AN EMPIRICAL TEST OF THE EFFECT OF BASIS RISK ON CASH MARKET POSITIONS

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Abstract: *Traditional theory holds that hedgers use futures markets to reduce the amount of price risk they bear. In doing so, they trade price risk for basis risk, that is, unexpected movements in the difference between the spot and futures prices. Theoretical work has shown that the presence of basis risk reduces output (of which storage is a special case) and the relative use of futures as a hedging instrument. This paper attempts to empirically measure the effect of basis risk on the cash market position. This study empirically tests the implication of reduced storage in the face of basis risk using data on the storage of corn. Results show that basis risk statistically and economically significantly reduces the level of storage. The implications of basis risk on cash market positions extend beyond commodity storage to any hedging situation, including the use of currency futures to insure against exchange rate risk.*

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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 proven 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]

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. This paper fills this void by testing the effect of basis risk on the cash market position.

Intuitively, why should basis risk matter? The importance of the basis and basis risk arises because very few contracts (less than 3%) are offset through delivery. To illustrate, consider a simple case of a storer who takes a position in the cash market and the

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[1] Estimates range from a low of .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, Deutschemarks, and Swiss Francs.

[2] Vollink and Raikes (1977) analyze the live cattle basis; Tilley and Campbell (1988) the wheat basis; Martin, Groenewegen, and Pidgeon (1980) the corn basis; Ward and Dasse (1977) the frozen concentrated orange juice basis; Garcia, Leuthold, and Sarhan (1984) livestock basis; and Figlewski (1984) the S&P 500 Index basis. The latter two also analyze the determinants of basis risk.

futures market in period 1 and reverses the position in period 2. She 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. Her profits are $(c_2 - c_1) + (f_1 - f_2)$, or, in terms of the basis, $b_i = c_i - f_i$, $b_2 - b_1$. 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.[3] Since 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.

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 change 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 the cost of storage between today and the expiration date of the contract. If the basis were higher than the costs of storage, an arbitrage opportunity would exist. Thus, if the hedge were opened two months before the contract expiration date and closed one month before expiration, the basis should narrow by one month's storage cost. Because this change in basis is expected, it should not be considered risk.

Section II begins with a standard portofolio model of storage and hedging to illustrate 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.[4] Then other theoretical papers are discussed to show that the result is fairly general and not dependent on the functional form used or other assumptions. The result is that as either basis risk or price risk increases, the agent will reduce the level of inventories. Section III develops an empirical test of the hypothesis that basis risk affects the cash market position and discusses the empirical methodology. The model is applied to the storage of corn. This application is chosen since detailed data on corn are available

[3] This simple example assumes a complete hedge (a hedge ratio of 100%). A more realistic model is developed below.

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

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.[5,6] Section IV describes the data. Section V presents the results, which demonstrate that basis risk has a significant negative impact on the level of storage. Section VI summarizes the paper and discusses the implications and future research.

II. The Model

The impact of basis risk on the cash and futures positions can be illustrated using a standard mean-variance model of storage (*e.g.*, Turnovsky (1983)). After illustrating the effect of basis risk on the level of inventories, I discuss other models that incorporate basis risk 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.[7] 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).[8] 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.

Variables are defined as: p_t is the 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 $t+1$; r is the interest rate; e and F are positive constants, where e is the per unit cost of storage and

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[5] Basis risk varies over time and across location because the futures price and local spot prices will be subject to different shocks over time.

[6] The working paper version of this manuscript also used data on storage of soybeans. The application was flawed because it only considered 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 which included data on the relationship between the cash price and the three futures prices would be required. See Anderson and Danthine (1981) for a model of hedging with multiple contracts.

[7] This assumption is relaxed below.

[8] Spoilage is ignored in the model.

