degree, the standard deviation) varies from location to location, with a low in Sioux City of \$2.14 and a high at the Gulf of \$2.59. At least part of this difference is explained by transportation costs. The levels of inventory differ significantly between the various locations, from lows of approximately 2 million bushels (St. Louis and Peoria) to highs of close to 20 million bushels (Toledo). Variability in storage also differs widely across locations. Notice that Minneapolis seems to differ substantially from the other locations. The mean price risk and mean basis risk are 23% and 41% higher than the average over the other locations. The standard deviation of both risk variables is also much larger than at other locations; that is, the level of risk at Minneapolis is both larger and more variable than at the other locations.[37]

[36]Recall that the risk variables are measured as the standard deviation of the change in the variable over the past eight periods.

[37]Recall also that Minneapolis is the only city at which the hypothesis that stocks Granger-cause basis risk is not rejected.

The results are presented in Table II. All coefficients have the predicted sign and are largely significant at conventional levels. The price risk variable is significant at the 11% level in the sample where Minneapolis is excluded. When periods of low stocks are omitted (primarily at the end of the crop year) in an effort to remove observations believed to be strongly affected by convenience yield, all explanatory variables have a larger magnitude, by an average of 15%. This is to be expected. In periods of low levels of inventory, convenience yield will be the dominant influence as opposed to risk and the return to speculative storage. When storage levels are higher, storage is motivated primarily by intertemporal arbitrage profits, so these effects dominate the convenience yield effect. The result is only suggestive, however, because the hypothesis that the coefficients are equal across the full sample and the sample without low stocks is accepted.

Contrary to expectations, when Minneapolis is excluded from the sample the coefficient on basis risk becomes more negative. The counterintuitive result may be explained by the fact that Minneapolis is out of position: it is the least integrated into the distribution pipeline, especially over the winter months when the top of the Mississippi freezes. Although inventory levels at all locations indicate not only pure storage but also handling (moving grain from truck to rail or barge or from barge to ocean liner, for examples), inventory at Minneapolis, given its location, comes the closest to pure storage. The theory may be expected to hold more strongly at Minneapolis, in which case the coefficient on basis risk would be larger.

Table III presents estimates of the magnitude of the effect of the independent variables on storage, which varies across location. Two measures are presented.[38,39] One is the elasticity calculated at the means of the levels of the variables (in the columns labeled "Elast."). The second measure gives the percentage of a standard deviation that stocks change when the indicated independent variable increases in levels by one standard deviation (in the columns labeled "Impact").[40] That is, when the

[38]Though the equations are estimated in differenced form to control for nonstationarity, the estimated coefficients from the differenced form give unbiased estimates of the coefficients from the level form of the equation. Thus, calculations proceed as usual.

[39]Calculations use the coefficients from the sample including Minneapolis and including all levels of stocks, which gives the most conservative estimated impact for basis risk. The basis risk coefficient from the sample excluding Minneapolis and excluding periods of low stocks would show basis risk to have a 27% larger impact.

[40]On average across the nine locations, the impact is slightly smaller when expressed as a fraction of the mean level of stocks.

TABLE III
Magnitude of Effect[1]

Location	Return		Basis Risk		Price Risk	
	Elast.[2]	*Impact*[3]	*Elast.*	*Impact*	*Elast.*	*Impact*
St. Louis	0.090	19.39	−0.087	−5.32	−0.114	−7.79
Chicago	0.005	3.45	−0.012	−1.11	−0.017	−1.51
Toledo	0.002	3.00	−0.008	−0.95	−0.010	−1.42
Gulf	0.087	22.11	−0.024	−3.49	−0.033	−5.47
Peoria	0.093	47.27	−0.072	−12.25	−0.094	−18.19
Sioux City	0.093	25.04	−0.030	−3.72	−0.037	−5.98
Kansas City	0.004	17.92	−0.025	−3.52	−0.033	−6.39
Minneapolis	0.009	9.18	−0.017	−4.50	−0.020	−4.50
Omaha–Council Bluffs	0.022	12.73	−0.011	−1.89	−0.013	−3.04
Simple Average	0.045	17.79	−0.058	−3.99	−0.041	−6.03

[1]Calculations use coefficients from column 1 of table II.
[2]Calculated at the means.
[3]The entries give the percent of a standard deviation storage changes when the indicated independent variable increases by one standard deviation.

return to storage increases by one standard deviation in St. Louis, stocks rise by 19% of a standard deviation.

Storage is inelastic with respect to all three independent variables. On average across all locations, a 1% increase in each independent variable causes stocks to change by about 0.05%. The elasticity at the means varies considerably across locations: the elasticity with respect to the return to storage ranges from a high of 0.093 at Peoria and Sioux City to a low of 0.002 at Toledo; the elasticity with respect to basis risk from −0.087 at St. Louis to a low of −0.008 at Toledo; and the elasticity with respect to price risk from −0.114 at St. Louis to −0.010 at Toledo. Note that the primary source of the variation in elasticities is due to the wide variation in mean levels of stocks at each location.

The impact column shows that, on average across all locations, a one-standard-deviation increase in the return to storage increases stocks by about 18% of a standard deviation or 1,345,000 bushels; basis risk decreases stocks by 4% of a standard deviation or 302,000 bushels; and price risk decreases stocks by 6% of a standard deviation or 456,000 bushels.[41] The impact numbers also vary considerably across locations. Peoria is most sensitive to changes in all the independent variables, and Toledo is the least sensitive.

[41]Alternatively, a one-standard-deviation increase in the return, basis risk, and price risk, causes stocks to change by, respectively, +15.7%, −3.5%, and −5.3% of the mean.