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 price in period i of a futures contract that expires in j; A is the coefficient of absolute risk aversion; ${}_t x_{t+1}$ 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:

$$\begin{aligned}\max_{s_t, z_t} & \left(\frac{{}_t p_{t+1}}{1+r} - p_t\right) s_t - (e s_t + F) \\ & + \left(\frac{f_{t,t+1} - {}_t f_{t+1,t+1}}{1+r}\right) z_t \\ & - \frac{1}{2} A \frac{s_t^2}{(1+r)^2} \sigma_p^2 - \frac{1}{2} A \frac{z_t^2}{(1+r)^2} \sigma_f^2 + A \frac{s_t z_t}{(1+r)^2} \sigma_{pf} \\ & s.t. \quad s_t \geq 0.\end{aligned}$$

The first two terms represent the expected profits from storage, the third term represents the expected profits from selling futures,[9] 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.[10] 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 same implications of basis risk on the futures position as previous studies. Optimization yields the standard hedging position

$$z_t = \frac{(f_t - {}_t f_{t+1})}{A(1+r)^{-1} \sigma_f^2} + \frac{\sigma_{pf}}{\sigma_f^2} s_t. \tag{1}$$

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

[9] Transactions costs in the futures market are ignored.

[10] 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.

the futures market requires that speculative profits be zero, in which case $f_t = {}_tf_{t+1}$.[11] 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 $(\sigma_p/\sigma_f)\rho_{pf}$, where 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 will be 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

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

The numerator gives the expected return to storage gross of fixed costs. 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 is the spot price, the more price risk the agent faces. Basis risk is higher the more independently the spot and

[11] 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. Results show no risk premium or are inconclusive. See Williams (1986) for a brief review of the literature through 1973. More recently see Kolb (1992) and Ehrhardt, Jordan and Walkling (1987).

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.

The corner solution states that storage is zero when the return to storage is non-positive. However, storage is often observed to be positive even when the return is negative. To explain this observed paradox, Kaldor (1939) and Brennan (1958) 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 non-linear 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. 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

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

where $c(s_t)$ is convenience yield as a function of the level of inventories. Total differentiation shows that 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 (1981) present a model of hedging with multiple contracts (of which this model is a special case with one futures contract). Their model is also more general in that they do not make the assumption that $f_t = {}_t f_{t+1}$. In that case, it is possible for basis risk to increase the cash market position. However, this occurs only when speculative profits from *buying* futures ($f_t < {}_t f_{t+1}$) 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 work shows that the cash position will not be independent of basis risk.

Paroush and Wolf (1989) maximize the expected utility as a function of profits of a firm that 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. Thus, profits are given by $\pi_t = p_{t+1}s_t + (f_{t,t+1} - f_{t+1,t+1})z_t - c(s_t)$ (changing Paroush and Wolf's notation to match that above). To apply their model to the case of storage, $c(s_t)$ should be defined as $p_t s_t$. Paroush and Wolf assume that the cash price is equal to a mean value plus a normally distributed random shock. The futures price is a linear function of the spot price plus another, independently normally distributed 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.[12]

Thus, under a variety of assumptions and approaches, basis risk reduces the cash market position as well as reducing the hedge ratio. This paper proceeds to empirically test the result.

III. Empirical Methodology

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. At the market level, storage will also depend on the amount available to be stored. To capture these effects, the following equation is estimated

$$s_t = \alpha + \beta_1\, ret_t + \gamma_1\, brsk_t + \gamma_2\, prsk_t + \beta_2\, prodn_t + \epsilon_t, \qquad (1e)$$

where

$s =$ the level of storage, in thousand bushels,

[12] In a separate paper, 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.

ret = the present value of the return to storage, in 1988 cents,

$brsk$ = basis risk,

$prsk$ = price risk, and

$prodn$ = the level of U.S. production, in billion bushels.

The error term, ϵ, captures exogenous supply shifts and forecast errors and is assumed to be distributed normally. 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.

The agent chooses positions in the cash and futures markets at time t based on the expected return to storage between t and $t+1$, and based on the basis risk and price risk expected to prevail during that period.[13] If the position were held to maturity in period T, the return to storage would be given by $\tilde{p}_T - p_t$. Assuming that the futures market is efficient and unbiased, the futures price $f_{t,T}$ is the best estimate of the spot price in period T. Thus 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.*, $T-t$).

Basis risk and price risk are measured as the standard deviations of the change in the basis and the spot price, respectively, over the previous eight periods.[14] The basis is measured as the cash price less the futures price of the nearby contract.[15] Only unexplained changes in the basis can be classified as risk. As the contract approaches maturity, the basis will narrow because storage costs are reduced. Thus, each week as maturity approaches, the basis should narrow by storage charges for one week. Because storage charges are stable, the pattern of the change in the basis will be shifted down by the amount of storage

[13] The data are weekly.

[14] This measure of volatility is common to the literature on the effect of exchange rate risk on trade, *e.g.*, Kenen and Rodrik (1986).

[15] Ederington (1979) shows that a nearby futures provides a better hedge than farther futures.

charges. Thus the standard deviation of the change in the basis will be unchanged. Tilley and Campbell show that the contract affects the level of the basis. Since the standard deviation of changes in the basis are used as the measure of risk, the different basis level for each contract will be differenced out, so that this effect is not a source of bias in the measure of basis risk. Furthermore, Garcia, Leuthold, and Sarhan (1984) find little evidence that basis risk changes as maturity approaches.

Applying the Cochrane-Orcutt procedure to equation ($1e$) provides estimates of the degree of serial correlation at about .97 or higher at each location, which suggests the presence of a unit root (non-stationarity).[16] Univariate tests for non-stationarity, 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 non-stationarity give similar results.[17] Storage is non-stationary, except for Peoria; however, even the result at Peoria is borderline. To eliminate non-stationarity, equation ($1e$) is estimated in differences.

The return to storage (ret) is clearly correlated with the error term since 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. To control for simultaneity, I use intrumental variables in a two-stage least squares framework. The identifying instruments used are the yield of the surrounding farm area, the amount of corn inspected for export, the amount of corn shipped by waterways, state rainfall and temperature, and monthly dummies. Rainfall, temperature and monthly dummies are

[16] See Plosser and Schwert (1978) for an excellent non-technical discussion of the implications of a unit root, as well as how different estimating techniques in the presence of a unit root can lead to different inferences.

[17] The multivariate test is derived by quasi-differencing equation ($1e$), 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 using 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 $\hat{\tau}_\mu$ in Fuller (1976), and the test statistic on the other coefficients will follow the standard t-distribution.

clearly exogenous. The yield will help explain the return to storage in the following way: the higher the yield, the less need to spread the crop over the crop-year, and the lower the return to storage. Precipitation, temperature, and monthly dummies are other proxies for such supply effects. The amount of corn shipped by waterways and the amount inspected for export will affect the return to storage through changes in supply and demand.

The application of the empirical test involves storage at nine locations. The data are pooled over the nine locations and the six years. Chow tests for structural change accept the hypothesis that coefficients are equal across locations and years.

IV. Data

I test the model 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.[18] These are stocks held in country and terminal elevators.[19] Corn belt states comprise Minnesota, Iowa, Missouri, Illinois, Indiana and Ohio.

Daily futures prices for corn on the Chicago Board of Trade were obtained from the Center for the Study of Futures Markets at Columbia University. The average of the daily settlement prices is used as the weekly futures price.[20]

The daily cash prices are from the United States Department of Agriculture. They are the bid prices for grain to arrive in fifteen days at the major elevators in the area. The

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

[19] 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.