The variation in magnitudes may be explained by characteristics of the local market not captured in the model. For example, the high impact at Peoria may be explained by the ease with which grain can be moved from Peoria to Chicago or St. Louis if the economic environment is unfriendly toward storage. The delivery points, Chicago at par and Toledo at a discount, exhibit the smallest reaction to changes in the independent variables; delivery may be the largest impact at these locations.[42]

Of particular relevance to the hypothesis being tested, the results show that basis risk has a significant impact on the level of storage. A one-standard-deviation change in basis risk is associated with a decline in storage levels by 0.95% to 12.25% of a standard deviation, depending on location, with an unweighted average of 3.99%, or about 3.5% of the mean level of stocks at each location. The impact of the return to storage is three to four times larger, ranging from 3.00% to 47.27% of a standard deviation, as expected, because this is the primary motivation for storage. The impact of price risk is slightly larger than the impact of basis risk, ranging from 1.42% to 18.19% of a standard deviation. The empirical analysis indicates that, though the return to storage has the largest impact as expected, basis risk has a significant impact on the level of storage.

CONCLUSIONS AND IMPLICATIONS

This article empirically estimates the degree of the effect of basis risk on positions in the cash markets. A traditional portfolio model of risk-averse storers is used to demonstrate that basis risk negatively impacts the level of storage (as well as the hedge ratio). Basis risk reduces storage levels because it limits the effectiveness of futures as a risk management tool. As storers face more basis risk, they reduce their exposure by reducing the level of inventory. The result that basis risk affects the level of storage is then empirically tested with the use of data on storage of corn in nine major American markets in the mid-1980s. The empirical analysis shows that a one-standard-deviation increase in basis risk is associated with a decline in storage by between 1% and 12% of a standard deviation, depending on the location, or, on average, 3.5% of the mean.[43]

Although the impact of basis risk is statistically significant, some might argue that the magnitude is relatively small, and thus infer that

[42]Though less than 3% of contracts end in delivery, the average level of stocks in Chicago is less than 2500 contracts and the average level of stocks in Chicago and Toledo is less than 6200 contracts. In 1992, trade volume for corn was 10.3 million contracts; 3% of 10.3 million contracts is 309,000 contracts.

[43]The impact of the return to storage is three to four times larger.

analyses that ignore basis risk may not be introducing much in the way of error. Although this may be true for corn, in particular, and probably grains, in general, it would be a mistake to generalize the magnitude of the impact of basis risk to other industries. Of all the futures markets, the grain futures markets are the most developed and expose agents to the least amount of basis risk. The fact that even for this market a statistically and, arguably, economically significant impact is found suggests that the effect might be larger for other commodities. In a related exercise, empirical research estimating hedge ratios in the presence of basis risk gives quite different estimates depending on the commodity. For example, Ederington estimates an optimal hedge ratio of only 31% for 90-day T-bills but 92% for corn for 2-week hedges with the use of the nearby contract. The differences in optimal hedge ratios are driven, at least in part, by differences in basis risk. It seems likely that a similar range of magnitudes in the effect of basis risk on cash market positions may be observed. Only more empirical research will tell.

The fact that basis risk impacts storage also has implications for many studies of the impact of futures markets on price volatility. For example, in the models by Sarris and Turnovsky, the effect of futures markets on price volatility is driven by the impact of futures on storage behavior. In general, these articles find that the cash price will be stabilized if storage becomes more elastic with respect to the return to storage. Although storage becomes more elastic even if basis risk exists, basis risk limits the change in that elasticity. Thus, the estimates of Turnovsky and Campbell (1985), who simulate Turnovsky's model to estimate the degree to which a futures market reduces spot price volatility, should be interpreted as upper bounds on the degree of stabilization, because Turnovsky's model does not consider the impact of basis risk.[44,45]

Although this particular empirical application measures the impact of basis risk on storage, the models presented and discussed show that basis risk will affect the cash market position in all hedging situations by risk-averse agents. Thus, basis risk may affect positions in agriculture, energy, financial instruments, and any international transaction where agents use currency futures to hedge against exchange rate risk. For example, Netz (1992) examines the impact of basis risk and exchange rate

[44]Turnovsky and Campbell estimates of the degree of stabilization range from no effect to a 50% reduction, depending on parameter values and the source of uncertainty.

[45]Netz (1995), in her study of the impact of the development of the wheat futures market on spot price volatility, avoids this problem by studying the delivery location at a time when contracts often resulted in delivery (the mid- to late-1800s), that is, a situation where the assumption of no basis risk is reasonable.

risk on countries' aggregate storage and export levels in the wheat market.[46] The hypothesis empirically tested is that because foreign agents face greater basis risk and exchange rate risk, American agents have an advantage in storage over foreign agents; thus foreign countries export rather than store a larger proportion of supply shocks. Results support the idea that different levels of risk explain part of the difference in storage and export behavior.

The fact that basis risk reduces the cash market position and the futures market position relative to the cash position has implications for contract design and policy makers. One necessary element for contract success is volume (liquidity). By designing contracts that minimize basis risk, exchanges can encourage the use of the contract directly (because the hedge ratio rises with a reduction in basis risk) and indirectly (because the cash position, and hence the amount to be hedged, also rises). To the extent that policy makers wish to encourage cash market activity (*e.g.*, agricultural storage to smooth incomes and, perhaps, to reduce agricultural subsidies) or to encourage risk management (*e.g.*, encourage banks and savings and loans to hedge their risks through the use of financial futures), the government should also be interested in futures contracts designed to minimize basis risk.

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[46]Peck (1982) observes that Argentina exports a large percentage of supply shocks whereas the U.S. stores a large percentage of supply shocks, with Australia and Canada in between. She hypothesizes that risk faced and the availability of risk-management tools may explain the difference in behavior. Netz (1992) shows that differences in storage costs or capacity are not likely to explain the difference.

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