[20] I also tried using an average over Tuesday, Wednesday and Thursday, as well as the settlement price for the nearest contract on each weekday to avoid possible day of the week effects. The results from the different measures of basis risk give qualitatively similar results. For brevity, I only present results using the weekly average.

high and low bids are averaged over six to thirty 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 interest rate used for discounting is the monthly rate on one-month certificates of deposit in the secondary market from Citibase tapes. The price index used to transform nominal to real prices is the Census Bureau's monthly implicit consumer price deflator, also from Citibase. Since the rest of the data are weekly, I interpolate monthly values of the interest rate and deflator to estimate weekly data.[21]

U.S. production and yields are obtained from the Crop Reporting Board's *Crop Production* publication. 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.[22] Because distribution will be affected by production (harvest) at each location, national production is used.[23] 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 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.

V. Results

Simple statistics are presented in table I. Of interest is the fact that the mean level of basis risk is smaller than the level of price risk at all locations. Recall that the risk

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[21] I also try assuming each monthly value holds for each week of that month. The results are substantially the same.

[22] Because only state-wide 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.

[23] Using local harvests, as defined above for the yield, leads to similar results.

Table I

Descriptive Statistics

(Standard Deviations in Parentheses)

Location	Cash Price[1]	Stocks[2]	Price Risk	Basis Risk
St. Louis	2.41 (0.37)	1,777 (1,973)	7.39 (5.61)	5.41 (3.66)
Chicago	2.32 (0.37)	12,414 (9,436)	7.48 (5.20)	5.30 (3.64)
Toledo	2.33 (0.39)	18,372 (9,701)	6.98 (5.03)	4.91 (3.21)
Gulf	2.59 (0.37)	6,292 (2,684)	7.48 (5.36)	5.19 (3.26)
Peoria	2.26 (0.38)	2,020 (794)	6.96 (5.27)	5.07 (3.39)
Sioux City	2.14 (0.40)	4,765 (2,171)	6.40 (4.75)	5.01 (2.81)
Kansas City	2.33 (0.38)	5,805 (1,964)	6.95 (4.58)	5.04 (2.41)
Minneapolis	2.27 (0.38)	12,040 (5,288)	8.65 (8.69)	7.20 (8.28)
Omaha-Council Bluffs	2.14 (0.40)	13,684 (4,269)	6.40 (4.75)	5.01 (2.81)
Unweighted Average	2.31 (0.40)	8,572 (7,560)	7.19 (5.62)	5.35 (4.12)

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

variables are measured as the standard deviation of the change in the variable over the past eight periods. The mean cash price (and, to a lesser degree, the standard deviation) vary 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 two million bushels (St. Louis and Central Illinois) to highs of close to twenty million bushels (Toledo). Variation in storage levels also differs widely across locations, as is evident from the coefficient of variation (the standard deviation divided by the mean).

As discussed above, equation ($1e$) is estimated in differenced form and instrumental variables are used in two-staged least squares to control for the endogeneity of the return to storage.[24] A few variations are estimated. First, Minneapolis is included in one estimation and excluded in another. 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

[24] See pp.357-361 of Kmenta (1986) for a textbook explanation of instrumental variable techniques.

the other locations. The standard deviation of both risk variables is also much larger than at other ocations; that is, the level of risk at Minneapolis is much more variable than at the other locations. The coefficient of variation on both risk variables is greater than one, which is 35% and 109% greater than the coefficient of variation of price and basis risks, repsectively, at the other locations. Also, Minneapolis is the only city which supports the hypothesis that stocks also cause basis risk (as well as basis risk causing stocks) when a Granger causality test is conducted. If true, then the basis risk variable will be correlated with the error term. The coefficient would pick up the effect of basis risk on stocks (expected to be negative) and stocks on basis risk (also expected to be negative), so the coefficient would be biased downward.[25]

Another variation is limiting the sample to observations where stocks are not in the lowest decile. 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. Ward and Dasse (1977) devise a measure which is a function of the level of inventories, but that would be inappropriate here since the level of inventories is the dependent variable. To analyze the effect of periods in which convenience yield is most important in determining storage, the equation is re-estimated omitting observations with low storage levels.

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 17% level in both equations where Minneapolis is excluded. Interestingly, when Minneapolis is excluded the coefficient on basis risk becomes more negative. This is counter to expectations. It was suspected that stocks cause basis risk in a negative fashion, leading to a downward biased coefficient. If true, then the coefficient in the absence of Minneapolis would be smaller in absolute value. When periods of low stocks are omitted (primarily at the end of the crop year) in an effort to control for convenience yield, all explanatory

[25] No variables are available to instrument for basis risk.

Table II

Storage

(Standard errors in parentheses)

Independent Variable	All Cities,[1] All Stocks	No Minneap., All Stocks	All Cities, No Low Stocks	No Minneap., No Low Stocks
Constant	–293.87***	–307.98***	–310.65***	–324.99***
	(98.96)	(100.49)	(107.56)	(109.60)
Return	63.29***	54.49**	68.57***	60.73**
	(22.05)	(21.62)	(25.42)	(25.85)
Basis Risk	–27.63**	–33.75**	–28.53*	–37.94**
	(14.23)	(16.39)	(15.42)	(18.37)
Price Risk	–22.33*	–19.42	–25.96*	–23.12
	(13.24)	(14.17)	(15.36)	(16.95)
U.S. Prodn.	37.04***	39.46***	41.05***	43.52***
	(13.04)	(13.26)	(14.28)	(14.55)
F	3.43***	3.12**	3.18**	2.95**
D-W	2.06	2.07	2.07	2.08
n	2691	2393	2412	2145
ρ range	–.37 to .54	–.37 to .55	–.39 to .55	–.39 to .55

***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

variables have a larger magnitude, by an average of 11%. This is to be expected; in periods of low levels of inventory, convenience yield will be a dominant influence.

Interestingly, basis risk is more significant and has a larger impact (see below) than does price risk. This result might seem counter-intuitive, since the idea is that agents use futures markets in response to price risk. However, it is precisely the trade-off between price and basis risks that explain the result. Working's (1953) hypothesis is that agents either speculate on the spot price or the basis, whichever is more favorable. When speculating on the basis, the agent will completely hedge, in which case she will not face price risk at all. If speculating on the basis occurs more often than speculation on the spot price, basis risk will be more important than price risk. Alternatively, the portfolio approach to hedging assumes that agents will form a portfolio of hedged and unhedged stocks. The estimated optimal hedge ratio in the presence of basis risk for corn ranges from 86% to 98%, depending on when the hedge is lifted relative to the expiration date (Castelino (1992)). If such a large proportion of the inventory is hedged, the amount that is subject to price risk is quite small. Thus it would be natural for basis risk to be a stronger determinant of stocks than price risk.

Table III presents estimates of the magnitude of the effect of the independent variables on storage, which varies across location. Two measures are presented.[26,27] One is the elasticity calculated at the means (in the columns labelled "Elast."). The second measure gives the percentage of a standard deviation that stocks change when the indicated independent variable increases by one standard deviation (in the columns labelled "Impact"). That is, when the return to storage increases by one standard deviation in St. Louis, stocks rise by 13% of a standard deviation.

Storage is elastic with respect to all three independent variables. On average, a 1% increase in each independent variable causes stocks to change by about .03%. The impact column gives a more reasonable measure of the magnitude of the effect. On average, a one standard deviation increase in the risk variables causes stocks to increase by over 4% of a standard deviation, and a one standard deviation increase in the return to storage increases stocks by over 12% of a standard deviation. The magnitude of the effect varies considerably across locations. Peoria is most sensitive to changes in the independent variables. This 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 towards 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.[28]

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[26] Though the equations are estimated in differenced form to control for non-stationarity, 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.

[27] Calculations use the coefficients from the sample excluding Minneapolis but including all levels of stocks. Because the coefficients do not change substantially across specifications, the entries in table III are not much changed when other coefficients are used.

[28] Though less than 3% of contracts end in delivery, the average level of stocks in Chicago is less than 2500 contracts. In 1992 trade volume for corn was 10.3 million contracts.

Table III

Magnitude of Effect[1]

Location	Return Elast.[2]	Return Impact[3]	Basis Risk Elast.	Basis Risk Impact	Price Risk Elast.	Price Risk Impact
St. Louis	.061	13.31	–.103	–6.26	–.081	–5.52
Chicago	.004	2.37	–.014	–1.30	–.012	–1.07
Toledo	.001	2.06	–.009	–1.12	–.007	–1.01
Gulf	.060	15.17	–.028	–4.10	–.023	–3.88
Peoria	.064	32.44	–.085	–14.41	–.067	–12.90
Sioux City	.064	17.18	–.035	–4.37	–.026	–4.24
Kansas City	.003	12.30	–.029	–4.14	–.023	–4.53
Minneapolis	.009	6.30	–.020	–5.29	–.014	–3.19
Omaha-Council Bluffs	.022	8.74	–.012	–2.22	–.009	–2.16
Simple Average	.030	12.21	–.037	–4.80	–.029	–4.28

[1]Calculations use coefficients from column 3 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.

Of particular interest, the table shows that basis risk has an economically significant impact on the level of storage. A one standard deviation change in basis risk is associated with a decline in storage levels by 1.12% to 14.41% of a standard deviation depending on location, with an unweighted average of 4.80%, or about 2.1% of the mean at each location. The impact of the return to storage is larger, as expected, since this is the primary motivation for storage. A one standard deviation increase in price risk decreases the level of storage by 1.01% to 12.90% of a standard deviation, and a one standard deviation increase in the return to storage increases the level of storage from 2.06% to 32.44% of a standard deviation.

The empirical analysis indicates that basis risk has a statistically and economically significant impact on the level of storage.

VI. Conclusions and Implications

This paper represents the first attempt to empirically estimate the effect of basis risk on positions in 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. The result that basis risk affects the level of storage is then empirically tested using data on storage of corn in the nine major American markets in the mid-1980s. This particular test is chosen given data availability.

The model suggests that basis risk negatively affects the level of storage, since the existence of basis risk limits the effectiveness of futures as a risk management tool. As agents face more basis risk, they reduce their exposure by reducing the level of inventory. A one standard deviation increase in basis risk is associated with a decline in storage by between 1% and 14% of a standard deviation, depending on the location, or on average 2.1% of the mean.

While this particular empirical test is of 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, petroleum, and any international transaction where agents use currency futures to hedge against exchange rate risk. For example, basis risk (and exchange rate risk) places foreign agents at a disadvantage when using futures markets in another country. Netz (1992) shows that because foreign wheat agents face 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.

References

Anderson, Ronald W. and Jean-Pierre Danthine. (1981):"Cross-Hedging," *Journal of Political Economy*, 89:1182–96.

Brennan, Michael J. (1958):"The Supply of Storage," *American Economic Review*, 48:pp. 50–72.

Castelino, Mark G. (1992):"Hedge Effectiveness: Basis Risk and Minimum-Variance Hedging," *Journal of Futures Markets*, 12:pp. 187-201.

Crop Reporting Board. (January 1981 to December 1989):*Crop Production*, Washington, DC: United States Department of Agriculture.

Economic Research Service. (March 1993):*Feed Situation and Outlook Yearbook*, Washington, DC: United States Department of Agriculture.

Ederington, Louis H. (1979):"The Hedging Performance of the New Futures Markets," *The Journal of Finance*, 34:pp. 157–70.

Ehrhardt, Michael C., James V. Jordan and Ralph A. Walkling. (1987):"An Application of Arbitrage Pricing Theory to Futures Markets: Tests of Normal Backwardation," *Journal of Futures Markets*, 7:21–34.

Figlewski, Stephen. (1984):"Hedging Performance and Basis Risk in Stock Index Futures," *The Journal of Finance*, 39:pp. 657-69.

Fuller, Wayne A. (1976):*Introduction to Statistical Time Series.* New York: Wiley.

Garcia, Philip, Raymond M. Leuthold, and Mohamed E. Sarhan. (1984):"Basis Risk: Measurement and Analysis of Basis Fluctuations for Selected Livestock Markets," *American Journal of Agricultural Economics*, 66:pp. 499-504.

Kaldor, Nicholas. (1939):"Speculation and Economic Stability," *The Review of Economic Studies*, 7:1–27.

Kenen, Peter and Dani Rodrik. (1986):"Measuring and Analyzing the Effects of Short-term Volatility in Real Exchange Rates," *Review of Economics and Statistics*, 68:pp. 311-5.

Kmenta, Jan. (1986):*Elements of Econometrics*, New York:Macmillan Publishing Company.

Kolb, Robert W. (1992):"Is Normal Backwardation Normal?," *Journal of Futures Markets*, 12:75–91.

Livestock and Grain Market News Branch. (January 1981 to December 1989):*Stocks of Grain at Selected Terminal and Elevator Sites*, Washington, DC: United States Department of Agriculture.

Martin, Larry, John L. Groenewegen, and Edward Pidgeon. (1980):"Factors Affecting Corn Basis in Southwestern Ontario," *American Journal of Agricultural Economics*, 62:pp. 107-12.

Moser, James T. and Billy Helms. (1990):"An Examination of Basis Risk Due to Estimation," *Journal of Futures Markets*, 10:pp. 457–67.

Netz, Janet S. (1992):"Basis and Exchange Rate Risks and Their Impact on Storage and Exports," working paper.

————. (1994):"The Effect of Futures Markets and Corners on Storage and Spot Price Variability," *American Journal of Agricultural Economics*, forthcoming.

Paroush, Jacob and Avnar Wolf. (1992):"The Derived Demand with Hedging Cost Uncertainty in the Futures Markets," *The Economic Journal*, 102:pp. 831–44.

————. (1989):"Production and Hedging Decisions in the Presence of Basis Risk," *Journal of Futures Markets*, 9:547–63.

Peck, Anne E. (1975):"Hedging and Income Stability: Concepts, Implications, and an Example," *American Journal of Agricultural Economics*, 57:pp.410–419.

Plosser, Charles I. and G. William Schwert. (1978):"Money, Income, and Sunspots: Measuring the Economic Relationships and the Effects of Differencing," *Journal of Monetary Economics*, 4:637–60.

Stein, Jerome L. (1961):"The Simultaneous Determination of Spot and Futures Prices," *American Economic Review*, 51:pp. 1012–25.

Telser, Lester G. (1958):"Futures Trading and the Storage of Cotton and Wheat," *Journal of Political Economy*, 66:233–55.

Teigen, Lloyd D. (1992):*Weather in U.S. Agriculture*, computer file #92008B, Washington DC: Economic Research Service, U.S. Department of Agriculture.

Tilley, Daniel S. and Steven K. Campbell. (1988):"Performance of the Weekly Gulf-Kansas City Hard-Red Winter Wheat Basis," *American Journal of Agricultural Economics*, 70:929–35.

Turnovsky, Stephen J. (1983): "The Determination of Spot and Futures Prices with Storable Commodities," *Econometrica*, 51:pp. 1363-87.

Vollink, William and Ronald Raikes. (1977): "An Analysis of Delivery-Period Basis Determination for Live Cattle," *Southern Journal of Agricultural Economics*, 9:179–84.

Ward, Ronald W. and Frank A. Dasse. (1977): "Empirical Contributions to Basis Theory: The Case of Citrus Futures," *American Journal of Agricultural Economics*, 59:pp. 71–80.

Williams, Jeffrey. (1986): *The Economic Function of Futures Markets.* Cambridge: Cambridge University Press.

Working, Holbrook. (1949): "The Theory of Price of Storage," *American Economic Review*, 39:pp. 1254-62.

Working, Holbrook. (1953): "Hedging Reconsidered," *Journal of Farm Economics*, 35:pp. 544-61.